State of Zero-Emission Vehicle Secondary Market and Accessibility Impacts in California's Underserved Communities

DRAFT Final Report

California Air Resources Board Agreement No. 22STC016

December 2025

Prepared by:

Electric Vehicle Research Center

Institute of Transportation Studies
University of California, Davis

Research Team

Principal Investigator Gil Tal

Sina Nordhoff

Scott Hardman

Aviv Steren

Theodora Konstantinou

Juan Garcia Sanchez

Dahlia Garas

Matthew Favetti

Contact Information - Research Team

Electric Vehicle Research Center
Institute of Transportation Studies
University of California, Davis

Principal Investigator
Gil Tal, PhD
Director
🖂 **Email:** gtal@ucdavis.edu

Research Team Members
Sina Nordhoff, PhD
Postdoctoral Research Scientist
🖂 **Email:** snordhoff@ucdavis.edu

Scott Hardman, PhD
Assistant Director & Research Faculty
🖂 **Email:** shardman@ucdavis.edu

Aviv Steren, PhD
Postdoctoral Research Scientist
🖂 **Email:** asteren@ucdavis.edu

Theodora Konstantinou
Researcher
🖂 **Email:** -

Juan Garcia Sanchez
Policy Analyst
🖂 **Email:** jcgarciasanchez@ucdavis.edu

Dahlia Garas
Program Manager
🖂 **Email:** dmgaras@ucdavis.edu

Matthew Favetti
Applications Programmer
🖂 **Email:** mpfavetti@ucdavis.edu

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Executive Summary

Project Description

This study examines the used plug-in electric vehicle market in California through an integrated analysis of Department of Motor Vehicles household registrations from 2023, S&P Global interstate transfer data from 2016 to 2023, and a statewide survey of vehicle owners with approximately 3,396 respondents. This includes understanding socio-economic, demographic, geographic, and behavior of not only buyers of used ZEVs but also buyers of new and used internal combustion engine (ICE) vehicles. The analysis provides empirical evidence on consumer behavior, market dynamics, and barriers to adoption that can inform policy decisions aimed at expanding plug in electric vehicle access across California's population.

Key Findings

Used PEV Buyers Resemble New ICEV Buyers but Show Greater Cost Sensitivity

Used PEV buyers are more likely than new PEV buyers to come from lower-income households and disadvantaged communities, though their incomes remain similar to new gasoline vehicle buyers rather than typical used car buyers. These buyers demonstrate greater price sensitivity, with upfront cost identified as the primary PEV adoption barrier. Used PEV owners express higher concern about battery performance, charging availability, and technology maturity compared to new PEV buyers, yet remain less skeptical than non-owners, suggesting direct experience reduces perceived barriers.

Policy Implication: The demographic profile positions the used vehicle market as a potential equity mechanism, but current barriers, particularly home charging access and battery information gaps, limit this potential. Targeted incentive programs for used PEV purchases, point-of-sale rebates, and financing assistance for credit-constrained buyers could advance equity objectives.

Home Charging Access Is Essential, Not Optional

Sixty-three percent of non PEV owner respondents would consider purchasing a battery electric vehicle (BEV) if home charging were available, and 90% of those willing to purchase at price parity also require home charging access. Used BEV owners are more likely to lack home charging (6.8% without home charging vs. 4.5% for new BEV owners), if they do have home charging rely more heavily on level 1 charging at home, and use more public infrastructure. Respondents identified home charging as essential infrastructure, citing concerns about public charging availability, reliability, and time required to locate functional stations as significant deterrents.

Policy Implication: Limited home charging access, particularly for renters and residents of multi-unit housing, represents a substantial equity barrier. Policy options include mandating or incentivizing charging infrastructure in multi-unit dwellings, requiring new *residential construction to be EV-ready, and providing installation subsidies targeted toward lower-income households. California's Clean Vehicle Assistant Program offers up $2,000 for charging equipment for income-eligible households in disadvantaged communities, providing a model for addressing this barrier.*

Battery Information Gaps May Suppress Market Development

Battery condition emerged as an important factor in used PEV purchase decisions, with around two-thirds of buyers inquiring about battery health prior to purchase. Among those who sought information, most relied on seller statements or dashboard displays rather than independent testing or manufacturer documentation. Approximately 60% of used PEVs were under warranty at acquisition.

Policy Implication: Standardized battery health reporting requirements could reduce buyer uncertainty and support market development. Options include mandating battery health reporting for used vehicle sales, supporting independent testing and certification programs, requiring dealers to provide verified condition reports, and expanding consumer education regarding battery degradation and warranty terms. Federal and state battery warranty requirements provide foundation, but transparency in remaining warranty and actual battery condition remains inadequate.

Incentives Drive Both New and Used PEV Adoption Equally

Survey experiments demonstrate that new and used vehicle buyers respond similarly to incentives. Aomung PEV adopters HOV lane access increases the probability of choosing a PEV from 0.90 to 0.94. A $5,000 state rebate increases probability from 0.90 to 0.95. Federal tax credits of $7,500 or $10,000 increase probability from 0.87 to 0.95. Combined incentives (HOV access, $5,000 state rebate, $7,500-$10,000 federal credit) increase probability to 0.97. Without any incentives, probability drops to 0.79, suggesting approximately 21% of current PEV buyers would not choose a PEV if incentives were eliminated.

Policy Implication: While new-vehicle incentives effectively drive adoption, focus on new vehicles may inadvertently suppress used-vehicle demand and may reduce reduce resale values, contributing to increased out-of-state exports. Expanding and promoting used-vehicle incentives could better serve cost-sensitive buyers and advance equity objectives.

California Exports Over 240,000 Used PEVs to Other States

Analysis reveals that approximately 240,000 used PEVs left California between 2016-2023, compared to about 35,000 incoming vehicles. California accounts for 34% of all U.S. PEVs and supplies substantial numbers to neighboring states, with Nevada, Arizona, and Oregon receiving the largest shares. States offering strong new-PEV incentives import fewer used PEVs from California, suggesting a lack of new-vehicle subsidies may strengthen used-PEV demand. Exported PEVs operate in states with electricity grids approximately 79% more carbon-intensive than California's, complicating emissions benefit calculations, though net impact depends on what vehicles these PEVs replace in destination states.

Policy Implication: The outflow of subsidized vehicles limits affordable used PEV availability for California residents while potentially reducing realized climate benefits from state incentives. This creates tension between state adoption goals and national emissions outcomes. Policies encouraging in-state retention (e.g., extended warranty programs, certified pre-owned programs for used PEVs) could benefit original owners through higher resale values while expanding supply for subsequent California buyers. The equity implications are ambiguous: exports may help electrification in other states but reduce options for California's lower-income households.

Used PEVs Function Similarly to New PEVs Once Adopted

Annual vehicle miles traveled do not differ significantly between new and used PEVs or across vehicle technologies. Used PHEV owners charge their vehicles at similar rates to new PHEV owners (approximately 80%). However, the used market disproportionately channels buyers toward shorter-range, older-generation vehicles. Short-range BEVs (particularly early Nissan Leaf models) now primarily reside in the secondary market. Used BEV owners rely more on public charging, including DC fast charging and report higher rates of driving limitation due to charging constraints (20% vs. 10% for new long-range BEV owners).

Policy Implication: The concentration of shorter range vehicles in the used market increases infrastructure sensitivity and may limit utility for households without reliable home charging. This reinforces a tiered transition where lower-income or risk-averse households access vehicles with more limited capability. Public, work, and home charging network development remains critical for serving populations without home charging access, with priorities including geographic coverage in underserved areas, reliability and uptime improvements, real-time availability reporting, and interoperability across networks. Early-generation vehicles also face technological obsolescence as charging standards evolve (e.g., CHAdeMO decline), but we are not suggesting a similar need for public charging for those vehicles but a need for infrastructure transition planning.

Vehicle Supply Patterns Shape Market Development

Nearly all vehicles remain with original owners after one year. Approximately half transfer to subsequent owners within 3-4 years, leveling at 10-15% remaining with original owners after 7-8 years. However, larger shares of older BEVs remain with original owners, possibly reflecting higher purchase prices or lower residual values for early short-range models. When purchasing new vehicles, 37% of gasoline vehicle buyers and 46% of used gasoline vehicle buyers add vehicles to household fleets, while new PEV buyers generate substantial used vehicle supply including 20% BEVs, 9% PHEVs, and 47% gasoline vehicles. Survey data suggests 15% of used PEV buyers replace existing PEVs in their household fleet.

Policy Implication: The relatively slow turnover of early BEVs may reflect market uncertainty about residual values or battery concerns, potentially suppressing value and supply. As the PEV fleet ages and more vehicles enter secondary markets, supply *constraints should be eased. Certified pre-owned programs and extended warranties could help address uncertainty and support both supply development and buyer confidence.*

Synthesis and Conclusion

The used PEV market holds substantial promise as a pathway for broader and more equitable electrification, but structural, informational, and infrastructure barriers limit current realization of this potential. While used PEV buyers include higher shares of lower-income households than new PEV buyers, they remain demographically similar overall and are not similar to used gas car buyers. This suggests price reductions alone are insufficient without complementary policies addressing charging access, information gaps, and risk perceptions. Furthermore, supply is the main limiting factor and higher incentives may not generate higher supply.

Home charging access operates as a foundational prerequisite rather than optional convenience, creating an equity filter that disproportionately affects renters and multi-unit housing residents. Battery information transparency represents an underdeveloped market element despite being the most important purchase factor when choosing a used BEV. The absence of standardized, credible disclosure likely suppresses demand by increasing perceived risk. Incentive programs demonstrate high effectiveness for both new and used buyers, but concentration on new vehicles may inadvertently slow secondary market development and contribute to out-of-state exports that reduce affordable supply for California residents.

Evidence suggests used PEV ownership can serve as a confidence-building entry point, with used owners demonstrating less skepticism than non-owners about technology and infrastructure. However, without targeted interventions, including expanded home charging access, battery health disclosure requirements, used-vehicle incentive programs, and certified pre-owned programs, this experiential pathway remains limited to households already positioned to overcome key constraints. Policy attention to these barriers is essential for realizing the equity potential of California’s growing used PEV market.

1. Introduction

Plug-in vehicles (PEVs) are a solution to improve air quality and mitigate climate change. PEVs are vehicles with batteries that are plugged into the electrical grid to be charged, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs only run by electricity, and PHEVs run by electricity and gasoline or diesel (Kurani, Caperello, & TyreeHageman, 2016). We use the term PEVs to refer to both BEVs and PHEVs. When distinctions between BEVs and PHEVs are relevant to the context of our study, we refer to them separately. Many countries have set ambitious targets to phase out internal combustion engine vehicles (ICEVs) and transition to 100% zero-emission vehicle (ZEV) sales within the next few decades. For instance, Norway aimed to end new ICE vehicle sales by 2025, while the United Kingdom, Canada, and the European Union had set targets for 2035. Other nations, including France and Spain, have established goals for 2040 (ZEVTC, 2024). Achieving these targets necessitates not only the widespread adoption of new PEVs but also the development of a robust and accessible used PEV market. This is crucial to ensure that all segments of the population can participate in the transition to cleaner transportation options. To achieve the global emission goals and ensure that PEVs trickle down to all segments of the population, it is necessary that PEVs enter the used vehicle market (Chakraborty et al., 2024; Tal et al., 2017; Turrentine et al., 2018). However, fewer PEVs have entered the used vehicle market to date, as most remain with their original owners (Tankou et al., 2021). Importantly, the used vehicle market is more than twice as large as the new vehicle market as demonstrated by 40 million used vehicle sales compared to 17 million new vehicle sales in the U.S. in 2019.

There is a wide literature investigating the adoption of new PEVs (Asadi et al., 2021; Chang, 2023; Cruz-Jesus et al., 2023; Dong et al., 2020; Higueras-Castillo et al., 2023; Maybury et al., 2022; Mohamed et al., 2016a; Secinaro et al., 2022; Shanmugavel et al., 2022; Wicki et al., 2023). Some of these studies examined the factors explaining and predicting PEV adoption or demand, while others developed PEV business models, or examined consumer attitudes toward new PEVs (Maybury et al., 2022). The main factors influencing PEV adoption include technical factors (e.g., acceleration, driving range, recharging time), contextual factors (e.g., charging availability, environmental impact, policy incentives), cost-related factors (e.g., purchase and operational costs, resale value), socio-demographic factors (e.g., age, gender, income, and education), experience (e.g., knowledge, familiarity), and social factors (e.g., norms, neighborhood effect) (Wicki et al., 2023). As PEVs require plugging in to recharge, the availability of charging access at or near home parking spaces and the authority to install new charging infrastructure was also examined in several studies (Axsen & Kurani, 2012; Ge et al., 2021).

Wicki et al. (2023) suggest that critical research gaps in our understanding of PEV adoption remain unaddressed. One major limitation of previous work is that studies have mainly focused on consumer adoption of new rather than used PEVs, presumably because PEVs represent an emerging technology (Busch, 2021; Chakraborty et al., 2024; Sheykhfard et al., 2025). imilarly, used PEV buyers may differ from new PEV buyers as well, mainly in terms of their demographic profile, such as living situation, tenure, and income (Ge et al., 2021). PEVs are still relatively new to the fleet (Loh & Noland, 2024). Zou et al. (2020) emphasize the importance of understanding the preferences and concerns of used PEV buyers to encourage the adoption of used PEVs. While these buyers may benefit from lower vehicle price, they also face several challenges, including limited or no purchase incentives, uncertainty battery condition and limited access to charging infrastructure (Lim et al., 2015; Loh & Noland, 2024; Turrentine et al., 2018). Furthermore, they may face other barriers such as difficulties in securing financing, potentially higher maintenance costs, and limited information about how to properly operate and maintain the technology (Turrentine et al., 2018).

1.1. Project's research questions

While existing literature has advanced our understanding of the adoption of used PEVs (Tal et al., 2017; Tal et al., 2021; Turrentine et al., 2018), critical knowledge gaps remain. This report addresses the following project's research questions:

- Are used ZEV buyers significantly different than new ZEV car buyers?
- What is the use pattern (miles, charging behavior) of used ZEVs?
- What is the impact of new and used incentives on the market?
- How many cars leave California and where to?

The results of the analysis will inform the following policy discussion centered around three main research questions:

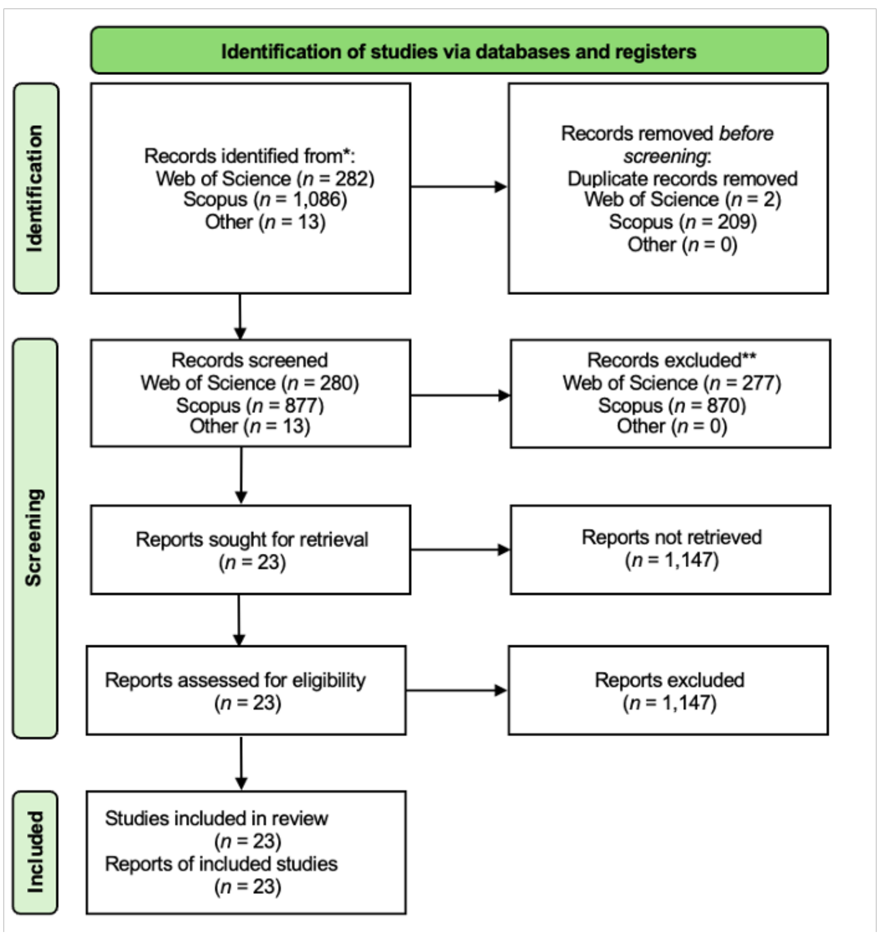
- What is the impact of the used market on equity?
- Are there hidden barriers that will drastically reduce the resale value of vehicles?
- Are there policies needed to shape this growing retail sector?

2. Literature review

We performed a systematic review of literature on used PEVs and used ICEVs. We screened literature using “Scopus” and “Web of Science” databases. We used the following combinations of keywords: *used cars*, *secondhand cars*, *secondary cars*, *used electric cars*, *secondhand electric cars*, *secondary electric cars*, *used electric vehicles*, *secondhand electric vehicles*, and *preowned electric vehicles*. To identify whether the identified studies were eligible for our study, we examined the titles, abstracts, and keywords. We also performed a narrative review of “used things”. The assumption here was that this knowledge can further inform our understanding of the adoption of used PEVs. We did not limit the identified literature by publication date, or type. Only studies in English were included in our review. We also examined the reference lists of the studies that we identified and searched for literature on Google Scholar and ResearchGate.

The initial review resulted in 1,381 studies, as presented in Figure 3. After removing 211 duplicates, we reviewed the abstracts of 1,170 studies, leading to the exclusion of 1,147 studies that did not meet our search criteria. These studies include theoretical modeling studies, studies that examined technical aspects around used vehicles, or that were unrelated to our specific domain. The remaining 23 studies that were eligible examined the adoption of used vehicles, including both ICEVs and PEVs.

Figure 1 Results of review methodology.



The most common data collection instruments in the studies we reviewed were online survey studies, followed by studies using vehicle registration data, and interview studies. Most of the studies were conducted in North America, with others conducted in Europe and Asia. These studies examined socio-demographic and socio-economic differences as well as the perspectives of vehicle owners, and factors impacting the adoption decision. Table 1 presents an overview of the studies that examined the adoption of used vehicles, including both used ICEVs and PEVs. As the main research focus is on used vehicles, Table 1 does not present results on the adoption of ‘used products’.

Table 1 Overview of study characteristics

#	Source	Research objectives: To examine	Fuel type technology	Acquisition status		Data collection			Sample size (*n*)	
						Instrument	Year	Country	Used	New
1	Aigbojie & Osaiga (2010)	• Influence of perceived risks on purchase of used vehicles, and relationship with socio-demographic characteristics, and self-reported technical knowledge	ICEV	Used		Paper questionnaire	*NA*	*NA*	127	-
2	Boelhouwer et al. (2020)	• How vehicle owners are informed about Advanced Driver Assistance Systems (ADAS) when purchasing a vehicle	ICEV	Used	New	Online survey	2019	The Nether-lands	713	365
3	Busch (2021)	• Equity impacts of used PEVs	PEV	Used		Literature review	2017 / 2018	United States	*NA*	-
4	Canepa et al. (2019)	• Differences between PEV buyers from disadvantaged versus non-disadvantaged communities in terms of their socio-demographic characteristics, and availability of charging infrastructure	PEV	Used	New	Online survey, vehicle registration data, location of electric charging stations	2016	United States	10,040	187,701
5	Chakraborty et al. (2024)	• Factors influencing consumer's choices of new and used passenger cars, light trucks / vans, and compare prices of	PEV, ICEV	Used		Mail survey, link to online survey	2018-2021	United States	17,127	-

#	Source	Research objectives: To examine	Fuel type technology	Acquisition status		Data collection			Sample size (*n*)	
						Instrument	Year	Country	Used	New
		used PEVs with prices of used vehicles								
6	Hatt et al. (2020)	• Perceived incentives and barriers to purchasing PEVs	PEV	Used	New	Online survey	2020	United States, Canada	282	17
7	Klein et al. (2023)	• How and where lower-income household acquire cars and the consequences for their lives	ICEV	Used	New	Online survey	2022	United States	615	384
8	Lim et al. (2015)	• Impact of range anxiety and resale anxiety on the adoption of PEVs	PEV	Used	New	Model calibrated to “realistic” dataset	2014	United States	*NA*	*NA*
9	Loh & Noland (2024)	• Characteristics and concerns of used PEV owners	PEV	Used		Online survey	2022	United States	1167	-
10	Mashrur & Mohamed (2025)	• Factors affecting consumers’ decisions regarding pre-owned electric vehicles	PEV, ICEV	Used		Online survey	2020	United States	8,991	-
11	Muehlegger & Rapson (2019)	• Purchase decisions of PEVs	PEV	Used		Vehicle purchases	2011-2015	United States	~400,000	-
12	Pedrosa & Nobre (2018)	• Better understanding of the perception of used PEVs, and analyze driver’s attitudes towards used PEVs, willingness to pay, and role of battery	PEV	Used	New	Interviews	*NA*	*NA*	-	17

#	Source	Research objectives: To examine	Fuel type technology	Acquisition status		Data collection			Sample size (*n*)	
						Instrument	Year	Country	Used	New
		condition and warranty options								
13	Peng & Bai (2023)	• Relative importance of several policy incentives on purchase decisions of PEVs, and how demographic characteristics, user perceptions of non-policy factors and policy intensity influence relative importance, and to determine barriers to policy implementation	PEV	Used		Online survey	2020-2021	China	369	-
14	Prieto & Caemmerer (2013)	• How socio-demographic characteristics impact decision to purchase used vehicles across different car segments	ICEV	Used	New	Online survey	*NA*	France	1,264	703
15	Reagan et al. (2023)	• How trust, understanding, and awareness of ADAS differs among individuals purchasing new vehicles versus used vehicles	PEV, ICEV	Used	New	Online survey	2021	United States	362	402
16	Roberson et al. (2024)	• Prior estimates of PEV value retention rates	PEV	Used		Vehicle purchases	2016-2019	United States	9,015,324	-
17	Setiawati et al. (2019)	• How marketing mix influence purchasing decisions of used	ICEV	Used		Paper survey, interviews	2017	Indonesia	105	-

#	Source	Research objectives: To examine	Fuel type technology	Acquisition status		Data collection			Sample size (*n*)	
						Instrument	Year	Country	Used	New
		vehicles in Palembang (Indonesia)								
18	Sheykhfard et al. (2025)	• Factors influencing consumer purchase intentions in the used PEV market	PEV	Used		Survey from Loh & Noland (2024)	2022	United States	992	-
19	Steren et al. (2016)	• Association between adoption of new vs. used vehicles and travel behavior	ICEV	Used	New	Paper survey	2007-2011	Israel	1,079	415l
20	Tal et al. (2013)	• Characteristics of EV buyers with respect to buyers of other technologies, and changes in household vehicle fleet after introducing a limited BEV range, and usage of PEVs	PEV	Used	New	Mail survey, link to online survey	2012	United States	-	1201
21	Tal et al. (2017)	• Motivations behind the purchase and use of used PEVs	PEV	Used		Mail survey, link to online survey	2016	United States	602	-
22	Tal et al. (2021)	• Number of total vehicles, number of PEVs owned by original, second, and third owners, and spatial concentration of used PEVs	PEV, ICEV	Used		Vehicle registration data	2017	United States	1406	-
23	Zou et al. (2020)	• Effects of charging infrastructure on preferences for PEVs	PEV, ICEV	Used	New	Stated preference choice experiment	2019	United States	533	450

2

3. Results

The descriptive presentation of the results of the literature review is organized around the three streams that we identified: Used ICEVs (Section 3.1), and used PEVs (Section 3.2), and used products (Section 3.3).

3.1. Adoption of Used ICEVs

First, we review literature on the adoption of used ICEVs. Our review shows that socio-demographic factors help explain the decision to purchase a used ICEV. Age appears to play a significant role: Chakraborty et al. (2024) found that households with a member aged between 40 and 50 were more likely to purchase used ICEVs, and households with individuals aged 60 years or older were less inclined to purchase a used truck or van. Similarly, Reagan et al. (2023) reported that new ICEV buyers were twice as likely than used ICEV buyers to be age 60 or older. In terms of gender, Prieto and Caemmerer (2013) found that men were less likely to purchase small used ICEVs. Reagan et al. (2023) also found that among new ICEV buyers, older males (60+) showed a higher level of trust in Advanced Driver Assistance Systems (ADAS) compared to younger individuals and females.

Education and employment status have also been found to influence used ICEV adoption. Buyers of used ICEVs were lower-educated and less likely to be employed than new ICEV buyers (Zou et al., 2020), supporting research that has shown that individuals owning a used ICEV were more likely to have no college degree (Chakraborty et al., 2024). Similarly, higher education has been positively associated with purchasing new rather than used ICEVs, and unemployment has been positively associated with purchasing used ICEVs, and negatively with purchasing new ICEVs. Income and access channels also affected purchasing behavior. According to Klein et al. (2023), lower-income individuals acquired used ICEVs through a variety of sources, including car dealerships (i.e., traditional brick-and-mortar and online dealers), informal purchases from an individual, family or friends, local auctions, sales advertisements, garages, repair shops, or as gift or inheritance. Some also gained access when moving in with someone who had access to a vehicle, or when someone with access to a vehicle moved in with them. Household composition also plays a role. Larger households – those with more than 4 members – were more likely to purchase used ICEVs (Chakraborty et al., 2024), though Prieto and Caemmerer (2013) found that household extension through childbirth decreased the probability of purchasing a used ICEV. Households residing in urban areas were also less likely to purchase both used and new ICEVs (trucks or vans) (Chakraborty et al., 2024).

Used ICEV buyers were also more likely to purchase affordable ICEVs (Prieto & Caemmerer, 2013). Finally, Reagan et al. (2023) noted that the distribution of used versus new ICEVs owners across car brands was similar. As to vehicle usage, used ICEV owners were more likely to drive daily and reported higher mileage compared to new ICEV owners (Reagan et al., 2023). However, additional driving among households that purchased either new or used ICEVs appears to be moderated by vehicle efficiency (Steren et al., 2016).

Used ICEV buyers were also more satisfied than new ICEV buyers with the information they received at the point of sale (Boelhouwer et al., 2020). They were also more likely to report that sellers informed them about the presence of a given system in their vehicle, and how to switch systems on and off and make adjustments to the settings (Reagan et al., 2023). However, research has also shown that used ICEV buyers were less likely to be informed about the automated driving systems in their vehicles (Boelhouwer et al., 2020), and were generally less knowledgeable and aware of the automated driving systems in their cars compared to new ICEV buyers. They were also less able to provide accurate system descriptions (Reagan et al., 2023). Despite this, used ICEV buyers were more likely to report that seller demonstrated how to use the systems (e.g., via test drives, online training, or information) (Reagan et al., 2023). In terms of crash avoidance technologies, used ICEV owners were more likely to consider them in their purchase decision, whereas new ICEV owners were more likely to state that crash avoidance technologies in vehicles did not influence their decision. Nevertheless, both used and new ICEV owners rated the importance of crash avoidance as highly important, and both viewed technologies aimed at reducing their workload and boredom of driving as least important (Reagan et al., 2023).

3.2. Adoption of Used PEVs

3.2.1. Sociodemographic Factors

Several studies have examined the socio-demographic factors associated with used PEV adoption. Used PEV owners tend to be male, younger-to middle-aged, higher-educated, full-time employed, and relatively affluent (Canepa et al., 2019; Hatt et al., 2020; Loh & Noland, 2024; Sheykhfard et al., 2025). Mashrur and Mohamed (2025) found that the vehicle ownership of used PEVs was slightly higher among younger individuals with full-time employment and higher education. In Sheykhfard et al. (2025), however, older individuals were more likely to own used PEVs. Moreover, Tal et al. (2021a) found that regions with a higher ratio of used PEVs had a population with a higher median age, and a higher share of white households. This supports research by Muehlegger & Rapson (2019), which has shown that non-Hispanic White households accounted for the largest number of total PEV purchases (both new and used), followed by Asians (new PEVs), and Hispanics (new PEVs). In contrast, in Sheykhfard et al. (2025) the Hispanic ethnicity/race positively correlated with the socio-demographic profile of used PEV owners. Household size had a small positive effect on the adoption of used PEVs (Sheykhfard et al., 2025).

Muehlegger & Rapson (2019) have shown that lower-income individuals are less likely to purchase PEVs, but if they do, they are more likely to buy used rather than new PEVs. The important role of income for the adoption decision of used PEVs was also supported by Sheykhfard et al. (2025). Households with an annual income between $100,000 to $500,000 or with 2 or more earners were more likely to purchase new trucks, whereas households earning between $70,000 to $100,000 were more likely to purchase used trucks (Chakraborty et al., 2024). In Tal et al. (2021) regions with a relatively lower income had a higher share of used PEVs, supporting research that has shown a higher proportion of used PEVs in households from disadvantaged communities than the share of used EVs in non-disadvantaged communities (Canepa et al., 2019). As income increased, the marginal effects of being concerned about pricing and charging availability decreased and concerns about the performance of the battery increased (Loh & Noland, 2024).

3.2.2. Built Environment Factors

An additional factor affecting the decision to adopt a used PEV is the type of residential dwelling and dwelling ownership. Used PEV owners were more likely than new PEV owners to live in single-family homes (Canepa et al., 2019; Loh & Noland, 2024). Moreover, individuals with access to parking amenities, such as private garages or assigned parking spaces, were more likely to choose used

PEVs (Mashrur and Mohamed, 2025). Counterintuitive is the finding that residents of multi-family unit dwellings had lower odds of being concerned about charging availability than residents of single-family units (Loh & Noland, 2024).

Studies have also provided information about the adoption of used PEVs by residential location. Urban and suburban areas and West Coast States in the U.S., such as California, Oregon, and Washington, had a higher concentration of used PEV sales than East Coast States, such as New York, Maryland, and New Jersey (Tal et al., 2021). Other research has shown that used PEV owners were mostly from California, Florida, Texas, Arizona, New York, or Virginia (Loh & Noland, 2024).

3.2.3. Travel Behavior Factors

Individual's travel behavior has also affected the decision to adopt a used PEV. Studies have shown a higher affinity towards used PEVs among individuals with a moderate to higher travel frequency (Mashrur & Mohamed, 2025). This is in line with the study of Sheykhfard et al. (2025), which has shown that the majority of used PEV owners reported driving less than 100 miles per day. The vehicle type has also influenced the decision to adopt used PEVs. Individuals owning a used PEVs were more likely to choose economy and sedan vehicle types than SUV bodies (Mashrur & Mohamed, 2025).

3.2.4. Charging Access

Having access to slow charging at home and public fast charging is related to the purchase of a used PEV (Canepa et al., 2019), aligning with research that has shown that accessibility to home charging and satisfaction with public charging is related individual's choice to purchase used PEVs (Mashrur & Mohamed, 2025). Sheykhfard et al. (2025) have shown that almost half of their study participants (49.5%, n = 992) reported using a standard household 120-V-outlet for charging and 43.2% used a 240-V outlet for charging. The majority of study participants found it easy to locate public chargers, and almost 70% were satisfied with the public charging infrastructure. More than 70% reported to have 2 or more public chargers available, and around 60% commonly used public charging stations (Sheykhfard et al., 2025). The likelihood of purchasing a used PEV was higher when slow home charging was provided compared to when workplace charging was available. However, the availability of public fast charging stations reduced the effects of access to slow home charging for used PEV buyers and at work for new PEV buyers (Zou et al., 2020). Moreover, not surprisingly, individuals without public charging stations near home had higher odds of being concerned about the availability of public charging stations compared to those with at least 1 public charging station within a 15-minute drive (Loh & Noland, 2024).

3.2.5. Attitudinal and Perceptual factors

Furthermore, the results of the review have also shown that the reasons for purchasing new rather than used PEVs were related to concerns about vehicle safety, battery range, charging time, the availability of local service shops or PEV service centers, and uncertainty about whether local dealerships or garages were knowledgeable about PEV maintenance (Hatt et al., 2020). Battery range concerns included having less range in more extreme weather conditions (e.g., winter, heat), concerns about the warranty and battery life, uncertainty with regards to the longevity, range limitations of smaller / more affordable PEVs, charging the vehicle away from home and the lack of charging stations, especially in rural areas and on longer trips (Hatt et al., 2020; Loh & Noland, 2024; Sheykhfard et al., 2025). In Sheykhfard et al. (2025) used PEV buyers expressed high satisfaction with the performance of the battery, whereas limited driving range was mentioned as a moderate concern. Other reasons for purchasing new rather than used PEVs were concerns about the potential outdated technology, vehicle lifespan and the resale value (Hatt et al., 2020; Roberson et al., 2024; Sheykhfard et al., 2025). Another vehicle-related attribute is brand. Used PEV owners purchased one of the top car brands (e.g., Tesla, Nissan, BMW) (Loh & Noland, 2024). The lack of available used vehicle options by the time of purchase was another reason to purchase new rather than used PEVs (Hatt et al., 2020).

Affordability, lower fuel and maintenance costs, and cost savings were other stated benefits of used PEVs and motives for the purchase of used PEVs (Hatt et al., 2020; Sheykhfard et al., 2025). Moreover, the vehicle purchase price was a concern of used PEV owners, perhaps due to the high initial purchase price, and the installation costs for home chargers was a concern of around a quarter of used PEV buyers (Sheykhfard et al., 2025). Other study participants indicated they would consider the purchase of a used PEV at a lower or equal price of an ICEV, and some participants indicated that they would be willing to pay a price premium (Pedrosa & Nobre, 2018). Purchase incentives and rebates available at the time of the purchase of the vehicle motivated the purchase of new PEVs, leading to reductions in purchase prices and accordingly total cost of ownership of both new and used PEVs (Busch, 2021; Hatt et al., 2020).

3.2.6. Contextual Factors

Regarding where used PEV owners acquired their used PEV, Sheykhfard et al. (2025) reported that almost half of participants acquired their used vehicles from car dealerships, followed by online retailers and peer-to-peer platforms (e.g., eBay, Facebook Marketplace). A large majority of participants received information about used PEVs from the Internet and social media, followed by online research, traditional media (e.g., TV/radio), newspapers/magazines, word-of-mouth, and dealerships. Almost all participants reported receiving correct information about PEVs prior to their purchase. The authors of this study also found that the familiarity of dealerships with PEV technology was a moderate concern of used PEV owners.

Moreover, this study also found that more than half of study participants reported intending to purchase a used PEV in the future, where around a third of participants did not intend to make another purchase of a used PEV. This study also revealed a positive relationship between ease of charging (i.e., finding a charger, satisfaction with battery, number of public chargers available in 15-minute drive) and the future purchase intention of used PEVs. Relying on information sources, such as TV, radio and online searches had a negative effect on the future adoption decision of used PEVs. The effect of driving experience (i.e., number of daily miles driven, miles driven before recharging, long-distance trips) on the intention to purchase a used PEV in the future was negative (Sheykhfard et al., 2025).

3.3. Adoption of ‘Used Products’

Several studies have identified different factors related to the adoption of used ‘products’ (e.g., clothing, appliances), which include socio-demographic, economic, ethical and ecological and emotional-affective dimensions.

Studies have highlighted that those who were more experienced with acquiring used things had more positive attitudes toward used products. The same study also reported gender differences as affecting the decision to purchase used things, with males having less favorable towards shopping for used things than females and having more difficulties finding items they are looking for (Markova & Bayanduuren, 2017). However, Wang et al. (2022) suggested that males are more likely to acquire used items more frequently than females. While Frahm et al. (2025) showed that women were more positive about the acquisition of used things than males. The effect of age on general attitudes towards purchasing used things was negative yet weak, indicating that elderly individuals are less likely to be positive towards the acquisition of used things than younger individuals (Frahm et al., 2025).

Economic motivations are captured by several constructs in the literature, which include the preference to pay less, the search for a fair price, price/price orientation, bargain hunting, the efficient allocation of expenditures and price appraisals, low earnings, frugality, the unaffordability of new products, price-performance ratio, individuals' concern about their financial situation (frugality), and financial risks (Dharma, 2023; Frahm et al., 2025; Guiot & Roux, 2010; Koay et al., 2023; Mukherjee et al., 2020; Rodrigues et al., 2023; Roux & Guiot, 2008; Wang et al., 2022; Yan et al., 2024; Frahm et al., 2025).

Another dimension that has been identified is the 'ethical and ecological dimension'. These factors include the avoidance, distance, or escape from the classic market system, defined as the importance of reusing functional products, reducing the depletion of natural resources, and avoiding the unnecessary distribution of products (Frahm et al., 2025; Guiot & Roux, 2010; Padmavathy et al. 2019). Another factor is the anti-ostentation, which is defined as the deliberate and conscious rejection of everything that is associated with fashionable or mass consumption, valuing the use of products rather than their functions as signs or symbols (Guiot & Roux, 2008; Guiot & Roux, 2010; Roux & Guiot, 1988). Other ethical and ecological dimensions are the environmental concern, eco-consciousness, moral norms, ascription of responsibility, the perceived values on sustainability (consumer's evaluation of overall useability of the product), and the awareness of the negative consequences associated with the 'old behavior or technology/thing to be replaced' (Borusiak et al., 2021; Dharma, 2023; Frahm et al., 2025; Koay et al., 2022).

Studies have also identified emotional-affective factors impacting the adoption. These factors include social contact, stimulation, treasure-hunting fun, interacting and fun, and vintage-seeking fun given the opportunities of wandering around, experiencing a new environment, or having meaningful interactions with the seller. Other affective dimensions include superiority, which includes feelings of pride and vanity, and the perception of being part of an elite or private circle. This factor is also related to the need for social status (i.e., care for social standing), for social recognition, status symbol, social norms or social influence, sense of community (i.e., individual's irrational feelings and attachment towards a society or group and emotional bonds to this group), or perceived social risk (i.e., possibility of losing one's own social status as a result of buying secondhand) (Calvo-Porral et al., 2024; Dharma, 2023; Frahm et al., 2025; Guiot & Roux, 2010; Mukherjee et al., 2020; Wu et al., 2023; Xu et al., 2014; Zahid et al., 2023). Participants were also concerned that the acquisition of used things would be related to poverty (Wang et al., 2022). Observing the behavior of significant others also increased the likelihood of the individual to acquire used things (Mukherjee et al., 2020). Self-esteem, love, belonging, and the need for exclusivity, for being different, or unique (i.e., need of individuals to see and show oneself differently from others) are additional emotional-affective factors (Dharma, 2023; Frahm et al., 2025; Guiot & Roux, 2010; Lang & Zhang, 2019; Padmavathy et al., 2019). Similar factors are the perceived originality, uniqueness, nostalgia, or authenticity of the technology (Frahm et al., 2025; Guiot, 1988; Guiot &

Roux, 2010). The perceived enjoyment or fun derived from using the technology conceptually overlaps with the factor hedonic value (Xu et al., 2014). Markova and Bayanduuren (2017) have shown that participants considered shopping for secondhand clothing fun, and the purchase of trendy and fashionable items enjoyable.

Trust is an additional factor determining the adoption of used things. Trust captures the relationship between buyer and seller, which is based on respect for quality standards, mutual consent, reliability, trustworthiness, and keeping one's promises (Padmavathy et al., 2019). Trust in the seller is another reason for the acquisition of used things: Study participants reported that they purchase secondhand from personal sources, such as friends, relatives, or acquaintances, due to their trust in these sources, and the inconveniences and their mistrust in retail. Participants expressed concerns about being cheated with fake and stolen products if they had made their purchase from the secondhand market. Moreover, other reasons to purchase from trusted personal sources were the need to make payments in part and time constraints (Mukherjee et al., 2020).

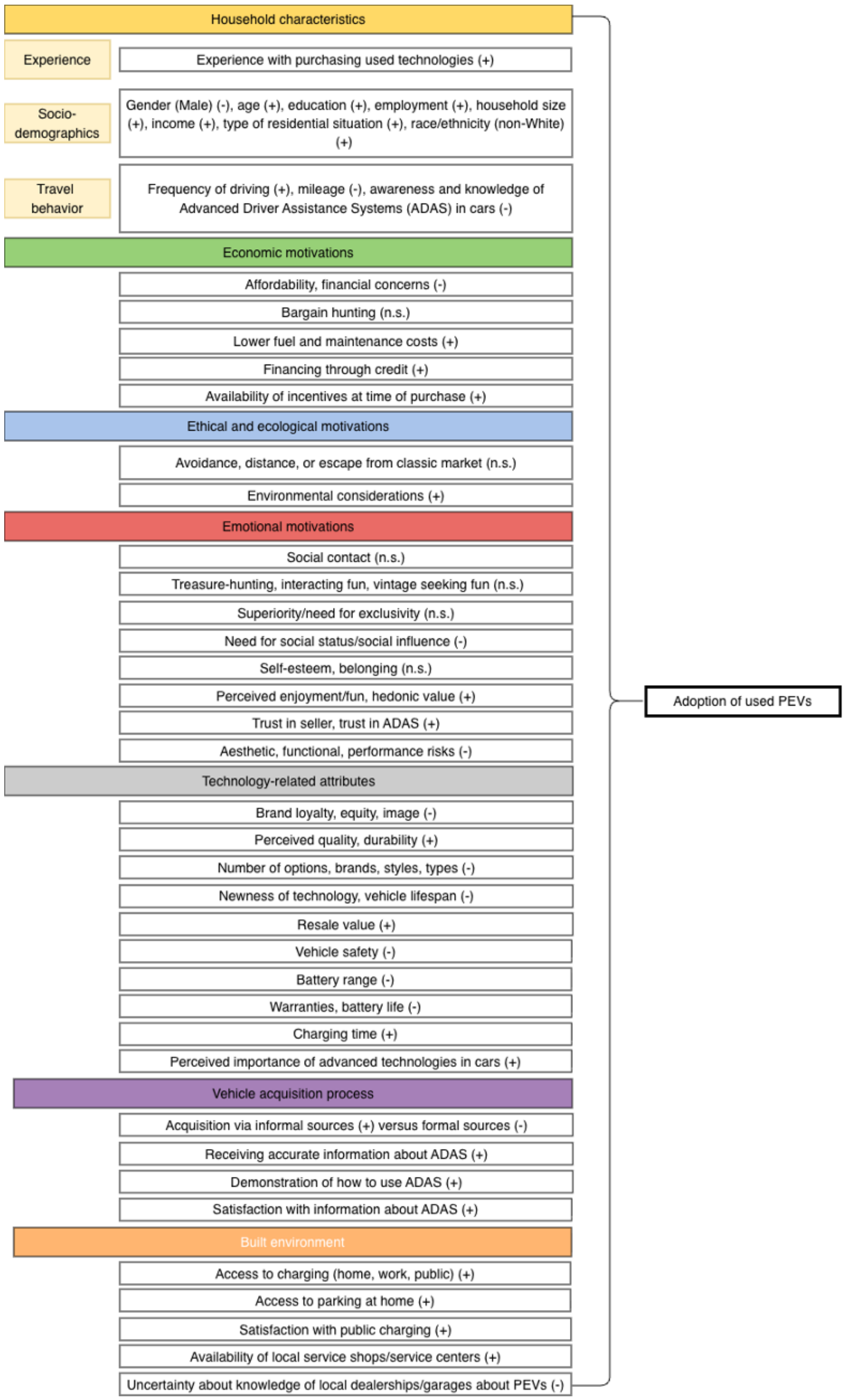
Functional characteristics of used things are other reasons for purchasing used things. These include brand loyalty (e.g., 'I consider myself to be loyal'), brand equity (e.g., 'It makes sense to buy X instead of any other brand, even if they are the same'), brand image, and the perceived quality and durability (Habib & Sarwar, 2021). Research has also shown that poor quality, low perceived value and product reliability were associated with the acquisition of used products (Calvo-Porral et al., 2024; Mukherjee et al., 2020; Yan et al., 2024). The limited number of options, brands, styles or types of used things were additional reasons that motivated the purchase of used things (Wang et al., 2022).

Overall, these results highlight some similarities with research on the adoption of used PEVs. The adoption of both used PEVs and used products are both related to demographic, economic, and attitudinal factors. However, for several attributes the direction of the relationship is different. For example, used PEV adopters tend to be male, while the buyers of used are sometimes found to be less likely to be male.

3.4. Synthesis

Here, we synthesize the results of the literature review by summarizing the main factors affecting the adoption of used PEVs in Figure 4. As presented in Figure 4 Factors determining the purchase of used PEVs. , the adoption of used PEVs is determined by household characteristics, economic motivations, ethical and ecological motivations, emotional motivations, technology-related attributes, vehicle acquisition process and the built environment.

Figure 2 Factors determining the purchase of used PEVs.



Note: Positive relationships are marked with '+', negative relationships with '-', and non-significant relationships with 'n.s.'.

3.5. Discussion

The present study reviewed literature on the adoption of used things, ICEVs and PEVs to gain a better understanding of why people purchase used PEVs. We have organized the results of the literature review around these three literature streams, and synthesized the results in Figure 4 provides an overview of the main factors underlying the adoption decision across technology types (used thing, used ICEV, used PEV).

Socio-demographic characteristics have been associated with the new adoption of a used PEV. We find that the characteristics of used PEV owners generally reflect the characteristics of new PEV owners. Most of the used PEV owners were male, middle-aged, white, well-educated, and with a higher-than-average income. It is plausible that the characteristics of new and used PEV owners will diverge further with a growing saturation of the used PEV market (Tankou et al., 2021; Turrentine et al., 2018). As long as PEVs remain unaffordable, lower-income households may not be able to purchase used PEVs (Loh & Noland, 2024). Policy incentives and subsidies may encourage their adoption (Langbroek et al., 2017). However, subsidies can also negatively affect retention rates (Roberson et al., 2024) and may thus promote resale anxiety, which was considered one of the major barriers to the mass adoption of used PEVs (Lim et al., 2015).

Unsurprisingly, used PEV owners were more sensitive to high upfront costs than new PEV owners (Hatt et al., 2020; Loh & Noland, 2024; Wicki et al., 2023), supporting assumptions about the purchase price being the main barrier to the adoption of used PEVs (Busch, 2021). At the same time, purchase price may not impede the adoption of a used PEV if owners have a real need for owning a used PEV and can financially afford it. The cost sensitivity of used PEV owners may be a stronger driver for the decision to adopt a used PEV and to replace a used PEV than for the decision to add a used PEV to an existing household fleet. We have also found that the purchase and ownership of a used ICEV and PEV can be a financial burden for owners (Klein et al., 2023). Low-income, single vehicle home-renters had higher annual vehicle ownership cost burden compared to multi-vehicle and more affluent homeowners (Chakraborty et al., 2024). This shows that post-purchase stress can increase the likelihood of selling the used vehicle, or not purchasing it in the first place given financial concerns. More information and / or education, e.g., at dealerships or financial institutes, may alleviate these concerns.

Concerns about battery performance and charging station availability are drivers to adopt both new and used PEVs. Studies have also shown that used PEV owners were more concerned about battery performance and charging availability than new PEV owners. This could be due to information gaps about battery condition and charging history, which reflect classic “lemon market” dynamics in used vehicle markets (Akerlof, 1970). The availability of public charging infrastructure decreased concerns about charging availability. Access to public charging may remain pivotal in promoting the adoption of used PEVs (Loh & Noland, 2024), especially on longer trips given that most people typically charge their vehicles at home (Ge et al., 2021). Seeing public infrastructure promoted respondents’ considerations to purchase a PEV (Kurani, 2018), but the density of public charging was not related to considerations to purchase a PEV (Hoogland et al., 2024). Increasing the battery range by 50 miles could increase the probability to purchase a PEV by around 4% for both new and used ICEV buyers (Zou et al., 2020), highlighting the role of driving range as a shared concern across buyer types. Lower-income residents were more concerned about the availability of charging, and less concerned about battery performance, supporting prior research on used PEV buyers who had limited access to parking (Busch, 2021). Moreover, residents of multi-unit dwellings were less concerned about the price and charging availability than residents of single-family homes, which is counter-intuitive as multi-unit dwellings are more likely to attract individuals from lower- to middle-income groups without access to charging. However, it is plausible that these participants may not accurately reflect the general population of multi-unit dwellers. They were also less likely to be concerned about battery performance, perhaps because multi-unit dwellers travel shorter distances (Loh & Noland, 2024). Future research should examine what exactly participants associate with battery performance, e.g., the state of health or safety of the battery. This knowledge can inform the development of targeted policy interventions to educate consumers about the condition of the batteries of used PEVs.

Our review has also revealed that used ICEV owners were less informed about ADAS in their vehicles than new vehicle owners, perhaps because used ICEV owners are more likely to purchase their vehicles from private or independent sellers that may not have the same resources as dealerships (see Boelhouwer et al., 2020). It is also plausible that used ICEV owners are less likely to consider the availability of ADAS in vehicles important.

4. Policy review

In the following we will provide an overview of key policies and purchase incentives to promote the adoption of used PEVs. As shown by Table 2, there are state, federal, and utility-level policies designed to reduce financial and infrastructural barriers to the adoption of used PEVs.

The California state programs, particularly Clean Cars for All and Clean Vehicle Assistant Program and the Clean Vehicle Assistant Program, offer purchase incentives of between $10,000-$12,000 plus $2,000 for home charging equipment. These programs are explicitly targeted at low-income households (≤300% of the Federal Poverty Level), with enhanced benefits for residents of Disadvantaged Communities (DACs), and in some cases include low-interest financing to address credit constraints.

At the federal level, the Used Clean Vehicle Credit provides a more modest but broadly applicable incentive - up to $4,000 (30% of vehicle price) - for qualifying used EVs priced at or below $25,000 and purchased from licensed dealers. Eligibility is restricted by income thresholds, but the credit applies nationwide and directly supports used-vehicle transactions.

Infrastructure-related incentives complement purchase subsidies. The federal home charging tax credit covers 30% of charger and installation costs (up to $1,000) for both new and used PEV buyers, while utility-sponsored programs offer rebates for charging equipment, electrical panel upgrades, and financial incentives (e.g., reduced electricity rates, reduced enrolment fees). These programs primarily benefit existing utility customers and help mitigate the home charging barrier identified in the study.

Finally, the table highlights battery warranty requirements. Mandatory minimum warranties (e.g., 8 years / 100,000 miles) apply to many PEVs, while most BEVs rely on manufacturer-specific warranty rules. These protections benefit both new and used buyers by reducing perceived battery risk.

Table 2. Policies/ consumer incentives for the adoption of used PEVs.

#	Policy / Incentive	Level	Description	Who Benefits
1	Clean Cars for All - Reduced	State	- Purchase incentives of up to $9,500 for a car aged 8 years old or a newer PHEV (plus up to $2,000 incentives for charging equipment) - Purchase incentives of up to $10,000 for car aged 8 years or newer zero-emission vehicles (plus $2,000 in charging equipment)	- Individuals with income eligibility of less than or equal to 300% Federal Poverty Level
2	Clean Cars for All	State	- Purchase incentives of up to $11,500 for car aged 8 years or older or newer PHEV (plus $,2000 in charging equipment) - Purchase incentives of up to $12,000 (plus up to $2,000 incentives for charging equipment) for car aged 8 years old or newer zero-emission vehicle	- Individuals with income eligibility of less than r equal to 300% Federal Poverty Level in Disadvantaged Communities

3	Used Clean Vehicle Credit[1]	Federal	- Federal tax credit of up to $4,000 (30% of vehicle price) for qualifying used EVs priced ≤ $25,000 and purchased from a licensed dealer	- Individual used-PEV buyers
				- Individuals with a modified adjusted gross income below the following thresholds:
				  - $150,000 for joint filers
				  - $112,500 for head-of-household filers
				  - $75,000 for single filers

4	Federal Tax Credit for Home Charging (IRS)	Federal	- Credit for 30% of the cost of your Level 2 AC (240-volt) home charger and installation, up to $1,000.	- Buyers of used and new PEVs

[1] Credit is no longer available for vehicles acquired after September 30, 2025.

5	Clean Vehicle Assistant Program	State	- Purchase incentives of up to \$10,000 and \$2,000 for charging for non-DAC residents - Purchase incentives of up to \$12,000 for DAC-residents + \$2,000 for charging - Low-interest rate loans, capped at 8% Annual Percentage Rate (APR)	- Low-income consumers to lease new or used clean vehicle
6	Utility-Sponsored Used EV Rebates	Utility / Local	- Electric utilities offer rebates for purchasing and installing home charging equipment, for upgrading electrical panels, and reduction in electricity costs	- Utility customers
7	EV Battery Warranty Requirements	Federal / State (Indirect)	- Mandatory minimum battery warranties (e.g., 8 yrs / 100k miles) for ICEV, PHEV and some partial zero-emission vehicles - Most BEVs require on automaker's own battery warranty rules	- Buyers of used and new PEVs

5. Stakeholder Engagement

Throughout the project, we implemented extensive engagement with stakeholder communities using multiple complementary methods.

During the survey development phase, we shared draft instruments and specific question modules, including questions related to knowledge gaps, access needs, language barriers, and charging challenges. Over the course of the project, we held meetings with representatives from SMUD, which focused on general survey accessibility and continuation strategies, as well as with representatives from EVNoire, The Niles Foundation based in Los Angeles, and Central California Asthma Collaborative, the EV Equity Program, and Miocar in the Central Valley . We also engaged with the REACH (Reliable, Equitable, and Accessible Charging for multi-family Housing) 2.0 grant team in Santa Barbra. In total, we engaged 16 individuals representing 11 different organizations as part of the survey design refinement and data collection planning process. We also engaged with representatives from GOBiz to provide input to the Statewide ZEV Equity Action Plan and presented research to the Caltrans ZEV Technical Advisory Committee.

Over the course of the project, we presented the project while in progress to gather feedback on the project. These included presentations at the STEPS+ Symposia held in November of 2024, with follow-up presentations and discussions in July and November of 2025. These events are attended by a broad array of state and federal agencies, automakers, and community based organizations.

On December 16, 2025, project findings were presented at the Sacramento e-Mobility Collaborative (virtual) meeting by researcher Sina Nordhoff. The talk was titled "Unlocking the Used Vehicle Market: A Multigroup Analysis of PEV Adoption in California" and was followed by an extensive Q&A period with the more than 30 people in attendance. Invited attendees at the Sacramento E-Mobility Collaborative meetings include representatives from local agencies, non-profits and companies that work in the e-mobility topic in the region.

The following is a list of entities, not including automakers and private companies, that we have engaged with through the course of this project:

- EVHybridNoire & EVNoire
- Ecology Action
- The Greenlining Institute
- Mobility Justice
- Mobility Development (Los Angeles region)
- Grid Alternatives
- MCE Clean Energy
- Fresno Metro Black Chamber of Commerce
- Sacramento Air Quality Management District
- Nor Cal Clean Cities Coalition (formerly Sacramento Clean Cities Coalition)
- Sacramento Municipal Utility District
- Sacramento Area Coalition of Governments
- SacBreathe
- Valley Vision

- United Latinos
- La Familia Counseling Center

6. Research Gaps and Future Research Opportunities

We identified several research gaps, some of which will be addressed by the present project.

6.1. Research opportunity 1: Tailor study design to the characteristics of the used PEV market

Used PEVs differ from new PEVs in several important ways, and the factors influencing individuals' decisions to purchase used PEVs may therefore differ from those influencing the purchase of new PEVs. Many prior studies did not tailor their research instruments specifically to the used PEV context. Our project tailors the survey instrument to the specific characteristics of used PEVs owners. In this project, we identify factors that are *specific* to used PEV owners versus new PEV and other vehicle owners, such as attitudes towards the acquisition of used vehicles, which may contribute to an individual's purchase decision of used PEVs.

6.2. Research opportunity 2: Compare differences between used vehicle owners

Informed by the results of the literature review, we propose testable hypotheses capturing the relationship between various independent variables identified in this study and the adoption of used PEVs. Some of these hypotheses are tested by this project, analyzing differences between owners of used ICEVs, new PEVs and used PEVs. Here we propose the main hypothesis that used PEV owners are more similar to new PEV owners than to used ICEV owners in their socio-demographics and economics. However, the socio-demographic and -economic differences between used and new PEV owners may become smaller when used PEVs trickle down to the main market. Moreover, beyond socio-demographic and socio-economic factors, the literature on used goods suggests that additional behavioral motivations may help explain the decision to purchase a used PEV.

6.3. Research opportunity 3: Recruit gender-, race-, and ethnicity-balanced samples

The number of participants of used PEV owners in the reviewed papers tends to be small, and most of them reflect the typical early adopter populations (male, middle-aged, white, well-educated, higher income), which makes the sample not representative of the general car driver population. This project recruits vehicle owners from the general population of vehicle owners in California that reflects the distribution of key characteristics of the general population of vehicle drivers.

6.4. Research opportunity 4: Examine attitudes

Many of the reviewed studies have focused on socio-demographic characteristics affecting PEV adoption even though attitudinal variables are considered stronger explanatory variables for the adoption of PEVs and other transportation technologies (Jansson, 2011; Kurani, 2018; Mohamed et al., 2016). Among these attitudinal variables is the role of the environment. Previous studies on the adoption of new PEVs have examined the role of the environment for individual's interest in and adoption of PEVs (Mohamed et al., 2016; Paradies et al., 2023; Salari, 2022; Wicki et al., 2023). There are several constructs that measure the role of an individual's environmental attitudes for the decision to adopt a PEV (new, and used), such as environmentalism, concern for the environment, environmental values, environmental self-identity, or green consumer values (Salari, 2022). In the case of used PEVs, the environmental appeal may be even stronger, as buyers may perceive a double environmental benefit: Both from driving a zero-emission vehicle and from purchasing a used product, which aligns with broader sustainability values. Moreover, we expect that the role of the environment for an individual's adoption decision may gain importance considering the climate crisis, and the growing awareness of the public. Our project investigates the impact of an individual's environmental orientation on vehicle adoption.

6.5. Research opportunity 5: Examine personality characteristics

Most prior studies have limited the analysis to vehicle owners' characteristics to participants' socio-demographic and -economic characteristics. Socio-demographic characteristics are very reliable, easy to administer, and less prone to changes (Prochaska, 1991). However, they provide insufficient information about *why* individuals hold certain attitudes and beliefs towards used PEVs. Even though used PEV owners take greater risks than first PEV owners, purchasing vehicles close to or after the end of warranty (Tal et al., 2021), the role of an individual's personality on the decision to adopt a PEV (both new and used) has been hardly addressed in the PEV adoption literature. Our project addresses this shortcoming, and examines the impact of an individual's willingness to take risks on the adoption of used PEVs.

6.6. Research opportunity 6: Examine the impact of information, communication, and policy on risk perception of used EV owners

The public might have some misconceptions about used PEVs, underestimating their performance and advantages in comparison to new PEVs, and overestimating potential risks. One of the largest barriers to used PEV adoption may be the limited access to and availability of charging stations, range anxiety, limited electrical driving range and the high vehicle purchase prices of PEVs compared to gasoline-powered vehicles. Owners may adapt to risks in unforeseen, negative, or in positive ways. For instance, if they underestimate risks, they may forget to charge their vehicle, and risk running out of battery. If they overestimate risks, they may not adopt a PEV, or stop using it. Negative behavioral adaptations may hinder adoption. Positive behavioral adaptations can serve as best practices shared among owners, supporting adoption. In this project, we examine an individual's willingness to adopt a BEV if two important barriers to BEV adoption are removed: access to home charging and high purchase prices.

7. Methods

7.1. General Discussion

The primary research tool for this project is a survey instrument designed to understand both the behavior and motivations of vehicle owners, particularly those who own or have owned alternative fuel vehicles. This approach is consistent with similar studies exploring the impact of technology and policy on vehicle purchase and travel behavior. In addition to the survey, we utilize the California Department of Motor Vehicles (DMV) vehicle registration dataset for multiple purposes: to generalize findings from the survey sample to the broader population, to inform our survey recruitment strategy, and to track the flow of used electric vehicles outside of California. Additional datasets on vehicle transactions help us understand patterns in the secondary market for electric vehicles.

The analytical approach is based on econometric methods and includes: (1) Descriptive statistics documenting key trends and patterns, (2) exploratory statistical analysis to identify relationships between variables, and (3) modeling of correlations between demographic, attitudinal, and behavioral factors.

Causal mechanisms that inform policy discussions are derived from direct questioning of surveyed individuals combined with evidence from secondary sources. As such, findings should be interpreted within the broader context of existing knowledge about electric vehicle ownership and usage in California.

Different sections of the survey exhibit varying levels of completion because many questions were optional and some are open-ended rather than mandatory. As a result, although the overall dataset is the same, the effective sample size after data cleaning may differ across sections (e.g., purchase decision versus charging behavior).

Additionally, two sets of Department of Motor Vehicles (DMV) data were used, differentiated by time period. Both datasets are from 2023; however, the second dataset includes all 2023 model-year vehicles and a subset of 2024 models, whereas the first dataset was used for sampling the survey. In both cases, the DMV data are more than one year older than the survey data and therefore reflect a lower penetration of electric vehicles than was present at the time of the survey.

Furthermore, the analyses were conducted over an extended period and reflect data collection efforts carried out over more than one year. Consequently, the sample size is reported separately for each analysis, and results from categories with sample sizes that are generally too small to be statistically meaningful are not presented.

Important contextual note: This research was conducted in 2025, a year marked by significant political and economic turbulence. This timing introduces additional uncertainty into both the data collection process and respondents' answers. The political climate and economic volatility may have influenced respondents' perceptions of vehicle ownership costs, policy stability, and future technology adoption. Consequently, the level of uncertainty in the findings is likely higher than would be expected under more stable conditions, and respondents' perspectives may have shifted more rapidly than in typical periods.

7.2. Data Sources

In this project, we use three different data sources that inform the design of this study and answer the project's main research questions.

- S&P data
- DMV household data (2022)
- Survey data

These data sources will be described in the following sections.

7.2.1. S&P Data

The S&P data provide comprehensive information on vehicles exported out of California, including the destination state and the exact date of transfer, allowing for precise tracking of used PEVs as they move across state lines. These records form the core empirical input used to characterize interstate flows of used PEVs originating in California.

The raw vehicle-level transfer records are aggregated to a state-by-year panel covering the period 2016-2023. Each transferred vehicle is assigned to the receiving state in which it is ultimately registered. In addition, S&P Global provides a separate snapshot of the BEV and PHEV fleet size in each US state for 2023. This fleet snapshot is used as a fixed baseline to normalize import volumes across states and over time.

7.3. Sampling Frame

To draw a sample from the California population, we developed a sampling frame using the DMV household data (2022). Our sampling strategy was designed to ensure sufficient representation across these four household PEV ownership categories. Given the very low prevalence of PEV ownership in the general population, a randomized or population-representative sample would yield too few observations in our groups of interest. We therefore intentionally departed from the population distribution to allow systematic comparisons across households with different PEV ownership statuses, including those with new, used, and mixed PEV fleets, as well as ICE-only households.

We created the sampling frame in the following three main steps.

1. Categorizing households (HH) by vehicle type:
    - PEV Ownership: If an HH has purchased one or more PEVs (BEV or PHEV), the HH is assigned to a group based on the most recent PEV purchase.
    - BEV Groups: For HHs with BEVs, there is an additional distinction between HHs that have purchased a Tesla and those that haven't – to avoid oversampling of Tesla HHs: The HH is placed in either the "New Tesla BEV" or "New Non-Tesla BEV" group if their most recent vehicle purchase is a new BEV, or in the "Used Tesla BEV" or "Used Non-Tesla BEV" group if their most recent purchase is a used BEV.
    - PHEV Group: If the most recent PEV purchase is a PHEV, the household is assigned to the "New PHEV" or "Used PHEV" group, depending on whether the vehicle was bought new or used.
    - ICE Ownership (HHs Without PEVs): HHs that do not own any PEVs are classified into either the "New ICE" or "Used ICE" group based on their most recent ICE vehicle purchase.

2. Sampling from each group: Once HHs are assigned to their respective groups, a random sample of 1,000 HHs is selected from each group for the first survey run.
3. Adjusting for the second survey: Based on the response rates from the initial survey, a second sampling was conducted following a similar process. However, the sample sizes were adjusted in the final stage to ensure that each group yields ~800 completed surveys. This is needed to achieve sufficient statistical power.

7.4. Survey Instrument and Procedure

An online questionnaire was distributed to a sample of 50,000 vehicle buyers in California, United States, of which 3,396 surveys were returned.

Respondents were invited via mail. The invitation letter informed them about the purpose and nature of the study, such as that the aim of this study is to gain a better understanding of their vehicle usage behavior in their household, with a focus on alternative fuel vehicles, including battery electric vehicles and plug-in hybrid electric vehicles. They were informed that their participation is voluntary, that every participant has the chance to participate in a lottery to win a $40 amazon gift card, and that it would take around 15 to 25 minutes to complete the survey. Moreover, the invitation letter stated that responses would be confidential and that the research will only be accessed by researchers at UC Davis. The results of the study would be used to write journal papers and reports.

The survey was specifically designed to be distributed to six vehicle owner groups who mainly differed with regards to fuel type technology and whether the household vehicles were new or used. These eight vehicle owner groups were owners of used and new battery electric vehicles, plug-in hybrid electric vehicles, and gasoline-powered vehicles. This means that the questionnaire was the same for all groups whenever possible. To account for the unique experience of vehicle owners, we adjusted the questionnaire whenever possible. To test the logic and effectiveness of the questionnaire, we piloted the survey with a smaller sample of our target population, resulting in changes in the wording of questions, and the addition and removal of questions.

We performed a soft launch with a smaller sample of our target population, which led to the refinement of the wording of some survey questions, and the addition and removal of some questions.

The survey was divided into the following sections, which will be briefly described below.

- Household vehicle ownership and use
- Household vehicle acquisition and vehicle purchasing behavior
- Attitudes towards batteries of BEVs
- Perceptions, knowledge
- Household and respondent characteristics and travel behavior

In the first section, respondents were asked to provide information about their household's vehicle ownership and usage behavior. For instance, they were asked to provide information about the number of vehicles in their household, including year, make and model, whether the vehicles were owned, acquired as new or used, when it was acquired as used, and whether it was purchased or leased, travel purpose, current odometer reading, odometer reading by the time of vehicle acquisition and annual mileage. Respondents could provide this information for up to five cars in their household, but respondents were asked to answer the remaining questions with regards to their "car main". "Car main" was defined as the most recently acquired vehicle. If the household had any PEVs, we considered only the PEVs as "car main". Throughout this document, we will refer to "car main" as the household's main car.

In the second section, respondents provided information about vehicle acquisition and purchasing behavior. For instance, we asked respondents questions about past vehicle trading in behaviors, incentives, total price, amount of incentives, total down payment (not counting incentives or trade in values), monthly payment, and original length of their lease/loan.

In the third section, respondents were asked attitudinal questions about the battery at the time of the vehicle purchase, and the type of information they sought about the battery. This section also included questions about the battery warranty that was left by the time they acquired the vehicle, and their assessment of the battery condition.

In the fourth section, we included questions about respondents' vehicle replacement behavior. For instance, we asked respondents whether the vehicle replaced another vehicle in their household, the type of vehicle they replaced and the next vehicle they plan to replace.

The fifth section included questions about respondents' travel behavior in the last year and household composition. For instance, we asked respondents to provide information about the household member's age, gender and ability to drive (access to valid driver's license), and trip origins and destinations.

In the sixth section, we asked respondents questions about their charging behavior. For instance, we asked respondents questions about where they charged their vehicle in the last 30 days, whether they could plug in their vehicle at home, which type of home charger they used, whether access to workplace charging was provided, and amenities at charging stations.

The seventh section included questions about the availability of incentives and a survey experiment to test the effect of and interactions between different incentives on vehicle's purchasing behavior. For instance, we asked respondents about receiving incentives for the installation of chargers at home, the amount and type of these incentives.

In the next section, we asked respondents questions about their information seeking behavior prior to their vehicle purchase, and attitudes towards the acquisition of used PEVs.

In the ninth section, we presented respondents with questions measuring their knowledge of BEVs, and perceptions of BEV characteristics. For instance, we asked respondents to name a BEV that is being sold in the US (e.g., make, model) and how far an average 2024 model year battery electric vehicle drive in miles until empty (in miles).

In the tenth section, we asked respondents to indicate their agreement with statements pertaining to the perception of BEVs. For instance, we asked respondents to what extent they agree with the statement that it takes too long charge to a BEV, that there are enough places to charge a BEV, and that BEV do not travel far enough.

The final section asked respondents to provide personal information, including, but not limited to, a survey taker's age, gender, description of home, highest level of formal education completed, their household's pre-taxed income for the past tax year, type of parking available, and principal work education.

7.5. Data Filtering

We preprocessed and cleaned the data. This involved removing respondents who:

- Completed the survey in less than 2 minutes;
- Indicated that they don't own a vehicle;
- Provided unreasonable answers to the question 'G42Q354[SQ001]. When fully charged, how far can an average 2024 model year battery electric vehicle drive in miles until empty? Provide your best estimate in miles. [Miles]';
- Provided unsensible information to the question 's4q2[SQ001_SQ002]. Please enter information below about your household members [You][Gender]` and declined to state their gender;
- Reported to be younger than 14 years and declined to state their age;
- Declined to state to provide a description of their home

This step resulted in the removal of 679 responses from the sample, leaving 2717 valid observations to be included for further analysis.

7.6. Sample

7.6.1. Survey Sample

provides an overview of the sample characteristics. Overall, 65% of our sample is male and 35% is female. The households span a wide age range, with very few represented in the youngest categories. Younger adults ages 19 to 29 make up 3%. Representation increases steadily with age: 9% are ages 30 to 39, 16% are 40 to 49, and 22% fall between 50 and 59. The largest age group is ages 60 to 69, comprising 26%. Those aged 70 to 79 account for 20%, while households with members 80 or older account for 4%. Households report a wide range of occupational backgrounds. A small share work in building and grounds cleaning or maintenance (0%, 3 households) or in farming, groundskeeping, or fishing (0%). Education levels skew strongly toward higher education. About 2% have a high school diploma or GED. Some college experience is reported by 14%. A bachelor's degree is held by 34%, while half of all households - 50% - report holding a graduate degree. The average household income midpoint is $218,850, with a standard deviation of $133,989, indicating substantial variation across households. Household sizes vary, but most are small. Single-person households represent 15%, while two-person households form nearly half of all households at 48%. Three-person households account for 16%, and four-person households also account for 16%. Larger households with 5 to 7 members make up 5%. More than 80% of respondents report to live in a detached house/single family home, followed by 9% of respondents reporting to live in an apartment or condo, and 8% in an attached house (townhouse, duplex, triplex).

Table 3 provides an overview of the sample characteristics. Overall, 65% of our sample is male and 35% is female. The households span a wide age range, with very few represented in the youngest categories. Younger adults ages 19 to 29 make up 3%. Representation increases steadily with age: 9% are ages 30 to 39, 16% are 40 to 49, and 22% fall between 50 and 59. The largest age group is ages 60 to 69, comprising 26%. Those aged 70 to 79 account for 20%, while households with members 80 or older account for 4%. Households report a wide range of occupational backgrounds.

A small share work in building and grounds cleaning or maintenance (0%, 3 households) or in farming, groundskeeping, or fishing (0%). Education levels skew strongly toward higher education. About 2% have a high school diploma or GED. Some college experience is reported by 14%. A bachelor's degree is held by 34%, while half of all households - 50% - report holding a graduate degree. The average household income midpoint is $218,850, with a standard deviation of $133,989, indicating substantial variation across households. Household sizes vary, but most are small. Single-person households represent 15%, while two-person households form nearly half of all households at 48%. Three-person households account for 16%, and four-person households also account for 16%. Larger households with 5 to 7 members make up 5%. More than 80% of respondents report to live in a detached house/single family home, followed by 9% of respondents reporting to live in an apartment or condo, and 8% in an attached house (townhouse, duplex, triplex).

Table 3. Descriptive statistics of key sociodemographic characteristics

Sample Characteristics	**Survey % of Total**	***N***
Household's Gender		
Female	34%	981
Male	65%	1854
Genderqueer/non-binary	0%	10
TransFemale/Transwoman	0%	3
Household's Age		
15 to 18	0%	12
19 to 29	3%	77
30 a 39	9%	244
40 to 49	16%	460
50 to 59	22%	610
60 to 69	26%	751
70 to 79	20%	554
80 or older	4%	126
Household's Principal Occupation		
Building and Grounds Cleaning and Maintenance Occupations (e.g., housekeeping, janitor worker)	0%	3
Business/Management/Administration	17%	448
Creative/Arts/Media	4%	109
Education/Academia	7%	182
Farming/Groundskeeping/Fishing	0%	6
Healthcare	6%	168
Legal	3%	76
Not Employed	33%	880
Protective Services	1%	21
Service/Personal Care	3%	68
STEM (Science, Technology, Engineering, Math)	18%	486
Trades/Construction/Extraction/Transportation	3%	71
Other/Unspecified	7%	176
Household's Education		

Less than high school (Grade 8 or less, some high school, no diploma)	0%	2
High school graduate or GED	2%	52
Some college	14%	380
Bachelor’s degree (e.g., BA, BS, BBA)	34%	896
Graduate Degree	50%	1340
Household’s Income (Midpoint)		
Average	218850.2	
Standard Deviation	133989.3	
Distribution		
$ 25,000	4%	101
$ 75,000	14%	340
$ 125,000	20%	463
$ 175,000	16%	390
$ 225,000	13%	297
$ 275,000	8%	200
$ 325,000- $ 525,000	25%	579
Household’s No. of People in Household		
1	15%	412
2	48%	1362
3	16%	452
4	16%	444
5-7	5%	170
Household’s Living Situation		
Apartment or condo	9%	254
Attached house (townhouse, duplex, triplex)	8%	206
Detached house/single family home	81%	2183
Mobile home	1%	30
Other	0%	8

47% of respondents report to have two vehicles in their household (not including recreational vehicles or non-operational vehicles), 20% report to have 1 vehicle, and 21% report to have 3 or more vehicles. More than 80% of respondents report to use their main car for running errands (including groceries) (83%) and leisure or social activities (82%), and more than half of the sample for commuting (57%). More than 80% of respondents report to purchase the main household car, followed by leasing it (14%). 63% report to have access to a personal garage, followed by a driveway or carport (15%). Table 4 presents descriptive statistics on key household vehicle characteristics, including vehicle types, acquisition patterns, and ownership distributions.

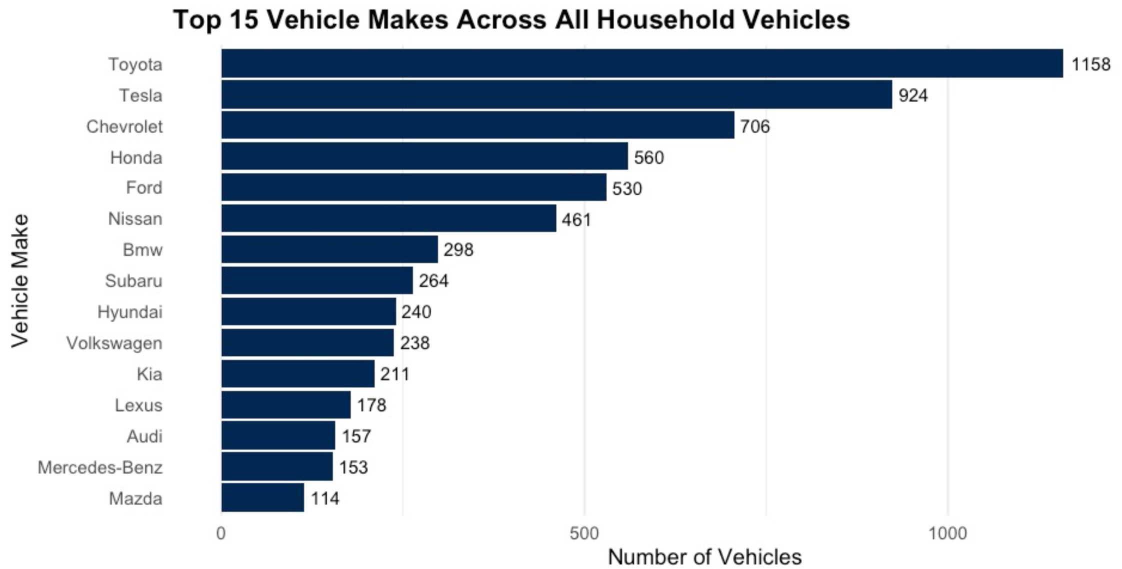
Table 4. Descriptive statistics of key household vehicle characteristics.

Household’s No. of Vehicles per Household		
1	20%	626
2	47%	1499
3	21%	676
4	8%	244

5 or more	4%	132
Odometer at Time of Acquisition		
0-10K	13%	133
10-30K	41%	412
30-60K	26%	263
60-100K	12%	122
100+K	7%	67
Household's Travel Purpose of Main Car		
Commuting	57%	1797
Business travel	19%	589
Leisure/social	82%	2597
Errands	83%	2645
Ridehailing/delivery	1%	35
Acquisition Status of Main Car		
Gifted or family transfer	2%	53
Leased	14%	411
Purchased	84%	2500
Household's Parking Situation		
Personal garage	63%	1995
Driveway/carport	15%	477
Parking garage (private)	3%	105
Parking garage (public)	0%	8
On-street (free)	1%	44
On-street (metered)	0%	0
Parking lot (no reserved space)	0%	14
Parking lot (reserved space)	1%	33
RV park/yard/field	0%	1
No parking available	16%	500
Replacement of Other Household's Car by Main Car		
Yes, it replaced a car that we no longer have	77%	2212
Yes, it will replace a car that we plan to sell/return	21%	65
No, it is an additional vehicle in the household	2%	603

As shown by Figure 5, the three top vehicle makes across all household vehicles are Toyota, Tesla, and Chevrolet, while the least common are Audi, Mercedez Benz and Mazda.

Figure 3. Top 15 Vehicle Makes Across all Household Vehicles.



Almost 2/3 of respondents report plugging in their car at home (connected to their home electricity) (62%) followed by plugging in their car both at home and away from home (29%), and plugging in their car away from home (including charging at work or at public charging stations, or at shared parking garages) (8%). Around a third of respondents report to use a 120 V regular plug (32%), whereas around a quarter of respondents report to have no option to charge the car at home (26%), or report that charging at home was possible because there was a charger installed (23%). Around a third of respondents report to have access to charging at their commute location (36%) compared to more than half of respondents reporting not to have access (56%). Almost half of the survey takers report that charging at their commute location is not free (46%), for around a third of the sample it is free (36%). We also asked respondents to what extent not having access to a level 2 (240 V) charger at home limit how much they drive their car, and around 62% of respondents selected the response option ‘not at all’ and 20% picked ‘very little’. 62% of respondents report that they never wanted to charge their car at their commute location but couldn’t because all chargers were occupied, followed by 10% of respondents facing charging unavailability 1 day per week and 9% less than 1 day per week.

Table 4 summarizes key charging-related characteristics across households, including home charging access, charger types, workplace charging availability, charging behavior, and related infrastructure.

Table 4. Descriptive statistics of key charging-related characteristics.

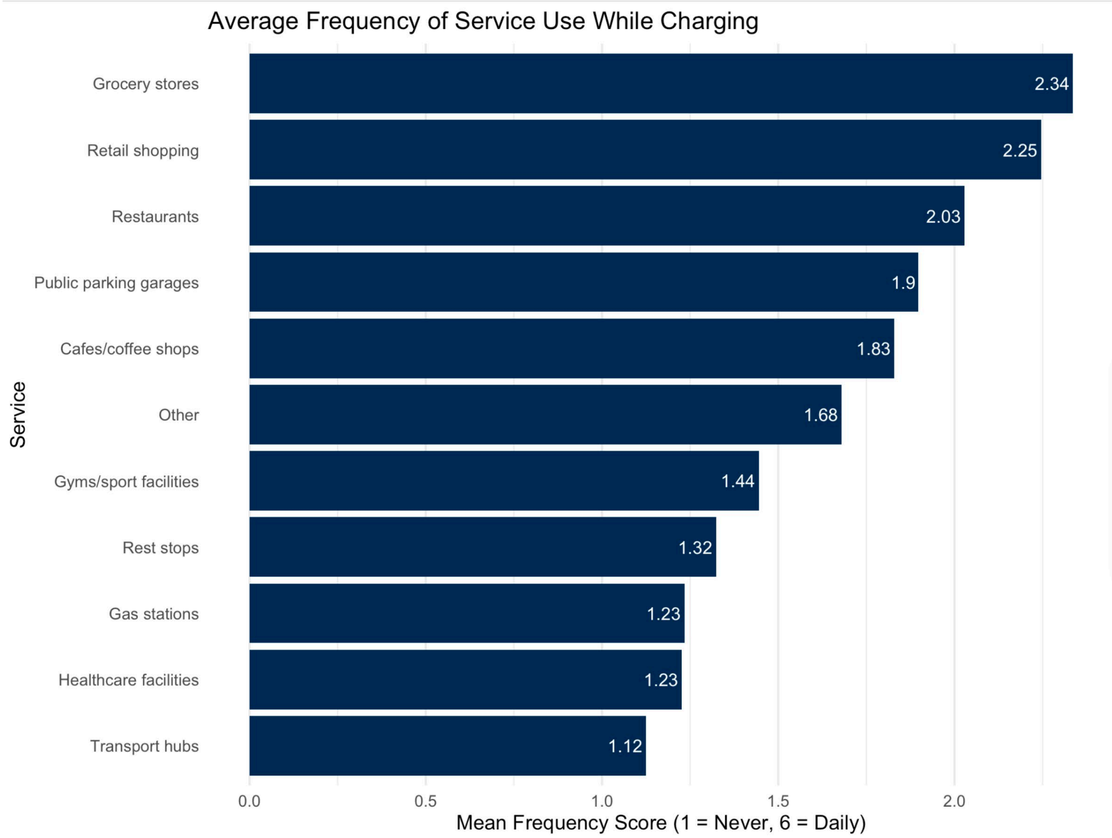
Ability to Plug-In Main Car at Home		
Yes, we could because there is a charger installed	23%	65
Yes, we could use a 120V regular plug	32%	91
Yes, we could use a 240V regular plug	10%	27
Yes, but we would need to use an extension cord	3%	8
No, we have no option to charge the car at home	25%	72
No, but we can leave the car next to a public charger	3%	9

Other	4%	8
Household's Charging Location Over the Last 30 Days		
Plugged car at home (connected to our home electricity)	62%	606
Plugged car away from home (including charging at work or at public charging stations, or at shared parking garages)	8%	175
Plugged car both at home AND away from home	29%	1308
Other	1%	17
Incentives for Installation of Chargers at Home		
Yes	25%	474
No	75%	1426
Household's Type of Charger		
Level 2 (240 V) charger at home	61%	847
Level 120 V outlet at home	34%	475
240 V dryer outlet at home	4%	53
Converted 120 V cord to 240 V operation	1%	11
Access to Tesla Chargers at Home (1= Yes, 2 = No, N/A = 3)		
Tesla-Branded Level 2 (240 V) Charger at home	50%	267
Non-Tesla Level 2 (240 V)	27%	142
240 V dryer outlet at home	14%	73
120 V outlet	9%	50
Converted 120 V cord to 240 V operation	0%	3
Impact of Having No Home Level-2 Charger on Driving		
Not at all	62%	319
Very little	20%	105
Neither a lot nor a little	3%	16
Somewhat	9%	48
A lot	4%	18
No idea	1%	7
Frequency of Returning to Your Car to Swap Charging Spaces or Cords		
Never	55%	175
Less than 1 time per week	8%	26
1 time per week	7%	22
2 times per week	9%	30
3 times per week	8%	24
4 times per week	6%	20
5 times per week	6%	18
6 times per week	1%	2
More than 7 times per week	1%	2
Availability of Charging at Commute Location		
Yes	37%	474
No	56%	718
I don't know	8%	99
Availability of Free Charging at Commute Location		
Paid	46%	311
Free	35%	235

Some free, some paid	10%	70
I don’t know	8%	56
Charging Availability at Commute Location in Last 30 Days (Number of Times)		
Never	62%	345
Less than 1 day per week	9%	49
1 day per week	10%	56
2 days per week	6%	33
3 days per week	4%	23
4 days per week	3%	19
5 days per week	2%	14
6 days per week	0%	2
7 days per week	1%	3
More than daily	1%	5
I don’t remember	2%	11
Number of Times of Fast-Charging in Last 30 Days		
0	68%	1491
1-3	18%	386
4-7	7%	158
8-15	5%	107
>= 16	3%	60
Availability of Solar Panels		
Yes, installed before we purchased the main car	36%	990
Yes, installed after the main car purchase	11%	291
Yes, installed together with the main car purchase	1%	29
No, we are unable to install them	22%	596
No, we don't want to install them	20%	534
No, but we plan to install them	11%	290

As shown by Figure 6, respondents most frequently used grocery stores, restaurants and retail shopping while charging their vehicles. Services such as gas stations, public parking garages, and transport hubs were used much less often during charging sessions. These results suggest that drivers prefer to spend their charging time in places where they can sit, relax, or work, or engage in shopping activities. Transport hubs -notably train or bus stations - show some of the lowest levels of use, likely because they are not commonly co-located with EV charging infrastructure. Gas stations are similarly rarely utilized, reflecting the shift away from traditional fueling locations among electric vehicle drivers. Taken together, the results suggest that EV drivers prefer amenities that offer food, beverages, and retail experiences over services tied to transportation, health, or fitness.

Figure 4 Average Frequency of Services Used While Charging.



7.6.2. DMV data: Group Comparison to DMV Data

To assess the representativeness of our sample, we compare its household and vehicle composition to the full population of California households as observed in the 2023 DMV registration data. The DMV data include approximately 25.3 million registered vehicles, corresponding to 12.5 million households, and provide a comprehensive benchmark for the statewide vehicle fleet.

In the full DMV population, household vehicle ownership is skewed toward smaller fleets. About 50% of households own a single vehicle, and an additional 26% own two vehicles, with only 5% owning five vehicles or more. In contrast, our sample exhibits a markedly different distribution: only 20% of sampled households own a single vehicle, while nearly half (47%) own two vehicles, and a substantially larger share own three or more vehicles. This divergence is expected and reflects the intentional design of the sample. The study targets households owning PEVs, a group that is disproportionately represented among multi-vehicle households. Higher household income and the limited driving range or charging flexibility of some PEVs may both contribute to higher vehicle counts among PEV-owning households. As a result, a sampling strategy that focused on PEV ownership necessarily oversamples households with more than one vehicle.

Differences between the sample and the full population also exist when comparing household fleet composition. In the statewide DMV data, over 90% of households own no PEV at all, while only 5.4% own at least one new PEV, 2.7% own at least one used PEV, and 0.4% own both new and used PEVs. These figures reflect the true penetration of PEVs in the overall California household fleet as of 2023.

The resulting sample is not representative of the California household population, and the descriptive statistics should not be interpreted as population estimates. Instead, the sampling strategy was explicitly designed to enable comparative analysis across household PEV ownership groups, with a particular emphasis on households owning used PEVs. Accordingly, the analysis prioritizes internal comparisons across household groups rather than external representativeness.

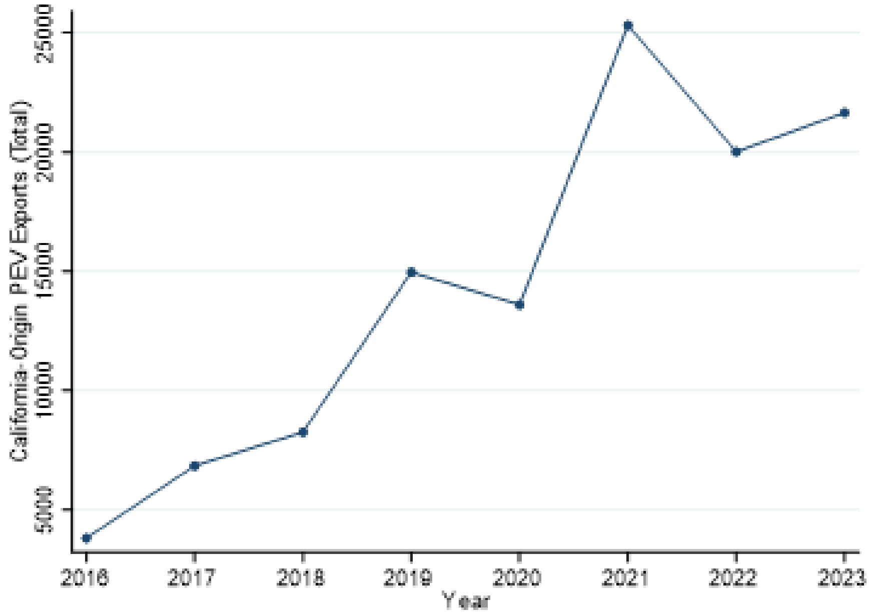
7.6.3. Descriptive Statistics of S&P Data

This analysis draws primarily on vehicle-level registration and transfer records obtained from S&P Global. To capture policy variation across destination states, we matched the S&P data with a hand-constructed panel of state-level PEV purchase incentives. Incentive information is compiled from the US Department of Energy's Alternative Fuels Data Center (AFDC)[1], which documents both active and expired state incentive programs. The raw entries are filtered to retain only consumer-facing financial incentives for the purchase of new PEVs. Non-monetary benefits (such as HOV lane access), incentives targeted exclusively at public or commercial fleets, sales-tax exemptions not specific to electric vehicles, and support for charging infrastructure are excluded. Each remaining program is hand-coded based on the program text and, where necessary, supplemented with information from state agency websites or official announcements. For each incentive, we identify enactment and expiration dates, construct annual indicators of availability, record incentive amounts, and code key program features such as vehicle price eligibility caps. These records are merged with the state-year import panel.

State-level demographic and socioeconomic characteristics are drawn from the American Community Survey (ACS) 5-year estimates. Using standard aggregation procedures and consistent geographic identifiers, we construct measures of population size, income, educational attainment, age composition, racial and ethnic composition, and residential characteristics. These variables are merged with the state-year panel and are used as control variables in the analysis.

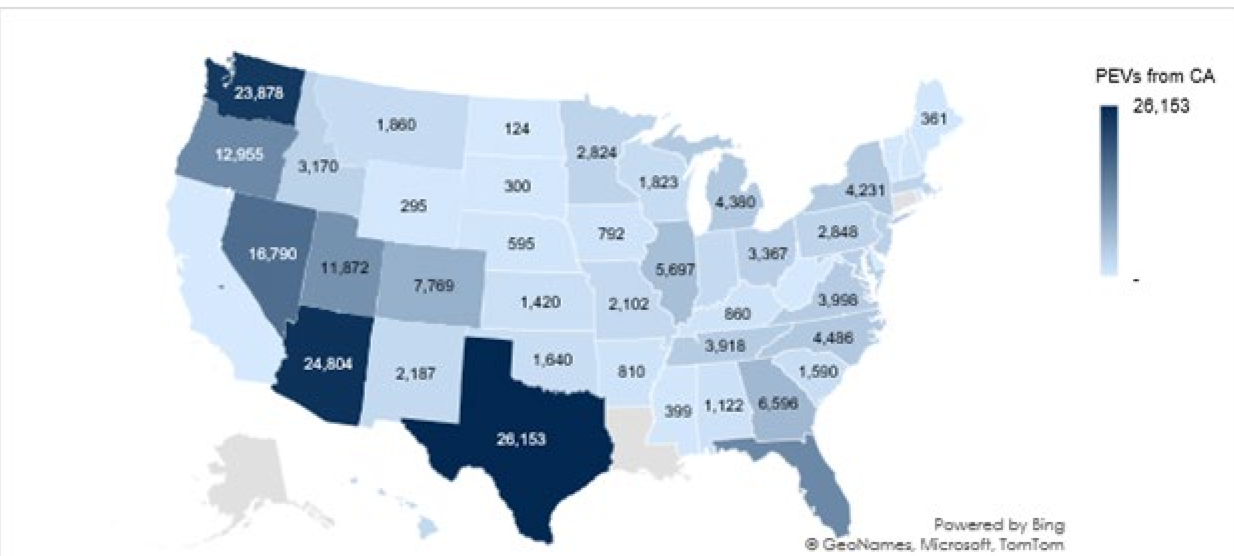
Descriptive trends indicate a rapid expansion of used PEV exports from California over the study period. Annual export volumes increase more than fivefold between 2016 and 2023, rising from fewer than 4,000 vehicles per year to over 22,000 vehicles. After a temporary slowdown in 2020, likely reflecting pandemic-related disruptions, exports rebound sharply in 2021 and remain elevated thereafter (Figure 7).

Figure 5 Annual California-Origin Used PEV Exports, 2016-2023.



The spatial distribution of these exports is highly uneven. Cumulative imports of California-origin used PEVs are concentrated in a relatively small number of destination states, mainly in the western United States. Nevada, Arizona, Texas, Washington, Florida, and Oregon emerge as the largest recipient markets over the full sample period (Figure 8).

Figure 6 Cumulative California-Origin Used PEV Imports by Destination State, 2016-2023.



8. Pathways to Used PEV Adoption

There are different ways of how used vehicles can enter the consumer market. When a household purchases a vehicle, it can either be an *addition* to the household fleet or a *substitution*. In the case of households adding a vehicle to their household fleet they already have a vehicle fleet consisting of vehicles that may or may not differ in fuel type technology and acquisition status. A substitution may involve the same technology, for instance, when an ICEV replaces another ICEV, or it can imply a change in fuel type technology and acquisition status (used versus new). Here we will briefly review the literature on households adding vehicle/s to their household fleet (without replacing them), and replacing vehicles in their household fleet.

8.1. Adding Vehicles to Household Fleet

Until now, little is known about the factors promoting the willingness of households to add a used PEV to their vehicle fleet. Empirical evidence has shown that purchasers of PEVs owned a larger number of vehicles, which may suggest that PEVs are typically used or purchased as additional vehicle and not as vehicle replacing an existing vehicle (He et al., 2017; Jakobsson et al., 2022; Klöckner et al., 2013). We posit that factors determining a household's willingness to add a PEV are household characteristics, characteristics of the existing household fleet, and the built environment. Research that has shown that multi-car households adding a PEV had the same mileage as households with ICEVs, but households owning a single PEV travelled shorter distances (Klöckner et al., 2013). Alternatively, it has been theorized that the PEV can be used for the main trips, with the main car in the household serving as the backup car, replacing the trips in the household as much as possible (Karlsson, 2017). Kurani et al (1994) defined the adaptability of households to BEVs as a function of their travel behavior, access to home or workplace charging and vehicle style. Households that pre-adapted to BEVs did not require changes in their travel behavior as access to home or workplace charging was provided, they did not need to change the body styles of vehicle they typically bought, and their routine activity space and the distance to the critical destinations they typically travelled to was small. Households that easily adapted to BEVs were able to switch between different vehicles in their household, they were more likely to charge at work, and had larger routine activity spaces and the critical destinations they typically travelled to were more far away. The non-adapted households had critical destinations beyond 150 miles away from home, large routine activity spaces, and were inflexible in terms of allocating vehicles between different household members.

Other household characteristics are the socio-demographics of household members. Wang et al. (2018) have shown that women, people aged between 26-30, who had a bachelor or higher degree, and a high annual income were more likely to purchase their PEV as their second vehicle. Another cluster analysis on used versus new vehicle owners among California households revealed that households who owned two used vehicles had a higher propensity to own their homes, to have a family size of two, and a larger annual income of around $80,000, and their vehicle fleet was on average five years old. In comparison, households who owned both used and new vehicles had a larger annual income, typically had a family size of two, and their vehicle fleet was on average around 6 years old (Chakraborty et al., 2024).

8.2. Replacing Vehicles in Household Fleet

Research explaining why vehicle owners replace their vehicles is surprisingly scarce. The decision to replace a vehicle is complex, and addresses different aspects, such as the timing of the replacement, and the replacement decision itself. The timing of the replacement decision pertains to when/at which stage in the technology's lifecycle it is replaced (e.g., early, late). The replacement decision captures the different factors that motivate the decision to replace the vehicle, which will be the main focus of this section. The factors explaining the decision to replace a used vehicle can relate to household characteristics, travel patterns, information seeking behavior or characteristics of the vehicle fleet. Replacement decisions may be 'forced', such as when there is an unforeseen 'product failure' (e.g., vehicle totaled in accident), or changed family circumstances (e.g., the birth of a newborn), or 'unforced', such as when replacement decisions may result from changes in preferences in technology style or features (Bayus, 1991). Given the range limitations of early PEVs and limited charging infrastructure available on a large scale, it may not be possible for some vehicle owners to replace their ICEV with a PEV without making changes to their daily travel even if they wanted to. Thus, even though respondents were told in the study by Jensen & Mabit (2017a) to use their PEV as primary vehicle, they still used their ICEV for the majority of their trips. This may imply that the EV did not suit their travel needs (Jensen & Mabit, 2017). Another survey study conducted with vehicle owners from California has shown that owners expressed the highest willingness to replace their gasoline or diesel vehicles with electricity to fuel their vehicles if needed, followed by natural gas, bio-diesel, hydrogen, ethanol, or propane (Kurani, 2018).

In a questionnaire study with 3,100 new ICEV buyers the age of respondents did not affect a household's replacement decisions (Bayus, 1991), while people aged between 41-50 were most willing to replace their ICEV with an EV in another study (Wang et al., 2018). Studies also investigated differences between early and late replacement buyers, and found that early replacement buyers (i.e., individuals more likely to replace their vehicles earlier/faster after acquisition) of ICEVs had higher incomes than late replacement buyers (Bayus, 1991). The replacement purchase intention was also positively associated with income (Marell et al., 1995), with participants with higher incomes being more likely to replace their ICEV with an EV (Wang et al., 2018). Another study looked at the effect of education and occupation on replacement decisions, and found that late replacement buyers had higher education and occupational status than early replacement buyers (Bayus, 1991). Similarly, a household's confidence in its financial position and general economic conditions had a positive effect on replacement intentions. Marital status also affected a household's replacement decisions, with households being in the 'co-habiting' category being less likely to intend to replace their vehicles (Marell et al., 2004). The number of children did not affect a household's replacement decision (Marell et al., 2004).

Moreover, people who replaced their old vehicles earlier used their vehicles more frequently than people who replaced their vehicles later (Bayus, 1991). Regarding the number of vehicles owned by households, multi-car households were more willing to replace their ICEV with a PEV (Wang et al., 2018), possibly because multi-car households have a greater flexibility to replace their ICEVs with a PEV. Björnsson & Karlsson (2017) studied the impact of replacing an ICEV by a PEV on the driving patterns, battery and energy savings in a two-car household, and found differences in the number of unfulfilled trips, battery and cost savings as a function of the household's usage strategies.

Regarding information seeking behavior preceding the replacement decision, early replacement buyers reported to engage in more information seeking behavior, spending more time gathering information and visiting dealerships, and considering magazine advertising as more informative and friends and newspaper advertising as less informative than late replacement buyers (Bayus, 1991).

The perception of vehicle characteristics also explained a household's replacement decision. Limited driving range and long charging times may reduce the likelihood of households to replace their ICEV with a BEV if the BEV is unable to meet the household member's daily travel needs (Jensen & Mabit, 2017). The replacement optimization model of He et al. (2017) models the decision to replace an ICEV by a PEV by economic factors alone (i.e., operation and maintenance costs, replacement cost, purchase price, government subsidy, trade-in for the old vehicle, gasoline price at the time of purchase, drift rate, volatility of gasoline price, gasoline consumption, expenditures), and found that switching to a PEV is not cost-effective without large subsidies, and that gasoline savings are not high enough when gasoline prices are high. However, PEVs can become cost-competitive with ICEVs if people large travel distances, particularly in regions with a stable fuel price.

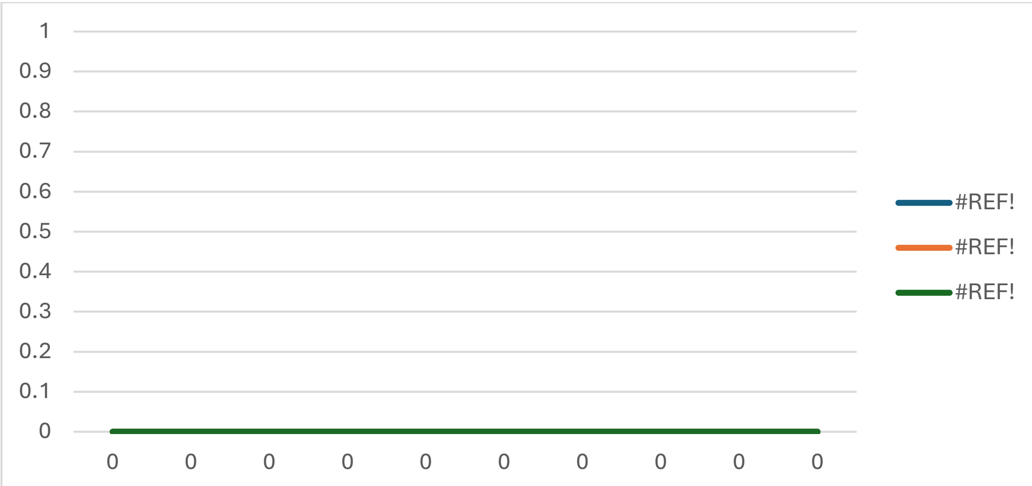
Early replacement buyers were more concerned with styling and image (product style, brand image), less concerned with size / comfort, and costs (product size, product costs) and more likely to purchase higher-priced, smaller cars from established car brands than late replacement buyers. Other reasons explaining early replacement decisions pertained to perceptual aspects (e.g., appearance of a new car), the desire for a larger vehicle, and the offering of a promotion or deal. Reasons for late replacement decisions were large repair bills, and damage to the car (Bayus, 1991), supporting research which has shown that the age of the car (in years), the total number of miles driven, and the anticipated number of repairs negatively affected the perception of the car to be replaced. A higher perceived quality of the current car was negatively related to the intention to replace the car (Marell et al., 2004), supporting research that has shown that participants describing their car more negatively were more likely to replace it (Chandler & Schwarz, 2010). The quality of the car was not related to replacement intentions when participants described their car in terms of personality characteristics (Chandler & Schwarz, 2010). The minimal quality of the new car accepted by the household had a positive effect on replacement intentions of the old car (Marell et al., 2004).

8.3. Analysis of Used PEV Supply

Figure 9 examines the share of vehicles in the fleet that are still owned by their original purchasers as a function of time since manufacture, measured from zero to ten years and beyond. A very similar exponential decay pattern is observed across all three vehicle types, including ICEVs, BEVs, and PHEVs. Nearly 100 percent of vehicles remain with their original owner after one year, approximately half transfer to a subsequent owner within three to four years, and the trend levels off at roughly 10 to 15 percent of vehicles remaining with the original owner after seven to eight years and beyond.

Larger share of older BEVs are still with the original owner maybe results from the higher purchase price of these vehicles or lower residual value reported for very early short range BEVs.

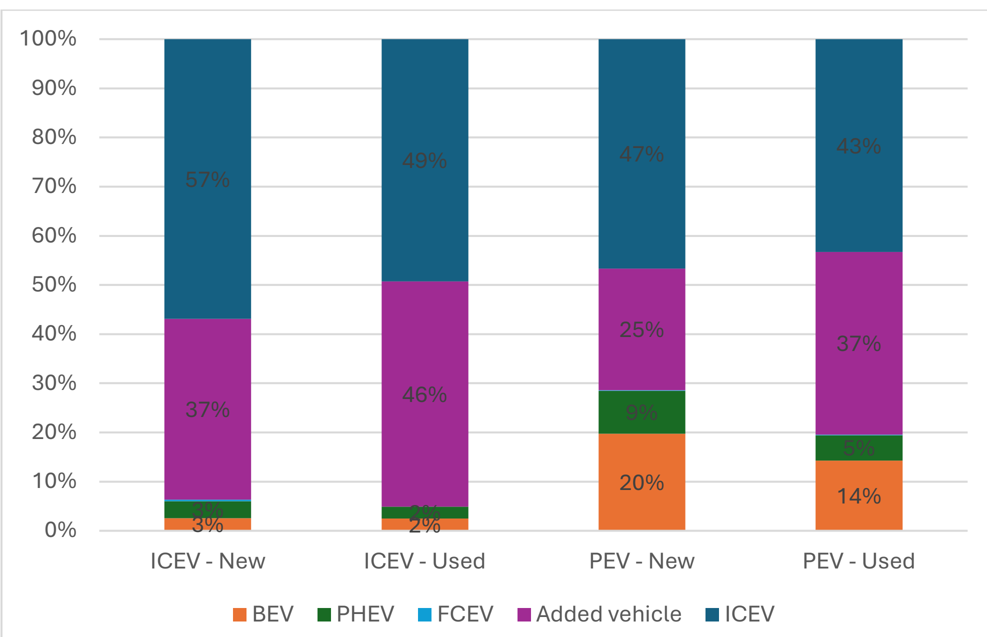
Figure 7 Share of LDVs Owned by the Original Buyer or Lessee.



As the volume of new PEV sales grows, we expect more used PEVs to enter the market. A slowdown in new sales may have the opposite effect, reducing the availability of affordable used EVs.

Figure 10 shows that purchases of new and used ICEVs are often made as additional vehicles in the household (37% and 46%, respectively), while buyers of new PEVs generate more used vehicles in the market, including 20% BEVs, 9% PHEVs, and 47% ICEVs. Our survey takers reported that 15% of used PEV buyers are replacing a new vehicle with another PEV from their existing fleet.

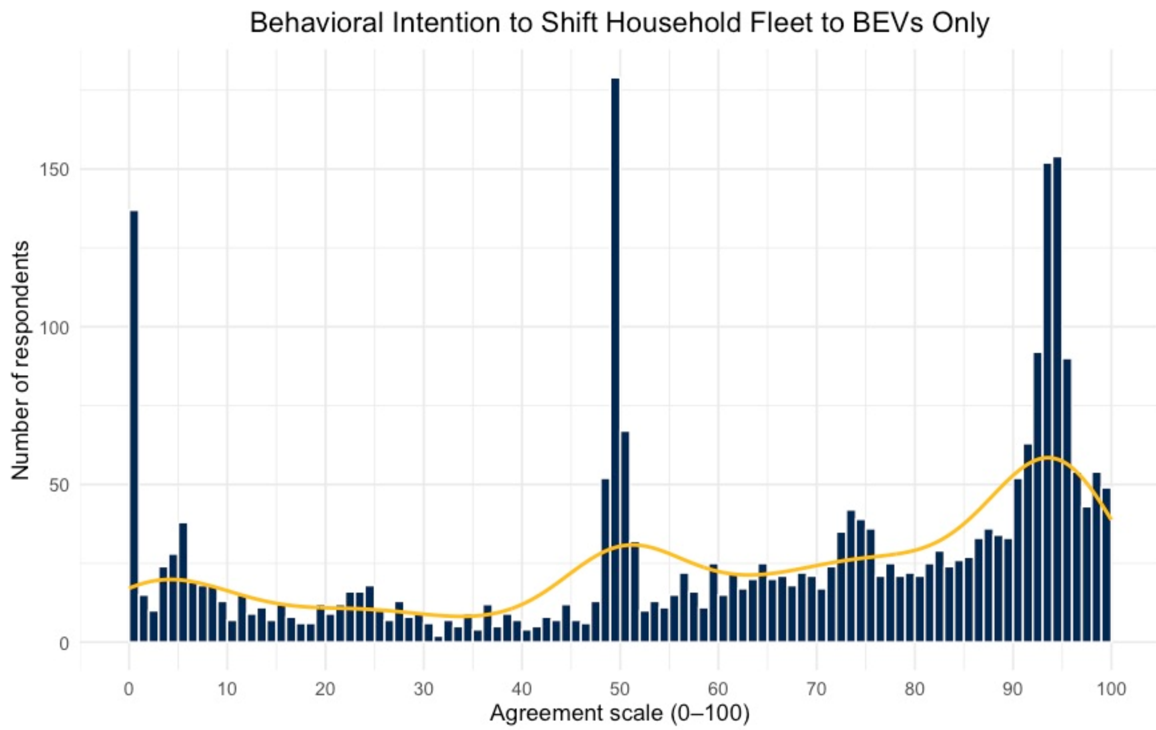
Figure 8 The Impact of buying new vehicle on the household fleet.



9. Willingness to Purchase BEVs

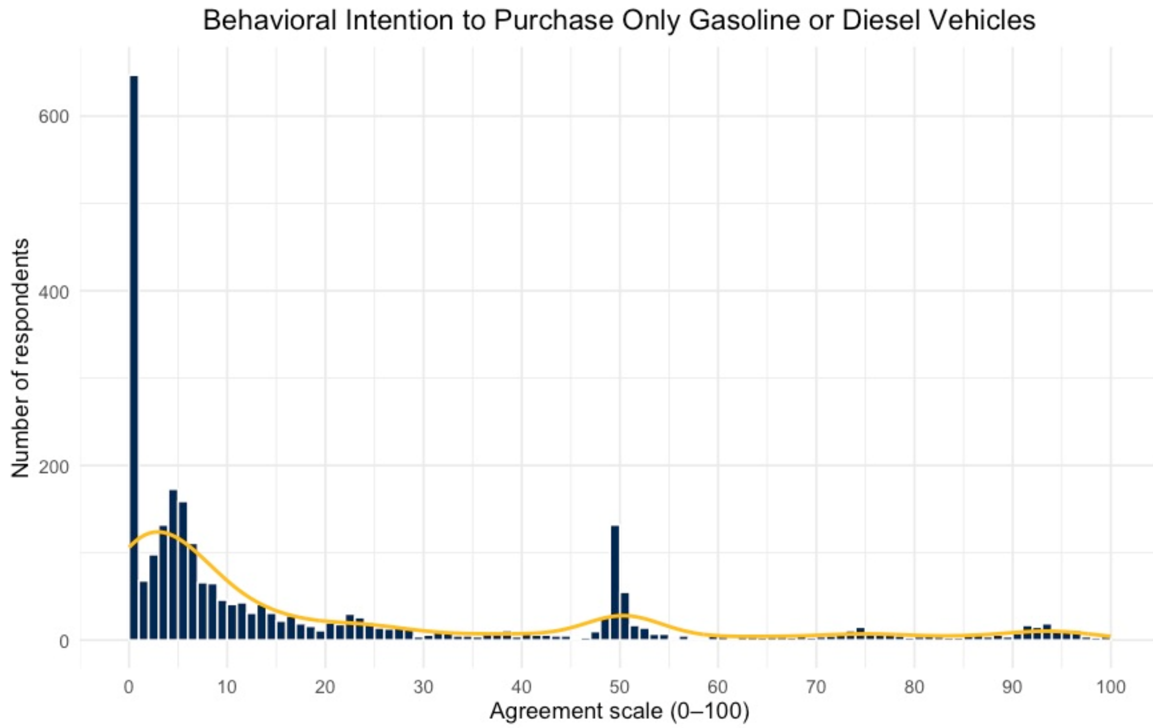
We measured respondents' willingness to purchase only battery-electric vehicles in the future, as shown by Figure 11. The distribution of behavioral intention scores shows a strong concentration at the lower end, with a large spike at 0 indicating many respondents have no intention of shifting their household fleet to BEVs only. Beyond that initial peak, the distribution becomes relatively flat and dispersed until another noticeable rise emerges in the higher range around scores in the 60-100 region. This pattern suggests a polarized population, with many firmly uninterested and a substantial minority expressing strong intention to transition their household to fully to BEVs.

Figure 9 Distribution of Intention to Transition Household Fleet to BEVs (M= 63.21, SD = 31.59, on scale from 0-100).



We also analyzed the distribution of the question measuring respondents' intentions to purchase only gasoline or diesel vehicles. A low intention to purchase only gasoline or diesel vehicles can predict individual's intention to purchase only BEV vehicles in the future. As shown by Figure 12, the distribution is heavily skewed toward the lowest score, with a very large cluster at zero (n=560), indicating many respondents have no intention of sticking exclusively to ICE vehicles. Beyond this initial spike, the number of respondents declines steadily as scores increase, showing diminishing commitment to ICE-only purchasing as intention rises. A moderate secondary bump appears around scores in the low 50s, suggesting a subset of respondents expresses ambivalence or mixed preferences. Higher scores above 70 are rare and appear only sporadically, indicating that strong intention to purchase only gasoline or diesel vehicles is uncommon. Overall, the pattern suggests that while a large portion of respondents decisively reject ICE-only purchasing, a smaller but notable group remains uncertain, and very few are strongly committed to exclusively buying ICE vehicles in the future.

Figure 10 Distribution of Intention to Purchase only Gasoline or Diesel Vehicles.



We asked respondents whether they would purchase a BEV if access to home charging was provided and if prices were equivalent to the prices of gasoline-powered vehicles (1 = Yes, 2 = No, 3 = I don't know). In a follow-up question, we asked respondents to motivate their previous response ("Why?"). Following best practices (Morgan, 2023; Sun et al., 2025; Zhang et al., 2023), we used generative AI (ChatGPT) to analyze the responses to these open-ended questions in addition to human coding using the grounded theory approach.

The use of GenAI was conducted in several steps.
In the first step, we provided ChatGPT with the following prompt:

- *What are the main topics in these responses? For the output, put the result in a table. The first column is the name of the theme, the second column is its frequency, the third column includes the quotes that belong to this theme and the name of the participant who made this comment, one row per quote.*

After the topics were generated, we used the following prompt:

- *In a bulleted format, what are the main topics that respondents mention when asked about their challenges and issues about [identified topic]? For the output, put the result in a table. The first column is the name of the theme, the second column is its frequency, the third column includes the quotes that belong to this theme and the name of the participant who made this comment, one row per quote.*

We repeated this process for every theme that was generated.

After we compiled a detailed list of themes that represent the reasons for purchasing a BEV under the condition of having access to home charging and price parity, respectively, we asked ChatGPT to count the number of themes, using the following prompt.

- *Can you do a count of this [identified topic]? If respondent A's response is similar to respondent B's, can you code and group these responses, but make sure to indicate the count by adding the number of responses? For the output, put the result in a table. The first column is the name of the identified topic, the second column is the frequency, the third column indicates all quotes that belong to this identified topic, and the name of the participant who made this comment, one row per quote. The number of entries in the second column (frequency) and third column should be the same (quotes).*

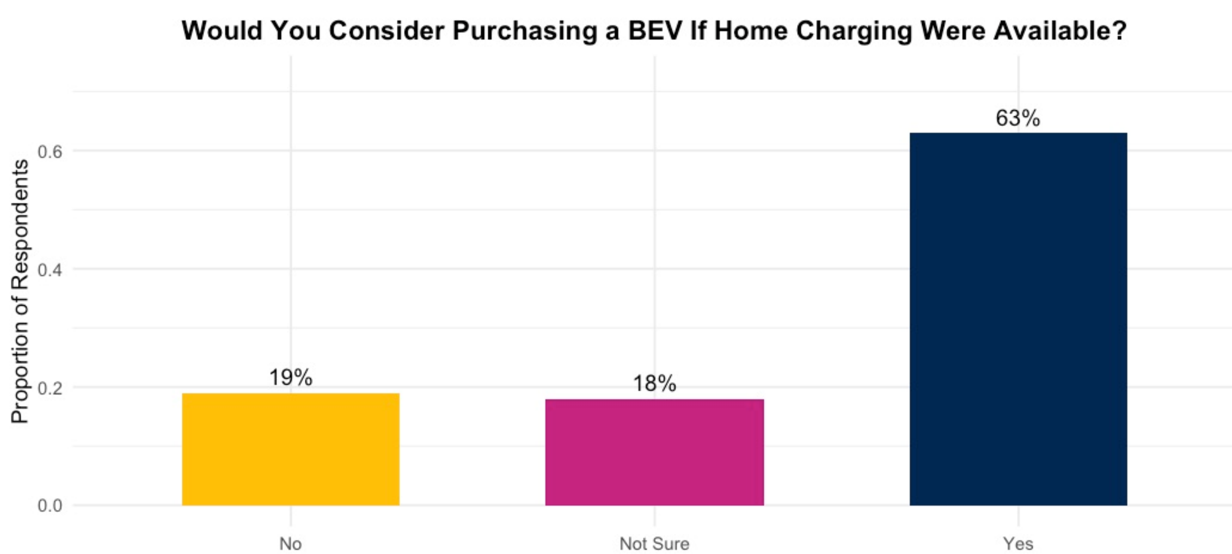
To represent each theme, we used succinct, illustrative quotes. We performed minor adjustments of the quotes (e.g., typos, grammar), if needed, but did not perform further changes beyond these small edits.

We analyzed 239 open-text responses. Of these, 66 would consider purchasing a BEV if home charging were provided, 25 would not, and 28 were unsure. Additionally, 63 would consider a BEV if prices matched gasoline vehicles, while 32 would not and 25 were unsure under price-parity conditions.

As shown by

Figure 13, a large majority of respondents (63%) indicated they would consider purchasing a BEV if home charging was available, highlighting the central role of charging access in consumer decision-making. In contrast, only about one-fifth expressed reluctance (19%), and a similar share reported uncertainty (18%), suggesting that concerns remain but affect a smaller portion of the sample. Overall, these results underscore that improving home charging availability could substantially increase consumer openness to adopting BEVs.

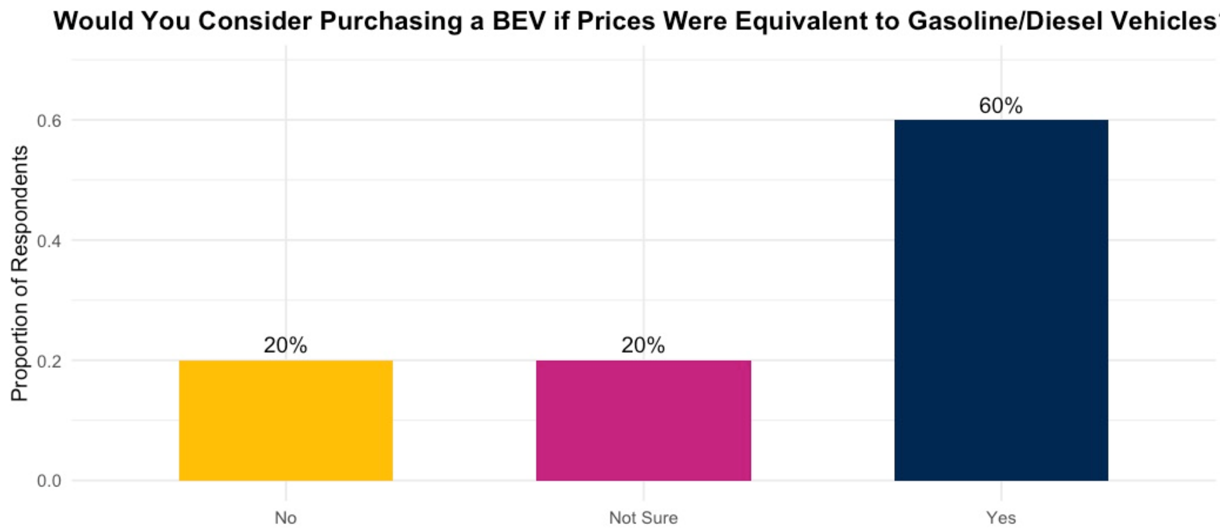
Figure 11. Willingness to Purchase a BEV With Home Charging Access.



As shown by Figure 14, a majority of respondents (60%) indicated they would consider purchasing a

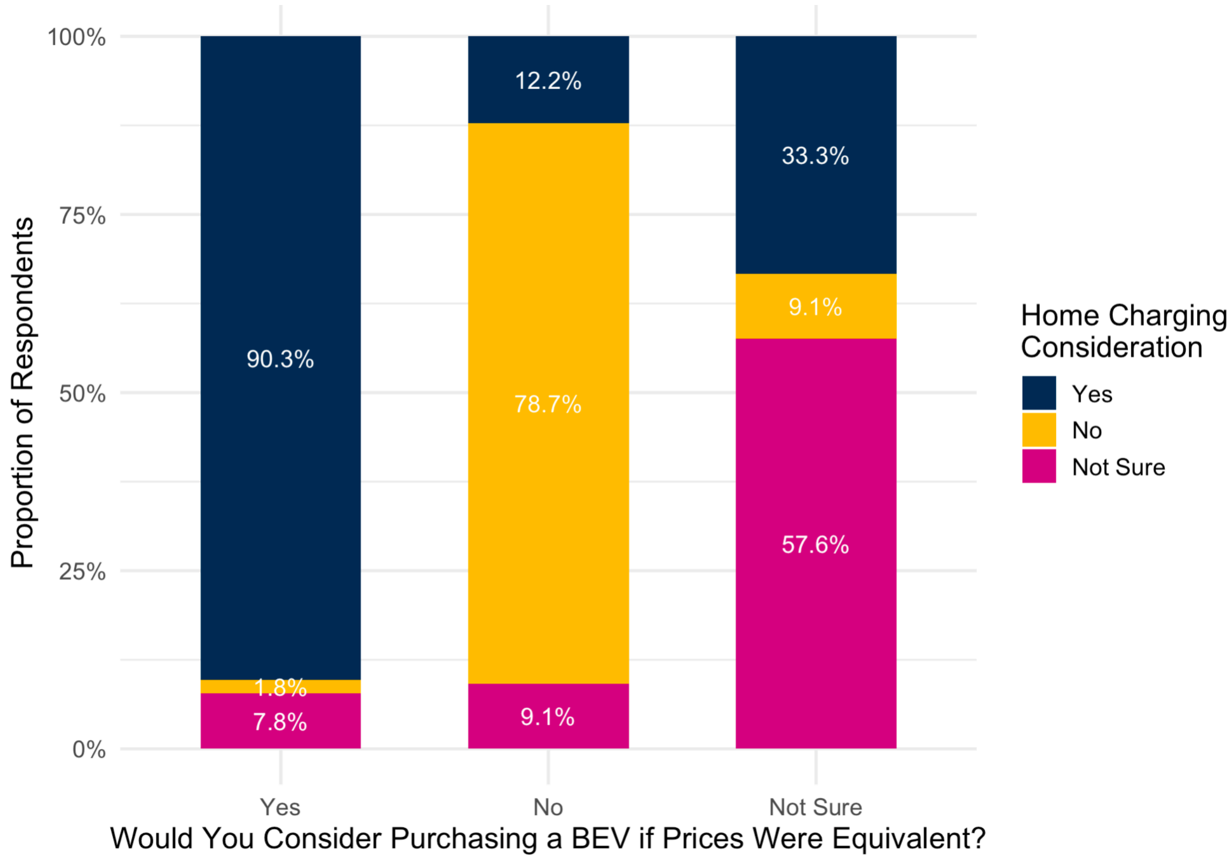
BEV if its price were equivalent to that of a gasoline or diesel vehicle, showing that cost parity is a strong motivator for adoption. In contrast, smaller but similar proportions reported that they would not (20%) or were unsure (20%), suggesting that while price is important, it is not the only factor influencing consumer decisions. Overall, these results imply that achieving price parity could significantly promote BEV interest, but additional barriers - such as charging access, range concerns, or familiarity - may still require attention.

Figure 12. Willingness to Purchase a BEV if Prices Were Equivalent to Gasoline/Diesel Vehicles.



We performed a crosstab-analysis of these two questions to examine their relationship as presented in Figure 15. Most respondents who would consider purchasing a BEV at price equivalence also report that they would purchase a BEV if home charging was provided (90%). Among those who would not consider a BEV even at equal price, the majority (79%) also indicate they would not consider purchasing a BEV if home charging was provided. Respondents who are unsure about purchasing a BEV even if BEV prices were equivalent to prices of gasoline-powered vehicles show a mixed pattern, with 58% reporting uncertainty, while 33% of respondents would consider purchasing if access to home charging was provided. These findings suggest that home-charging readiness appears strongly associated with the willingness to consider a BEV at price equivalence.

Figure 13. Relationship Between Home-Charging Readiness and BEV Purchase Consideration

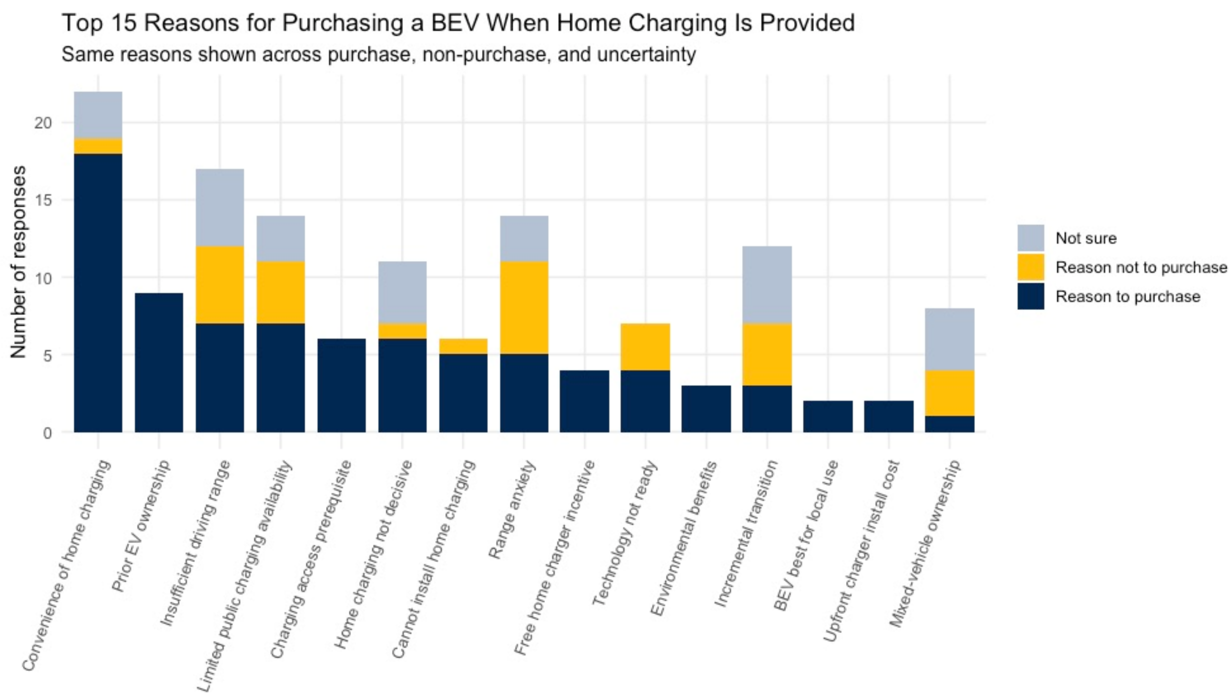


9.1. Purchase Consideration of BEVs Under Condition of Access to Home Charging

This section provides an analysis of the open-text box responses of respondents to motivate the purchase of a BEV under the condition of access to home charging. As shown by Table 5, there are various reasons for purchasing a BEV if home charging was provided, including convenience of home charging, unavailability of public charging, lack of (fast-)charging access in apartments and multi-unit housing, limited access to parking, limited electric driving range and limited charging speed, and high upfront cost of charger purchase and installation. The reasons for not considering purchasing a BEV under the condition of access to home charging are similar to the reasons that motivate people to purchase a BEV. Yet, respondents mention many more reasons for their decision not to purchase a BEV, many of which are unrelated to the performance of the vehicle (e.g., time to wait for charging a BEV, battery maturity). The top 15 reasons for purchasing a BEV if home charging are presented in

Figure 16.

Figure 14. Top 15 reasons for purchasing a BEV if home charging is provided



We will describe these results in more detail in the subsequent sections.

Table 5. Reasons for considerations to purchase a BEV if access to home charging is provided and price parity (compared to gas vehicles)

Conditions		Frequency					
		Access to home charging			Price parity		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Charging infrastructure							
Limited availability of public charging	Inaccessibility, no nearby chargers, having to drive elsewhere, lack of fast chargers, or reliance on public charging being impractical, distance to public chargers/ Remote / rural / destination gaps.	7	4	3	2	2	5
Reliability / functionality issues	Non-functional chargers.	0	0	2	0	2	0
Compatibility across vehicle makes	Incompatible plugs, charging standards (e.g., CCS, CHadeMO, NACS), multi-brand incompatibility.	0	1	0	0	1	0
Public charging congestion/wait times/queue anxiety	Waiting in lines, queues, chargers being occupied, congestion or crowding at stations, anxiety about other drivers competing for chargers.	0	1	0	0	2	0
Uncomfortable waiting conditions	Waiting in uncomfortable environments, lack of shelter, seating, restrooms, weather exposure, boredom, safety, or discomfort while waiting to charge.	0	1	0	0	1	0
Home charging							
Convenience of home charging	Having home charging already, home charging being convenient, easy, home charging being convenient, easy, or a consideration.	18	1	3	0	0	0
No ability to install home charging	Inability to install or use home charging due to apartments, HOAs, lack of electrical capacity, or lack of nearby alternatives.	5	1	0	0	0	0

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Charging access as prerequisite for EV ownership	Having charging access (especially home or work charging) is required to own or use a BEV .	6	0	0	0	0	1
Apartment / rental barriers	Apartments, rentals, shared housing, HOAs, or lack of ownership control that prevents installing home charging.	3	0	0	0	0	0
Landlord/lack of installation authority	No authority to install home chargers.	0	0	0	0	0	0
Insufficient electrical capacity at home	Only having a 120V outlet, and needing (or avoiding) an electrical panel/box upgrade.	2	0	0	0	0	0
Limited access to parking	Parking constraints (e.g., limited garage space, lack of dedicated parking).	1	1	0	0	0	0
Home charging not a decisive factor	Home charging is *not* the deciding issue in BEV consideration, includes respondents who say they already have home charging.	6	1	4	0	0	0
Vehicle performance							
Technology not ready yet	BEV technology insufficient or immature, excluding respondents who wait for better technology, insufficient range expectations, or slow charging as technological limitation.	4	3	0	1	2	1
Waiting for next-generation batteries	Waiting for improved, next-generation, or more mature battery technology.	2	1	0	0	2	2
Slow charging times	Slow charging duration or long charging times.	1	4	6	2	8	2
Range anxiety	Concerns about distance, range limits, or inability to travel far without recharging, fear	5	6	3	1	2	0

Conditions		Frequency					
		Access to home charging			Price parity		
Theme (name)	Description	Reason to purchase	Reason not to purchase	Not sure	Reason to purchase	Reason not to purchase	Not sure
	of running out of charge, safety concerns linked to range limitations.						
Insufficient electric driving range	Range, distance, battery capacity, or needing longer range, need or expectation for significantly higher driving range.	7	5	5	2	5	6
Real-world vs. advertised range scepticism	Questions, doubts, or contrasts stated/expected range vs. real-world performance.	0	1	1	0	0	0
Vehicle unreliability	PEVs considered unreliable, unable to be dependable, and prone to failure, malfunction or operational uncertainty.	0	2	0	0	2	0
Performance benefits	Vehicle performance characteristics (e.g., performance, driving quality, how it drives).	2	1	0	3	0	0
Performance advantages							
Perceived reliability advantages	Reliability, dependability, or reduced failure risk as an advantage.	0	0	0	1	0	0
Costs							
Upfront cost of charger purchase and installation	Upfront cost of purchasing and installing a home charger (e.g., charger hardware cost, electrician fees, panel upgrade specifically for charger installation).	2	0	0	0	0	0
Free home charger as incentive	Free or subsidized home charger (or installation) as an incentive.	4	0	0	0	0	0
Total cost of ownership comparison	Comparison of overall costs, long-term costs, or costs beyond upfront price (e.g., electricity bills, battery replacement, operating costs, cost–benefit assessments).	1	2	1	0	1	0

Conditions		Frequency					
		Access to home charging			Price parity		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Savings in fuel/charging	Lower fuel costs, free or cheaper charging, or economic savings from charging vs gasoline.	0	0	0	5	0	0
Time savings	Explicit mentions of time savings, and not having to visit gas stations.	2	0	0	1	0	0
Electrical panel/service upgrade costs	Needing to upgrade an electrical panel, service, or electric box.	1	0	0	0	1	0
Regulatory & policy-related costs	Taxes, fees, or surcharges imposed by government (e.g., registration fees, road-use fees), compliance costs driven by regulations or mandates), policy-driven financial penalties or requirements tied to EV ownership.	1	1	0	0	1	0
High vehicle purchase price	Price of BEV too expensive	1	3	2	9	3	6
Insurance costs	Insurance costs	0	1	0	2	0	0
Repair costs	Repair expenses or costly repairs	0	1	0	1	1	0
Battery replacement cost risk	Battery replacement and cost	0	0	2	0	1	1
Battery longevity vs gas engines	Battery lifespan vs engine lifespan, durability, or long-term viability	0	0	0	0	1	0
Charging costs	Cost of charging EV, charging being as expensive as or not cheaper than gas, rising or future charging-related costs	0	3	1	0	0	1
Electricity costs	High or rising electricity prices	0	3	2	0	0	0
Weak or uncertain total cost savings	EVs not being cheaper than gas vehicles, and have little or no savings once electricity, fees, or ownership costs are considered.	0	2	1	0	0	0

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Higher maintenance costs		0	1	0	0	1	
Reduced maintenance costs		0	0	0	3	0	0
Monthly payment avoidance	Monthly payment avoidance, preference for owning outright or avoiding debt tied to vehicle purchase.	0	0	0	1	0	0
Limited/fixed income	Budget limits, fixed income.	1	0	0	3	1	0
Waiting for prices to decline		0	1	0	3	3	2
Price important but not decisive		0	0	0	3	5	5
Safety concerns							
Battery fire risk	Battery fires, fire risk, safety concerns related to batteries.	0	2	0	0	4	0
Software & update dependence	EVs being disabled, delayed, or restricted due to software update, concern about digital control, updates, or software reliability affecting vehicle usability.	0	1	0	0	1	0
Solar integration/energy self-sufficiency							
Existing home solar enables EV adoption	Having home solar and linking it to BEV adoption.	2	0	0	0	0	0
Energy self-sufficiency reduces grid dependence	Energy self-sufficiency as a benefit or motivation, reduction of dependence on electric grid (e.g., home solar, batteries, off-grid charging).	1	0	0	1	0	0
Ease of use							

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Perceived complexity of charging setup	Confusion, uncertainty, or lack of knowledge about how to set up charging.	2	0	0	0	0	2
Uncertainty about how to get started	Uncertainty about *how to get started* with EV adoption (e.g., confusion about the first steps, setup process, or where to begin).	2	0	0	1	0	0
Environmental benefits and concerns							
EVs are better for the environment (positive motivator)	Environmental benefits as a reason or motivation.	3	0	0	4	0	0
Desire to minimize environmental harm	Desire to minimize environmental harm, concern about environmental harm and a wish to reduce it, concern about environmental harm and a wish to reduce it.	0	1	0	1	0	0
Low driving frequency reduces environmental urgency	Low driving frequency/low mileage reducing urgency or motivation to switch to a BEV.	1	0	0	1	0	1
Health-related benefits	Personal or public health benefits.	1	0	0	0	0	0
Environmental scepticism							
Environmental damage from battery mining	Environmental damage from battery mining (e.g., lithium, cobalt, rare earth extraction).	0	2	1	1	2	0
Battery production more harmful than gas vehicles	Battery production as sources of environmental harm.	0	4	0	0	2	0
Battery disposal & recycling concerns	Battery disposal and recycling as sources of environmental harm.	0	2	2	0	3	1

Conditions		Frequency					
		Access to home charging			Price parity		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Energy source scepticism	Questioning of cleanliness, reliability, or credibility of the electricity or energy sources powering EVs.	0	1	1	0	0	1
Grid reliability & power availability concerns							
Insufficient/ unreliable electrical grid capacity	Grid capacity limits, reliability concerns, electricity supply constraints, load issues, or inability of the grid to support widespread EV adoption given power outages.	0	4	0	0	0	0
Emergency evacuation reliability	Emergency situations, disaster evacuation, blackouts during emergencies, or the need for guaranteed mobility in crisis scenarios.	0	4	0	0	1	0
Charging demand during emergencies	Emergencies (e.g., evacuations, disasters, blackouts, wildfires) combined with charging demand, congestion, or inability to charge during such events.	0	2	0	0	2	0
Dependence on electricity vs fuel	Concern about reliance on electricity as an energy source, rather than fuel.	0	0	1	0	0	0
Vehicle ownership strategy (partial BEV adoption)							
Mixed-vehicle ownership preferred	Preference for not fully switching to BEVs, including wanting one BEV and preferring mixed fleet (BEV+non-BEV).	1	3	4	1	4	1
BEV best for local / commuting use	BEVs work well for short trips, daily driving, or commuting.	2	0	0	3	0	1
Gas or hybrid retained for long trips / reliability		0	4	6	4	0	1
Incremental / future-oriented transition	Willingness to adopt EVs gradually, conditional adoption tied to future	3	4	5	4	3	2

Conditions		Frequency					
		Access to home charging			Price parity		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
	improvements (range, technology, infrastructure, cost).						
Personal factors							
Prior EV ownership reduces concern	Current or past ownership of an EV or plug-in hybrid	9	0	0	4	0	0
Negative second-hand experiences	Negative or problematic experience with BEVs.	0	1	1	0	3	0
Negative own experiences	Personal frustration, inconvenience, difficulty, or dissatisfaction based on their own lived experience with EVs, charging, or plug-in vehicles (not hypothetical or general concerns).	0	1	0	0	1	1
Risk aversion for large purchases	Hesitation, waiting, or avoidance due to cost, uncertainty, maturity of technology, or perceived financial risk.	0	0	0	0	0	0
Household work patterns	Household employment or work patterns (e.g., working from home, retirement combined with work-from-home) as a reason affecting driving needs or EV purchase logic.	0	0	0	1	0	0
Life-stage timing, vehicle replacement							
No intent to replace current vehicle	Preference to keep current vehicle type (e.g., gas or hybrid).	0	0	2	1	0	2
Recently purchased a vehicle		0	0	1	0	0	0
Retirement / unlikely to buy another vehicle	Retirement and/or a low likelihood of buying another vehicle (e.g., keeping current vehicles indefinitely, no urgency or expectation of replacement).	0	0	1	1	1	2

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Purchase of used vehicles	Purchasing used vehicles or a clear preference for used vehicles (including used EVs).	0	0	0	2	0	0
Long vehicle ownership cycles	Keeping vehicles for many years, delaying replacement, or emphasizing durability/extended use.	0	0	0	1	0	2
Future-oriented but not now	Openness to BEVs in the future but indicate current conditions are not sufficient.	1	2	1	4	4	2
Preference for hybrid / gas vehicles							
Need for flexibility / backup fuel option	Retaining a non-BEV option, mixed fleet, backup capability, or conditional BEV adoption based on range/charging limits.	2	3	5	1	0	1
Hybrids as transitional technology	Hybrid vehicles (HEV/PHEV) as a bridge, interim, fallback, or more acceptable near-term alternative to full battery electric vehicles due to concerns about BEV readiness, infrastructure, range, cost, or technology maturity.	0	4	0	3	4	0
Performance preference (ICE feel)	Preference for internal combustion engine (ICE) driving characteristics, such as performance feel, sound, mechanical engagement, efficiency perceptions, or confidence in continued ICE improvement.	0	3	0	0	3	0
Scepticism or resistance to change	Reluctance to adopt new vehicle technologies, a preference to wait, resistance to trends, or a stated unwillingness to change current behaviours or technologies.	0	2	0	1	3	0
Incompatibility with mobility needs							

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Road trip inconvenience	Long trips, road trips, traveling, vacations, long distances, or charging difficulties specifically while away from home (e.g., charging on the road, long-distance travel inconvenience).	0	3	6	2	2	5
Vehicle availability / unmet needs	Missing body styles (vans, trucks, practical vehicles), luxury & feature mismatches, delayed or unavailable models.	1	0	1	3	4	1
Personal preference/experience/life cycle							
No intent to replace current vehicle	Preference to keep current vehicle type (e.g., gas or hybrid).	0	0	2	1	0	2
Policy and regulatory opposition							
Feeling forced into BEV adoption	Feeling forced, mandated, or coerced into BEV adoption.	1	0	0	0	0	0
Opposition to mileage taxes	Per-mile charges, mileage-based taxes or fees.	0	1	0	0	1	0
Perceived unfair burden on consumers		0	1	0	0	0	0
Privacy & tracking concerns	Privacy, data collection, surveillance, tracking, monitoring, mileage tracking, or digital oversight.	0	1	0	0	0	0
EVs viewed as politically motivated	EVs as politically motivated, government-driven, ideological, or imposed due to political agendas.	1	2	0	0	0	0
Distrust in government energy planning	Distrust in government energy planning (e.g., scepticism toward government competence, planning, or management of energy systems, grid planning, or EV-related energy policy).	0	2	0	0	3	0

		Frequency					
Conditions		**Access to home charging**			**Price parity**		
Theme (name)	**Description**	**Reason to purchase**	**Reason not to purchase**	**Not sure**	**Reason to purchase**	**Reason not to purchase**	**Not sure**
Distrust of government & utilities	Distrust of government or utilities (e.g., suspicion, blame, or lack of trust directed at government institutions, regulators, or electric utilities).	0	2	0	0	4	0
Resistance to moral pressure / ideology	Resistance to moral pressure or ideological messaging (e.g., rejecting EVs because of perceived moralizing, virtue signalling, ideological coercion, or "being told what's right").	0	2	0	0	4	0
Scepticism of government & elite agendas	BEVs, environmental policy, or electrification efforts as a "scam," elite-driven project, or disingenuous agenda, rather than as a neutral or well-intentioned policy.	0	2	0	0	1	0
Global fairness / futility argument	Individual, national, or local environmental actions (e.g., adopting BEVs) are ineffective or unfair because other countries or global actors are perceived as not contributing, making the effort feel pointless or symbolic rather than impactful.	0		0	0	1	1
Cultural / identity-based rejection	Rejection of EVs on cultural, identity, or lifestyle-identity grounds.	0	0	0	0	3	0
Desire for autonomy and self-maintenance							
Cannot perform DIY maintenance on EVs	Preference for working on one's own vehicle, inability or unwillingness to perform maintenance/repairs on EVs	0	1	0	0	1	1
Discomfort with software-controlled vehicles	Distrust or discomfort with software updates, automation, or digital control.	0	1	0	0	2	0

The most common reason for considering the purchase of a BEV if access to home charging is provided is the convenience of home charging, which has been considered easier ("It would be easier to charge without seeking out a charging station", P124), time-saving ("It's nice not having to go to gas station for time saving"), and better aligned with respondents' daily routines (e.g., overnight charging, no extra trips). Moreover, several respondents clarify that limited electric driving range is their primary concern ("Ambivalent on this question..charging is not the issue..distance IS !!", P32), and that an extension of the range is critical to meet their household's travel needs without relying on public infrastructure ("The range expectation is approximately 600 miles which allows our household to complete travels without being required to charge outside of the home", P44).

Many respondents frame home charging as necessary to avoid relying on public infrastructure, which is often insufficient, especially in rural areas ("Charging stations are relatively inaccessible in more rural areas", P10). Driving somewhere to charge is viewed as inconvenient ("When we acquired the Prius Prime, we did not have a charger at our home for the first several months. It was very inconvenient to keep it charged at other locations", P12).

Some respondents mentioned the lack of access to home charging, yet expressed an interest in charging their vehicle at home, if available ("I don't charge my c max because I can't charge it at home. If I could, I definitely would", P345). Reasons for the unavailability of home charging is insufficient parking ("We also only have 1 garage", P30) and missing permission for the installation of chargers by homeowners' associations ("We really want to move to exclusively battery electric cars, but cannot charge at home with more than a 120V outlet and our homeowners association is threatening to prohibit even that", P299).

Respondents explicitly state that free ("If the charger and installation were free, I would consider", P82), or subsidized chargers ("If you mean that there is some kind of government program whereby home charging stations are subsidized, then my answer is yes", P33) would meaningfully change their willingness to adopt a BEV. Other barriers for home charging are installation costs, charger costs, and potential electrical upgrades ("It would then mean that I don't have to upgrade my electric box", P35), albeit this was mentioned less frequently. Some respondents explicitly connect EV adoption and home charging with environmental benefits and health benefits ("It's nice not having to go to gas station for time saving and health reasons", P45). Some are open to one BEV but not an entire household fleet ("I would consider buying one BEV but not change my whole fleet to BEV only", P19), reflecting a more cautious or gradual approach to BEV ownership.

Reasons for not considering the purchase of a BEV include range anxiety, insufficient driving range, limited public charging availability, technology immaturity, the preference for an incremental transition and mixed-vehicle ownership (BEV+non-BEV).

Low electric driving range ("Not enough long distance range", P119) and limited fast-charging availability ("There is not enough availability or access to public charging stations for all makes of electric vehicles", P364) undermine confidence for anything beyond local trips. Range anxiety ("The range of an electric vehicle would not be enough to get me to safety," P18) and the corresponding fear of running out of charge is a dominant theme ("I don't want to run out of charge in an area where there are no charging stations", P445).

Respondents believe current batteries are not ready for mass adoption ("Battery technology is not mature enough for me to purchase a BEV", P45) due to limited range, slow charging, degradation, high replacement cost, and lack of long-term durability data.

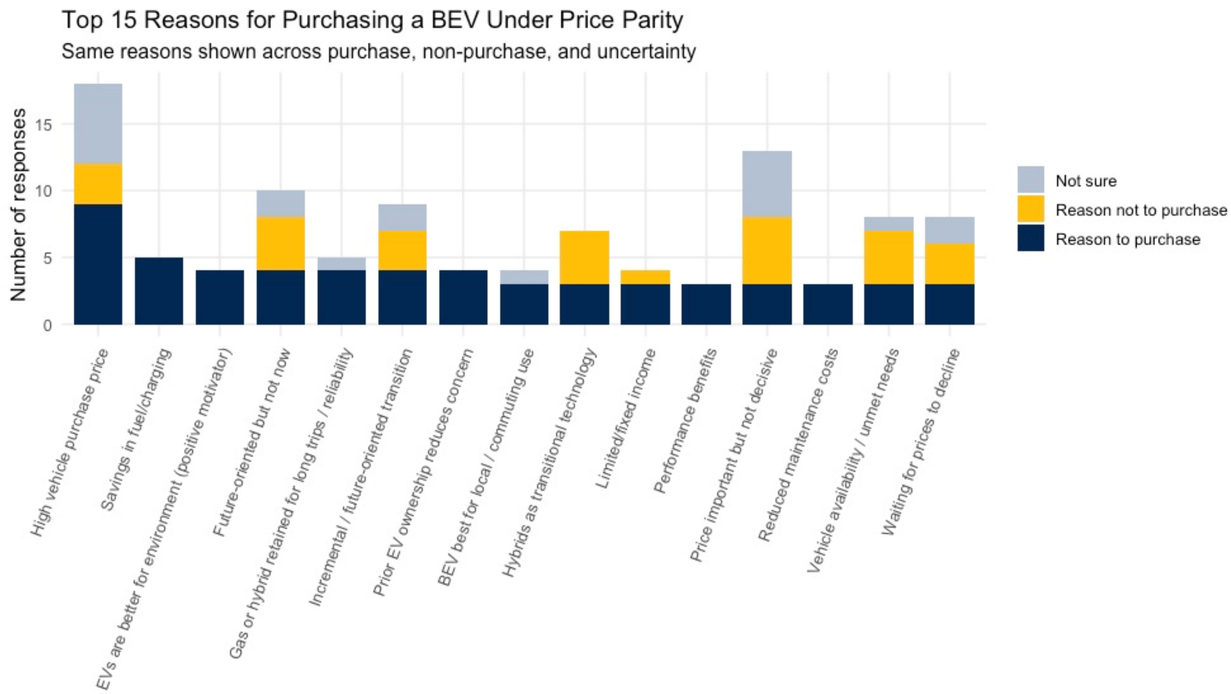
Respondents also mentioned the reasons underlying their uncertainty to purchase BEVs if access to home charging was provided. These reasons are similar to the reasons for not considering to purchase a BEV if access to home charging is provided. These include range anxiety ("The range anxiety of BEV's must be overcome...with ≥350 of actual BEV range", P10) and limited availability of public (fast-)chargers ("This wouldn't solve the challenge needed to fast charge when on the road", P55), limited electric driving range ("Limited Range – Needs to be 450 to 500 mile range", P15). Respondents explicitly prefer plug-in hybrids because they combine electric driving for daily use with gasoline backup for long trips, emergencies, or charger failures. This is framed as a *risk-reduction strategy* rather than resistance to electrification. Respondents acknowledge personal driving habits (waiting until very low fuel) that clash with BEV constraints. This self-awareness reinforces anxiety about running out of charge before reaching a charger ("I have a plug in hybrid as I don't like the thought of running out of charge", P334). Respondents also mentioned that home charging is not a decisive factor determining their purchase decision ("Charging system at home is a consideration, but only one of several considerations", P198).

Other less common reasons are the inconvenience of using BEVs on long-distance trips, making BEVs feel impractical due to extended charging stops. Less frequently mentioned themes are also the high upfront costs ("Cost of new EV are much higher than plug-in or gas models", P390), expensive battery replacement, and rising electricity rates. There seems to be no clear cost advantage over gas or hybrids ("No real cost benefit", P141). Concerns about battery degradation, replacement cost, and limited lifespan reduce trust in long-term BEV ownership. Several respondents doubt that EVs are truly environmentally superior once mining, production, electricity generation, and recycling are considered. Respondents are uneasy about being fully dependent on electricity - especially when chargers fail, rates rise, or access is uncertain during travel. Some respondents need electric trucks that don't yet meet work requirements ("I would need an electric truck for my job...very few electric truck options suitable", P131), or are retired and not planning another purchase ("As a retired person, I don't see myself buying another car," P310) - placing EVs outside their practical decision set. Several respondents are not rejecting EVs outright; they feel the technology, infrastructure, or economics are not yet ready for their needs. Some responses reflect timing constraints (just bought a car, retired, family needs like college parking) rather than attitudes toward EVs themselves. Respondents who have owned EVs or know EV owners cite first-hand inconvenience with range decline, charging difficulty, or usage limits, making their objections experience-based rather than theoretical ("It is the ability to charge on the road which is extremely difficult. My sister has an EV and won't drive it long distances because it is so hard to charge", P442).

9.2. Purchase Consideration under Condition of Price Parity

This section presents the results of the analysis of the reasons to purchase a BEV if the prices for BEVs are equivalent to the prices of gasoline-powered vehicles (see Figure 17 for the 15 top reasons).

Figure 15. Top 15 reasons for purchasing a BEV under conditions of price parity



Upfront cost is the most frequently cited factor ("Too expensive to purchase the EV", P216), followed by fuel cost savings ("Save money on gasoline", P87). Respondents - especially those on fixed or limited incomes - see current BEV prices as too high relative to gas or hybrid vehicles. Price parity is often described as the *minimum condition* for consideration ("If the price long term would be similar to gas, I would consider it", P141). Retired respondents or those with constrained incomes emphasize caution around large purchases, monthly payments, and insurance costs. Some respondents value BEVs for driving feel, performance, and quiet operation, reinforcing that BEVs can be preferred *if* cost and usability align.

The reasons for not considering purchasing a BEV even if prices were equivalent to gasoline/diesel vehicles were slightly different from the considerations to purchase a BEV. The most common reason for not considering the purchase is that price is considered only one factor impacting respondents' purchase decision ("The price is only one factor. Charging speed, range, and reliability are others", P15), followed by limited vehicle availability/unmet vehicle needs ("I drive a small sporty two-door car that weighs 3,400 pounds. As of 1/13/2025, no one is making an affordable sporty electric car", P166) and the preference for hybrids as transitional technology, especially in emergencies ("In case of emergency, a fueled-up car is easier to use/move to safety", P387). Respondents also mentioned the preference to adopt BEVs incrementally, waiting for prices to decline ("As batteries evolve and become lighter and more efficient, I may consider buying a gasoline/electric vehicle", P117), signaling that the cost of ownership is still considered a major barrier for price-sensitive people.

The main reason for being uncertain about the purchase of a BEV is the high vehicle purchase price ("I feel the price would have to be cheaper to convince me to buy one", P47), followed by considering prices as only one factor impacting individual's purchase decision ("Price alone isn't the total determinant", P55). Respondents also clearly distinguish between local, daily driving (where EVs may work well) and long trips, off-road travel, or intercity travel (where EVs are seen as impractical) ("Depends on usage. For local trips, when can charge at home, will likely purchase an EV. For a vehicle for long trips and offroad travel, will not likely consider an EV", P17).

Less frequently mentioned topics are limited real-world range ("The issue is range. Current generation has limited range", P34). Respondents specify minimum acceptable ranges (300+, 450–500 miles), especially for long-distance trips.

While charging at home is not considered a problem for respondents who have access to home charging, charging away from home was considered a problem given the lack of chargers in remote areas ("Again, access to charging stations is a concern", P237), the difficulty to find chargers on road trips, and long charging times ("We make occasional trips from NorCal to SoCal and I don't like the time needed to recharge", P417).

Others expressed the concern that technology is not ready yet (technology immaturity) ("I simply don't think we are there yet", P63), reflecting a belief that EV technology, infrastructure, and model availability have not matured enough to meet their needs. Other respondents plan to keep their current cars long-term and are not planning to purchase another car ("I don't intend to purchase a new car in the future, my Honda Civic is good to go for many more miles", P197).

Expressing uncertainty about purchasing a BEV if prices were equivalent are DIY maintenance and repair concerns: Respondents who repair their own vehicles see new EVs as incompatible with self-maintenance and worry about mandatory dealership service and higher ownership complexity ("I am handy and often fix my own cars. If I bought a new vehicle, id have car payments and be unable to fix my own vehicle any longer", P131).

Moreover, high battery replacement costs and uncertainty about battery lifespan make EVs feel like a risky long-term investment ("Cost of replacing battery is too high", P286). Some respondents question whether BEVs are truly cleaner once electricity generation and battery recycling are considered, weakening motivation to compromise on usability ("The electric vehicle is not as environmentally friendly as people think", P286). First-hand or repeated negative experiences with EVs (range, charging, ownership hassles) strongly shape resistance ("I'm not ever planning on buying a full electric vehicle because of my personal experiences", P214), making respondents less responsive to future improvements. Beyond availability, the cost of charging, especially away from home - is viewed as high and unpredictable, reducing the perceived advantage over gasoline.

10. Are Used ZEV Buyers Significantly Different than New ZEV Car Buyers?

10.1. Introduction

The used vehicle market generates twice the number of transactions per year as the new vehicle market as demonstrated by 40 million used vehicle sales compared to 17 million new vehicle sales in the U.S. in 2019. There is a wide literature investigating the adoption of new vehicles, including plug-in vehicles (PEVs) (Asadi et al., 2021; Dong et al., 2020). PEVs are vehicles with batteries that are plugged into the electrical grid to be charged, including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). BEVs only run by electricity, and PHEVs run by electricity and gasoline or diesel (Kurani et al., 2016). Yet, critical research gaps remain (Wicki et al., 2023). One major limitation of previous work is that studies have mainly focused on consumer adoption of new rather than used vehicles, including alternative fuel vehicles (Busch, 2021; Chakraborty et al., 2024). Relatively few PEVs have entered the used vehicle market to date, as most stay with their original owners (Tankou et al., 2021).

Inferring on used PEV buyers from studies on used internal combustion engine vehicles (ICEVs) buyers is not trivial, as the characteristics and considerations of the two consumer groups may differ significantly. Similarly, used PEV buyers may differ from new PEV buyers as well, including in terms of their demographic profile, such as living situation, tenure, and income (Ge et al., 2021). Used vehicle buyers may benefit from lower vehicle price, they also face several challenges, including limited or no purchase incentives, reduced performance, reduced effective battery range (Turrentine et al., 2018), uncertainty about vehicle performance and limited access to infrastructure (Lim et al., 2015; Loh et al., 2024). Furthermore, they may face other barriers such as difficulties in securing financing, potentially higher maintenance costs, and limited information about how to properly operate and maintain the technology (Turrentine et al., 2018).

Zou et al. (2020) emphasize the importance of understanding the preferences and concerns of used PEVs buyers to encourage the adoption of used PEVs. To ensure that PEVs trickle down to all segments of the population, it is necessary that PEVs enter the used vehicle market (Busch, 2021; 8). The present study analyses survey data on used vehicle buyers in California. More specifically, we are examining differences in their socio-demographic and economic characteristics, general attitudes and travel behavior.

10.2. Household Classification Data Analysis

We analysed the data in several steps, as outlined below.

As the main focus of this project is to assess differences between households owning a used PEV compared to households owning a new PEV or a mix of vehicles, we manually created different vehicle household groups (see) following a systematic group classification procedure. First, we categorized each respondent's household fleet by combining vehicle acquisition mode with fuel type technology. For each vehicle reported (up to five), we used two questions: (1) whether the vehicle was acquired new or used, and (2) the reported fuel type (BEV, Plug-in Hybrid Vehicles (PHEV), Gasoline, Diesel, or Hybrid (ICEV)). Each vehicle was assigned a numerical code:

- 1 = New BEV
- 2 = Used BEV
- 3 = New PHEV

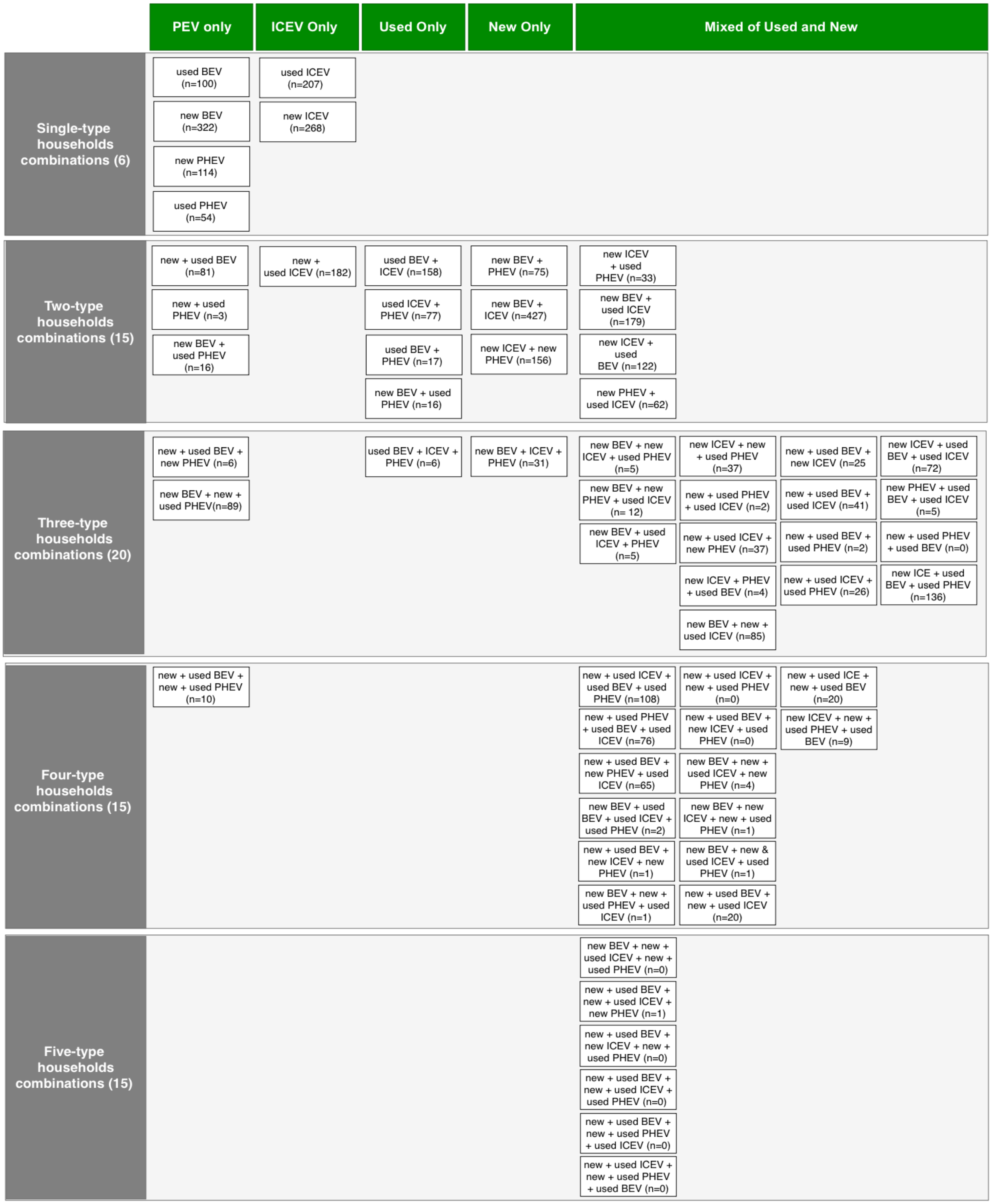
- 4 = Used PHEV
- 5 = New ICEV
- 6 = Used ICEV

Households were then grouped based on consistent patterns across all reported vehicles. For example, a household was classified as “New BEV only” if all household vehicles were coded as 1, and as “Used ICEV only” if all vehicles were coded as 6. We also identified mixed-household groups (e.g., “New and Used BEV”) if the household included both new and used BEVs but no vehicles from other categories. Grouping logic was applied across all five vehicle slots while allowing for missing responses.

This approach allows for a systematic classification of household fleets, enabling comparisons of socio-demographic and -economic, attitudinal and behavioral variables across ownership configurations.

In total, we identified 62 household vehicle combinations to represent an exhaustive and mutually exclusive set of vehicle combinations, as shown in Figure 18.

Figure 16 Household vehicle combinations.



In the next steps of the analysis, we divided these 62 household combinations into five main groups, including households owning only PEVs (i.e., BEVs, PHEVs), households owning only used vehicles, including both PEVs and non-PEVs, households owning only new vehicles, including both PEVs and non-PEVs, households owning used and new ICEVs, and households owning both new and used PEVs and non-PEVs. These five groups were then further divided into four main groups to allow for a systematic analysis of the differences between used and new PEV buyers, as shown by Table 6 Household vehicle groups. These four groups include households owning at least one new PEV (and no used PEVs), at least one used PEV (and no new PEVs), a mix of new and used PEVs, and no PEVs (i.e., ICE vehicles only, new/used or both).

Table 6 Household vehicle groups

# of household group	**Household group**	**Description**	**N**
1	New PEVs	Households owning at least one new PEV (i.e., BEVs, PHEVs)	1,538
2	Used PEVs	Households owning at least one used PEV (i.e., BEVs, PHEVs)	681
3	New and used PEVs	Households owning new and used PEVs (i.e., BEVs, PHEVs)	239
4	No PEVs	Households owning used and/or new ICEVs	699

In the third step, we analyzed the descriptive statistics of the questions subjected to our analysis. This step involves examining the distribution of the questions, means, standard deviation, relative and absolute values.

In the fourth step of the analysis, we performed a principal component analysis to explore the sources of variation in the dataset and reduce the complexity in the data. While our questionnaire items are mostly based on literature, we also developed new questions, considering the emerging literature on used PEV adoption. We applied the following best practices for conducting the PCA (see Abdi, & Williams, 2010):

- We computed Kaiser-Meyer-Olkin (KMO) measure to examine the suitability of the data for factor analytic purposes;
- We applied varimax rotation as the most common rotation method;
- We performed an analysis of the Screeplot and Eigenvalues to determine the number of the principal components, retaining principal components with an Eigenvalue of 1;
- We retained questions with loadings of 0.40 on their principal components, leading to the removal of questions with loadings not meeting this threshold.

The 19 questions that were subjected to the principal component analysis are presented in Table 7.

Table 7 Variables analyzed in principal component analysis.

Variable	**Question text**	**Response option**	**Source**
Innovation resistance	I rarely trust new ideas until I see whether most people around me accept them.	1 = Strongly disagree 2 = Disagree	Pallister & Foxall (1998)

		3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	
	I am usually one of the last people in my group to accept something new.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
	I must see other people using new innovations before I will consider them.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	??
Emotional reaction	When I am informed of a change of plans, I tense up a bit.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
	I often find myself skeptical of new ideas.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	??
	I generally consider changes to be a negative thing	1 = Strongly disagree2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
Risk tolerance	When purchasing a vehicle, I'm willing to take some risks.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
	Before I decide to buy a vehicle as used, it would be important to test-drive it.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)

Preferences for used products	Acquiring vehicles as used is a better match for my household than acquiring them new.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	??
	Buying a used vehicle minimizes the depreciation that comes with buying a new vehicle.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Self-developed
Price gratification	I can afford to buy more because I pay less for used and second-hand products.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
	Just because a vehicle is new doesn't mean it is worth paying a higher price over a used one.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
Environmental and political orientation	I am very certain that there is solid evidence the average temperature on Earth has been getting warmer over the past several decades.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Kurani et al. (2016)
	Powering a car with electricity poses less environmental risk than powering it with gasoline.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Kurani (2018)
	There is an urgent need to replace gasoline and diesel fuels with other sources of energy.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Kurani et al. (2016)
	The negative environmental consequences of car use can be reduced if individuals make changes in their lifestyle.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree	Adapted from Kurani (2018)

		5 = Strongly agree	
	Concerns about human-caused climate change are unjustified, so no action is required to address it.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	??
	By buying used and second-hand, I'm fighting against waste.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	Pallister & Foxall (1998)
	If government did not intervene, the market would produce electric vehicles if we needed them.	1 = Strongly disagree 2 = Disagree 3 = Neither disagree nor agree 4 = Agree 5 = Strongly agree	??

In the fifth step, we conducted a confirmatory factor analysis to confirm the factor structure identified in the prior step. This step also involved assessing the reliability and validity of our measurement model (which is represented by the relationships between the survey questions and their underlying latent factors). In this model, the questions are seen as the observed variables because they were directly measured (by the responses collected from our respondents). The latent factors are the hypothetical constructs or factors, which are not directly observable but are represented by questions. To assess reliability, we computed the internal consistency reliability (i.e., Cronbach's alpha), and composite reliability. To assess validity, we computed convergent validity, and discriminant validity. For the measurement model to have convergent validity, the factor loadings (i.e., lambdas) should be significant, exceeding the threshold of 0.60 on their respective scales. The Average Variance Extracted (AVE) should exceed the threshold of 0.50, and Cronbach's alpha values should be higher than 0.60. Discriminant validity, which assesses the extent to which the latent constructs are uni-dimensional, is established if the square root of the AVE of each latent construct exceeds the correlation coefficients between the latent constructs. We also assessed model fit, which is considered acceptable if the Comparative Fit Index (CFI) ≥ 0.95, Root Mean Square Error of Approximation (RMSEA) ≤ 0.08, and the Standardized Root Mean Square Residual (SRMR) ≤ 0.06.

In the sixth step of the analysis, we performed a Multinomial Logistic Regression Analysis to analyze the differences between the four owner groups. In this model, we included the following independent household-level and attitudinal variables (see Table 8). The dependent variable is the membership to the four household groups. Note that Table 8 does not present the factors identified in the principal component analysis. To rule out multicollinearity, we computed the Variance Inflation Factors for every variable in the model, which did not exceed 5, suggesting the absence of multicollinearity.

Table 8 Independent variables used in the Multinomial Logistic Regression Analysis, question text, and response option.

Variable	Question text	Response option
Income	My household's pre-taxed income for the past tax year was in the following range:	1 = Less than $50,000 2 = $50,000 to $99,999 3 = $100,000 to $149,999 4 = $150,000 to $199,999 5 = $200,000 to $249,999 6 = $250,000 to $299,999 7 = $300,000 to $349,999 8 = $350,000 to $399,999 9 = $400,000 to $449,999 10 = $450,000 to $499,999 11 = $500,000 or more
Gender	Please enter information below about your household members [You][Gender]	1 = Female 2 = Genderqueer/non-binary 3 = Male 4 = TransFemale/Transwoman
Age	Please enter information below about your household members [You][Age]	1 = 15 to 18 2 = 19 to 29 3 = 30 to 39 4 = 40 to 49 5 = 50 to 59 6 = 60 to 69 7 = 70 to 79 8 = 80 or older
Education	What is the highest level of formal education you personally completed? (In years)	1 = Less than high school 2 = Completed High School/High school graduate or GED 3 = Some college, no degree 4 = Technical Certificate or Associate's Degree 5 = Associate degree (e.g., AA, AS) 6 = Bachelor's degree 7 = Master's degree 8 = Doctorate or professional degree 9 = Master's, Doctorate or Professional License 10 = Prefer not to say
Household size	Including yourself, how many people are there in your household?	1 = 1 2 = 2 3 = 3 4 = 4 5 = 5 6 = 6 7 = 7
Number of vehicles	How many vehicles are there in your household? (not	1 = 1 2 = 2 3 = 3

	including recreational vehicles or non-operational vehicles)?	4 = 4 5 = 5 or more
Private parking (dummy)	What kind of parking do you have available at home? [Personal garage]	1 = Yes 2 = No
DAC		Creation of new variable that assigns respondents to DAC based on their address
Neighbors with BEVs	Please estimate, how many of your neighbors drive an electric vehicle?	5%-10%
Neighbors with BEVs	Please estimate, how many of your neighbors drive an electric vehicle?	10%-20%
Neighbors with BEVs	Please estimate, how many of your neighbors drive an electric vehicle?	20%-30%
Neighbors with BEVs	Please estimate, how many of your neighbors drive an electric vehicle?	More than 30%

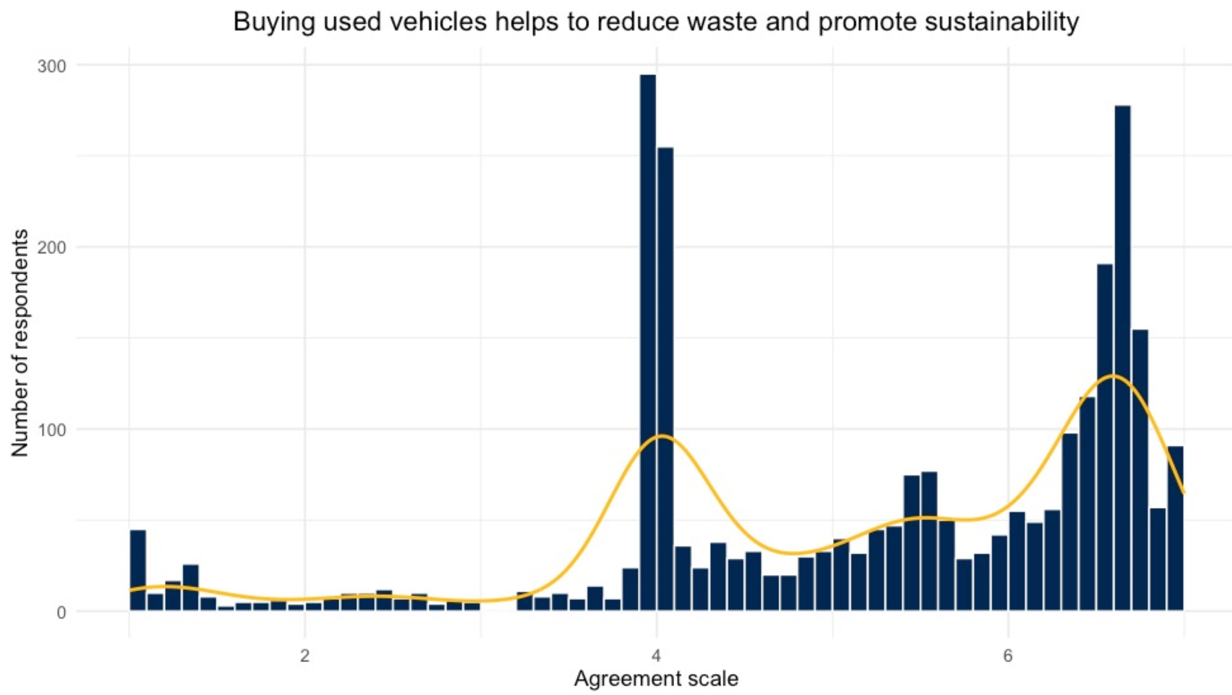
The first five steps were conducted with R. The sixth step was conducted with STATA. The code will be made available upon request.

10.3. Results

10.3.1. Descriptive statistics

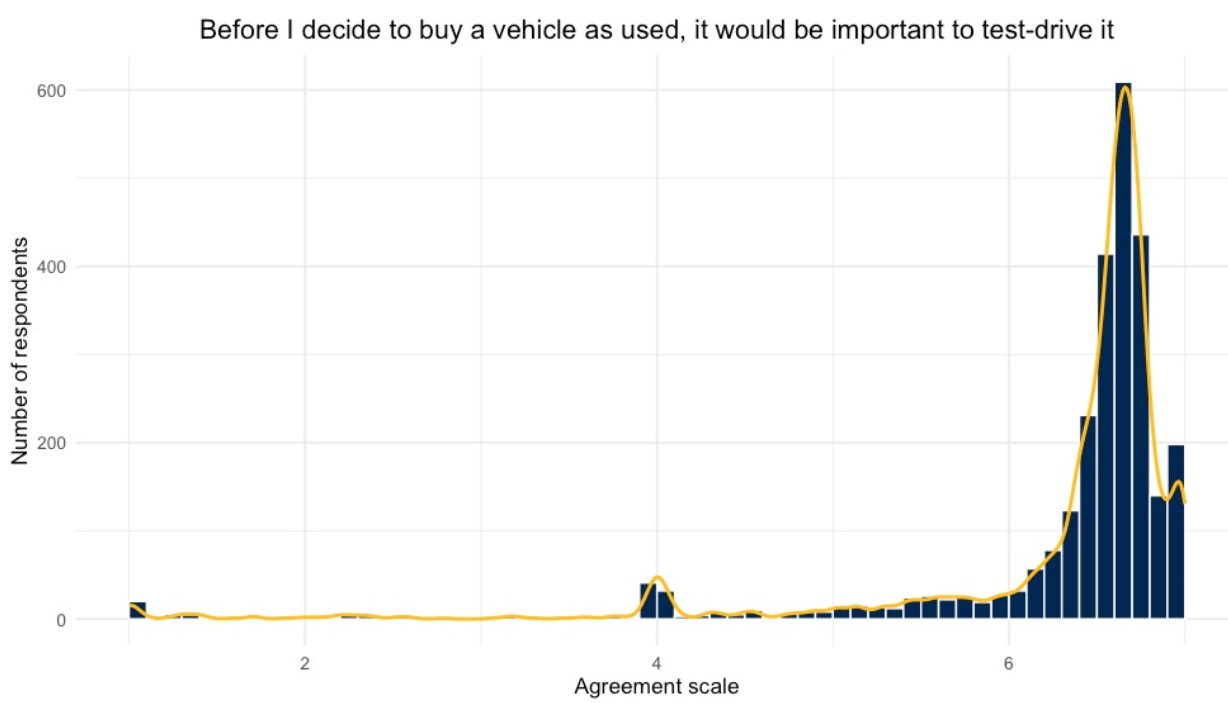
In this section, we examine the attitudes towards the acquisition of used vehicles of used PEV buyers. The survey asked respondents to indicate to what extent buying used vehicles helps to reduce waste and promote sustainability. The results show a strong agreement with the question, indicating that respondents agree with buying used vehicles to reduce waste and promote sustainability (*M* = 5.21, SD = 1.48, n= 2,717, min = 1, max = 7, see Figure 19).

Figure 17 Distribution of ‘Buying used vehicles helps to reduce waste and promote sustainability’



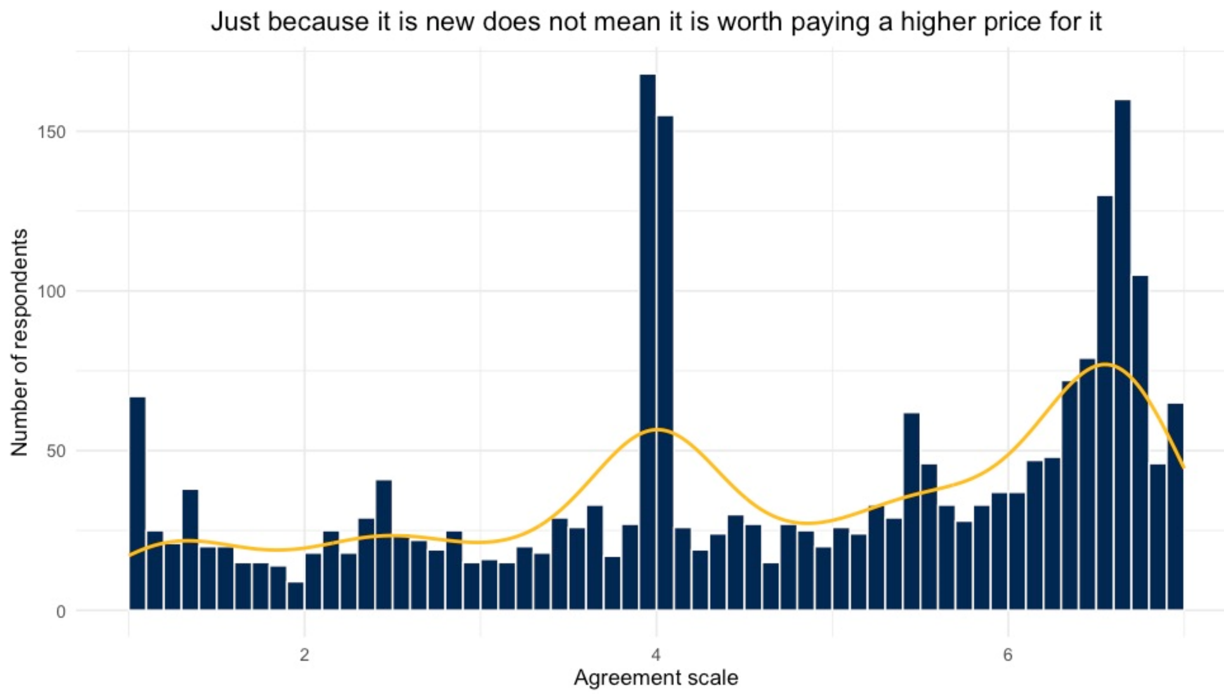
Respondents also reported a very strong agreement with the question that before deciding to buy a vehicle as used, it would be important to test-drive (*M* = 6.31, SD = 0.94, n = 2,717, min = 1, max = 7), with 83% of respondents providing their agreement with this question, as shown by Figure 20.

Figure 18 Distribution of ‘Before I decide to buy a vehicle as used, it would be important to test-drive it’



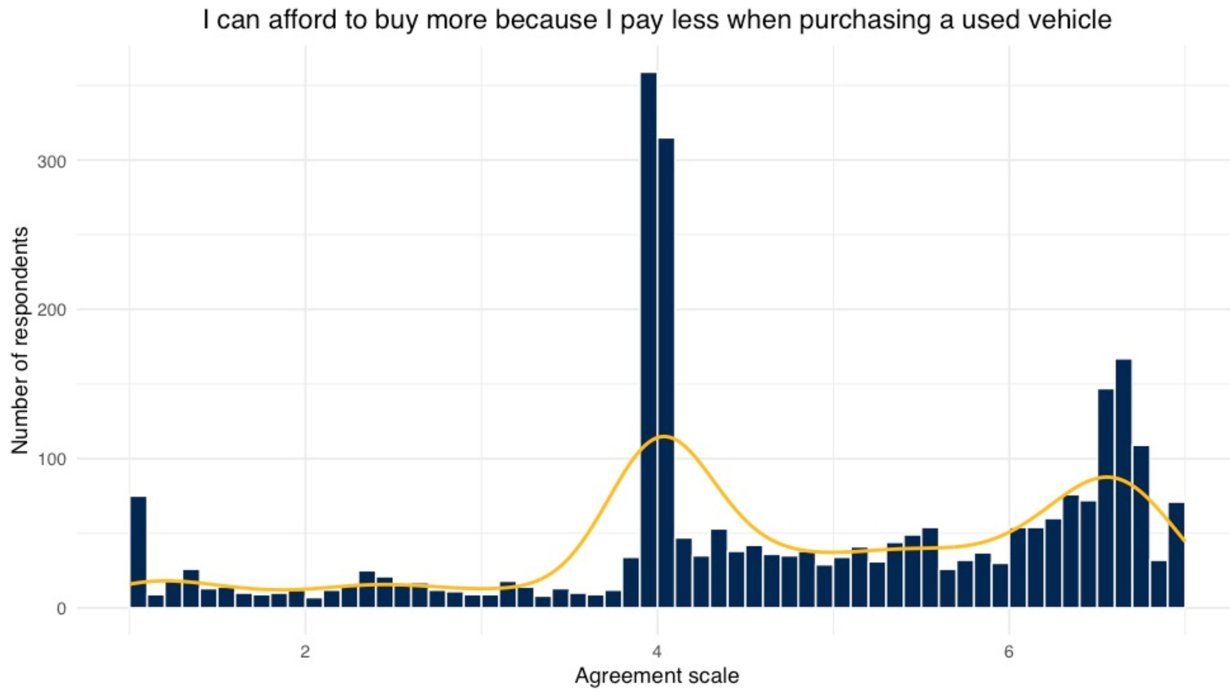
Respondents agreed less with the statement ‘Just because a vehicle is new doesn’t mean it is worth paying a higher price over a used one’ (*M* = 4.67, SD = 1.78, n= 2,357) (see Figure 21).

Figure 19 Distribution of question ‘Just because a vehicle is new doesn’t mean it is worth paying a higher price over a used one’.



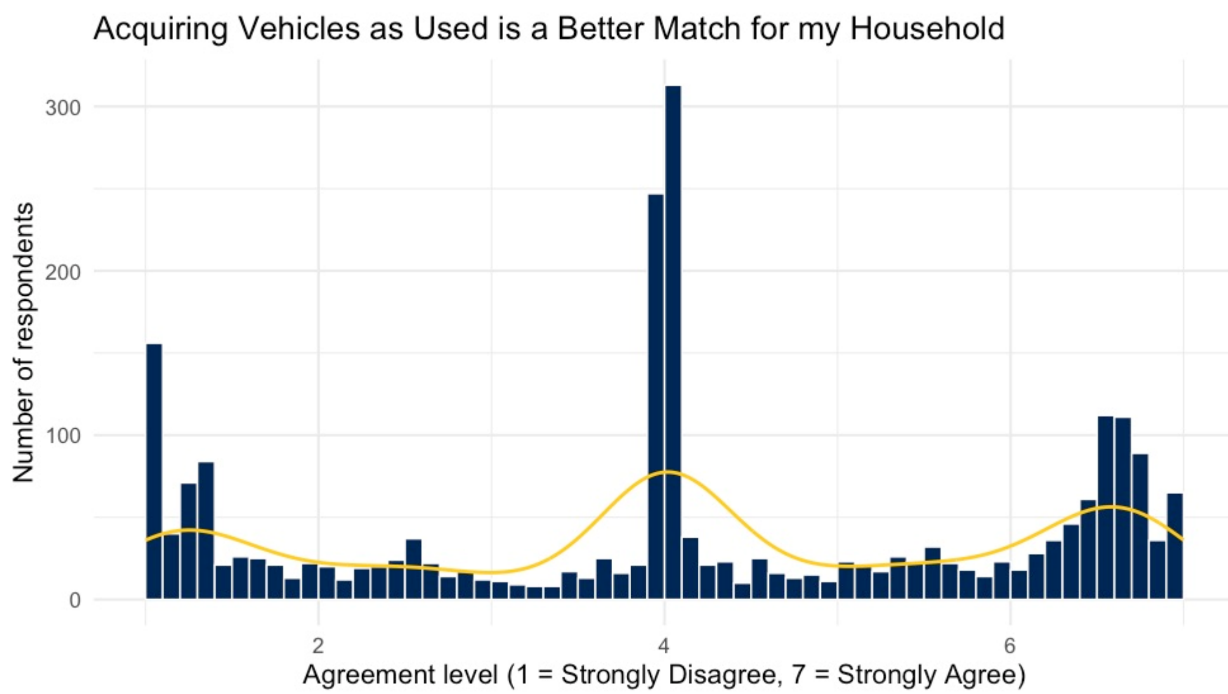
Similarly, respondents moderately agreed with the question saying that they can afford to buy more because they pay less when purchasing a used vehicle (*M* = 4.77, SD = 1.57, n = 2,688), as shown by Figure 22).

Figure 20 Agreement levels to question ‘I can afford to buy more because I pay less when purchasing a used vehicle’ (M = 4.77, SD = 1.57, n= 2,715, min = 1, max = 7).



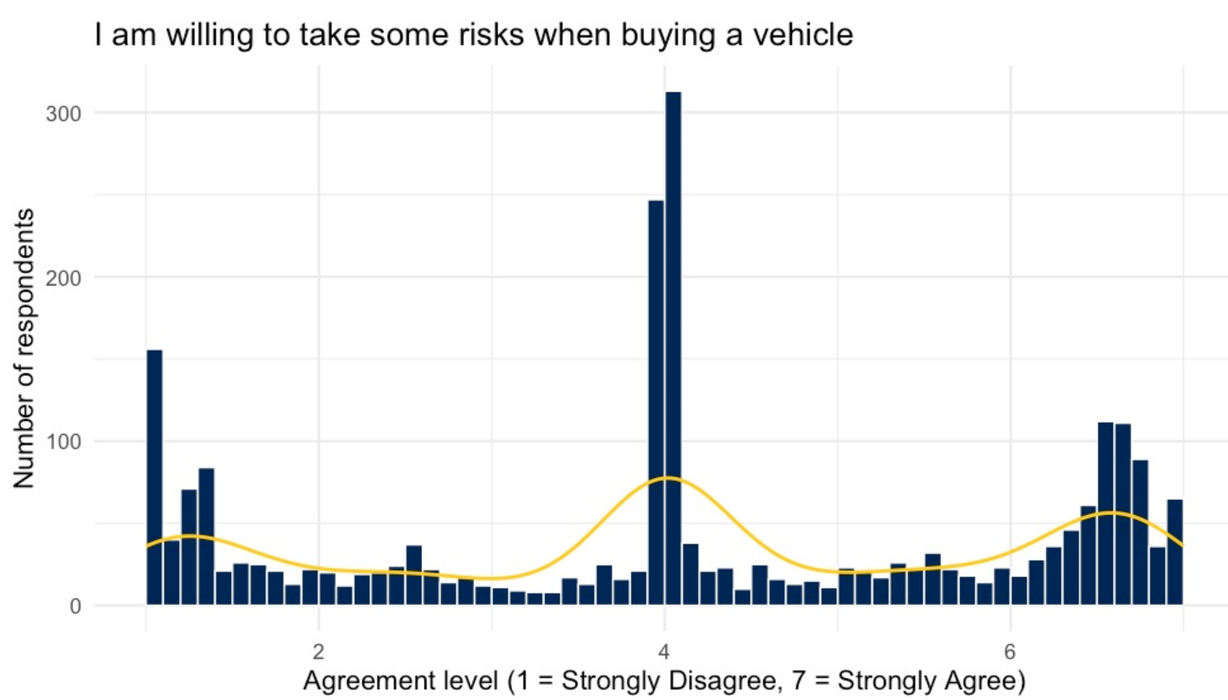
Moreover, the survey also asked respondents to indicate to what extent they agree with the statement saying that buying a used vehicle is a better match for their household (M = 4.14, SD = 1.91, n= 2,357, min = 1, max = 7) (see Figure 23).

Figure 21. Agreement levels to question ‘Acquiring vehicles as used is a better match for my household than acquiring them new’.



The strongest level of disagreement was found for respondents’ willingness to take some risks when buying a vehicle (*M* = 4.77, SD = 1.57, n= 2,715, min = 1, max = 7)., as shown in Figure 24.

Figure 22 Agreement levels to question ‘I am willing to take some risks when buying a vehicle’.

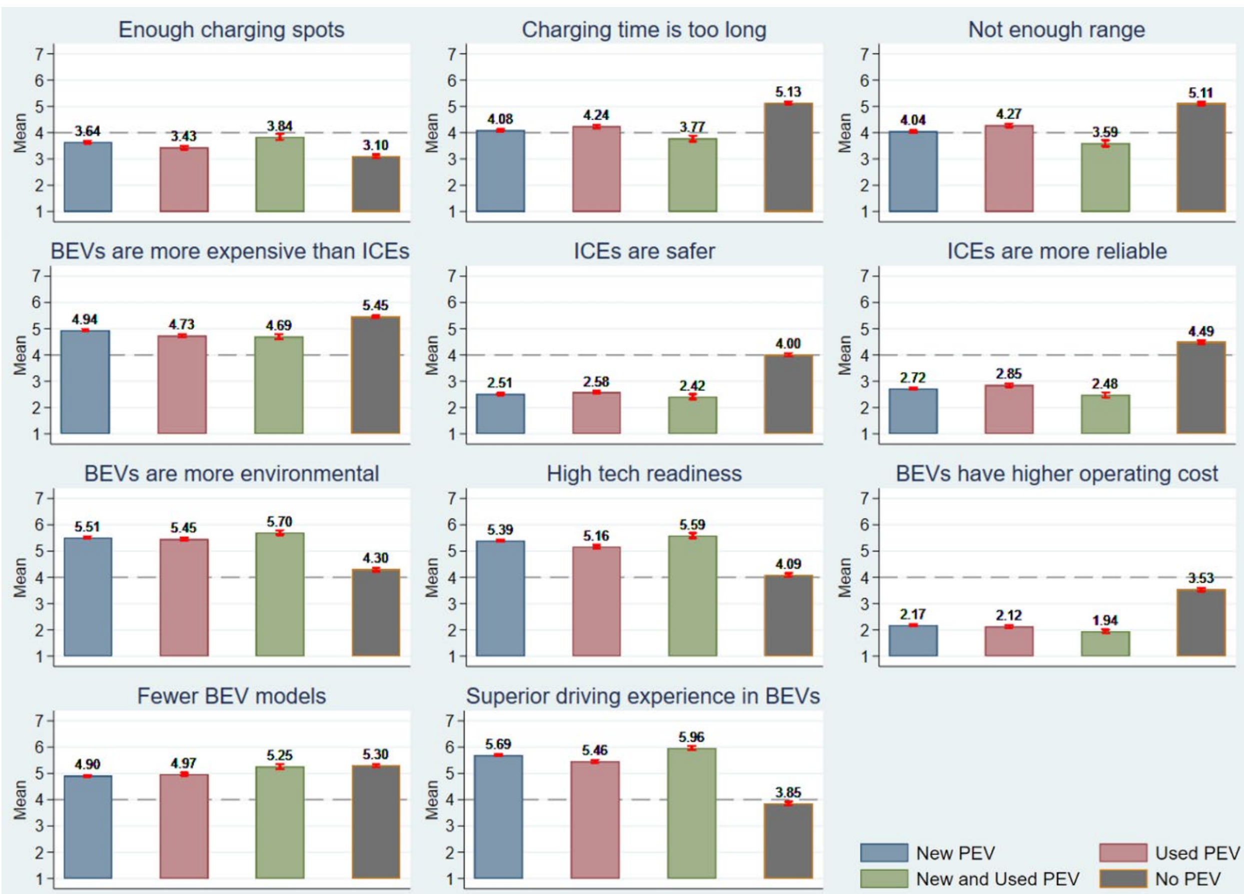


We also asked respondents to what extent they agree with buying a used vehicle minimizes the depreciation that comes with buying a new vehicle. The results have shown a strong agreement with this question as around 73% of respondents agreed with it compared to around 16% who reported to neither agree nor disagree with this statement (results not visually shown here).

10.3.2. Analysis of Group Differences

Figure 25 presents differences in mean agreement levels across the four household groups: new PEV owners, used PEV owners, households that owned both new and used PEVs, and those with no PEVs, on eleven BEV assessment questions operationalizing the performance of BEVs on different dimensions (see Kurani, 2024). Each item was rated on a 1-7 Likert scale (1=strongly disagree, 7=strongly agree), where values above 4 indicate agreement. We did not include these questions in the principal component and confirmatory factor analysis as each of these assessment questions measured single performance dimensions of BEVs.

Figure 23 Differences in agreement levels across four household groups.



Across nearly all questions, statistically significant differences were found among the four groups (Table 9; all $p < 0.001$). Used-PEV owners generally fell between new-PEV and no-PEV households in their responses (though typically closer to the new-PEV group) reflecting both positive perceptions and some remaining reservations. This pattern is consistent with households entering the BEV market through the second-hand segment, who tend to own older, lower-performance vehicles.

In terms of charging time, post-hoc tests confirmed that the no-PEV group differed significantly from all PEV-owning groups, whereas used- and new-PEV households were statistically indistinguishable.

Moreover, post-hoc comparisons show no significant difference between new- and used-PEV owners, suggesting that once households gain direct experience with BEVs, whether through a new or used vehicle, they similarly recognize the benefits of lower operating costs.

Taken together, the results position used-PEV owners as a transitional group. Their responses indicate both familiarity with BEV advantages and residual caution on practical issues such as charging convenience, reliability, and technology readiness. Whether group means lie above or below the neutral midpoint (4) provides further context: while adopters of both new and used PEVs express broad agreement with positive statements, the used-PEV group's slightly more moderate evaluations suggest experience coupled with awareness of remaining market barriers.

Finally, averages conceal substantial variation within groups, especially among households without a PEV. The histograms in Table 9 reveal broad and often polarized distributions for this group: while some respondents hold neutral or mildly positive views about BEVs, others express consistently negative opinions, particularly regarding charging time, range, and costs. This pattern suggests that the no-PEV segment encompasses both a large share of the general population with limited experience or information about BEVs and a smaller subset of clear resistors who reject BEV benefits across topics. In contrast, PEV owners, whether new or used, show narrower, more coherent response patterns, reflecting attitudes shaped by direct ownership experience.

Table 9 ANOVA results for assessment questions by household group.

#	**Statement**	**F (df = 3, 2,553)**	***p*-value**	**Direction (Mean > 4 = Agree)**
1	There are enough places to charge BEVs	14.55	<0.001	PEV ≈ 4, No PEV < 4
2	It takes too long to charge BEVs	57.50	<0.001	No PEV > 4, PEV ≈ 4
3	BEVs do not travel far enough	61.09	<0.001	No PEV > 4, PEV ≈ 4
4	BEVs cost more to buy than ICEs	25.95	<0.001	All > 4
5	ICEs are safer	125.50	<0.001	PEV < 4, No PEV > 4
6	ICEs are more reliable	158.61	<0.001	PEV < 4, No PEV > 4
7	BEVs are less damaging to the environment	92.14	<0.001	All > 4, No PEV lower
8	BEV technology is ready for mass market	94.35	<0.001	All > 4, PEV > No PEV
9	BEVs cost more to operate	125.16	<0.001	PEV < 4, No PEV > 4
10	There are fewer BEV models	10.11	<0.001	All > 4

11	BEV driving experience is superior	194.61	<0.001	PEV > 4, No PEV ≈ 4

10.3.3. Principal Component Analysis

This section presents the results of the principal component analysis (PCA). As mentioned before, the goal of this analysis is to explore the relationships between survey questions and their underlying latent (theoretical/unobserved) factor. Several questionnaire items had loadings that did not meet the recommended threshold of 0.40 or loaded on more than one principal component, leading to their removal from further analysis. The items that we excluded are:

- Buying a used vehicle minimizes the depreciation that comes with buying a new vehicle.
- Before I decide to buy a vehicle as used, it would be important to test-drive it.
- The negative environmental consequences of car use can be reduced if individuals make changes in their lifestyle.
- Concerns about human-caused climate change are unjustified, so no action is required to address it.
- If government did not intervene, the market would produce electric vehicles if we needed.

We re-run the analysis several times until a clear three-factor structure emerged without cross-loadings, as presented in Table 10.

The highest factor loading on the first component is ‘I rarely trust new ideas until I see whether most people around me accept them’, while the lowest was ‘I must see other people using new innovations before I will consider them’. For this reason, we label this component as ‘innovation resistance’.

The highest factor loading on the second component is ‘Acquiring vehicles as used is a better match for my household than acquiring them new’, while the lowest is ‘When purchasing a vehicle, I'm willing to take some risks’. For this reason, we label this component as ‘attitudes towards the acquisition of used vehicles’.

The highest factor loading on the third component is ‘There is an urgent need to replace gasoline and diesel fuels with other sources’, while the lowest loading is ‘Powering a car with electricity poses less environmental risk than powering it with gasoline’. For this reason, we label this component as ‘pro-environmental attitude’.

Table 10 Results of principal component analysis (PCA).

Question	PC1	PC2	PC3
I rarely trust new ideas until I see whether most people around me accept them.	0.72		
I am usually one of the last people in my group to accept something new.	0.71		
I generally consider changes to be a negative thing.	0.68		
When I am informed of a change of plans, I tense up a bit.	0.65		
I often find myself sceptical of new ideas.	0.52		
I must see other people using new innovations before I will consider them.	0.51		

Acquiring vehicles as used is a better match for my household than acquiring them new		0.80	
I can afford to buy more because I pay less for used and second-hand products		0.73	
Just because a vehicle is new doesn't mean it is worth paying a higher price over a used one		0.73	
By buying used and second-hand, I'm fighting against waste		0.62	
When purchasing a vehicle, I'm willing to take some risks		0.57	
There is an urgent need to replace gasoline and diesel fuels with other sources			0.87
I am very certain that there is solid evidence the average temperature on Earth			0.83
Powering a car with electricity poses less environmental risk than powering it with gasoline			0.83

In the second step, we subjected the principal components to a confirmatory factor analysis. This step is necessary as the composition of the principal components does not correspond with the original theoretical structure as supported by the literature. For instance, the question 'By buying used and second-hand, I'm fighting against waste' and 'When purchasing a vehicle, I'm willing to take some risks' loaded on the same component, even though these questions operationalize two different underlying latent constructs. The confirmatory factor analysis is therefore a critical step to confirm the validity and reliability of the measurement model.

The results of the principal component analysis are presented in Table 11. The standardized factor loadings exceed the recommended threshold of 0.60 for all constructs after we removed questionnaire items with loadings of < 0.60. We also computed Cronbach's Alpa and composite reliability for each latent construct to show that the constructs are internally consistent. Cronbach's alpha and composite reliability exceed the common threshold of 0.70 for all constructs.

Table 11 Results of confirmatory factor analysis (CR = Composite reliability, α = Cronbach's alpha).

Latent Variable	**Observed variable (survey question)**	**Std.Err**	**P(>|z|)**	**Lambda**	**AVE**
Innovation resistance (CR = 0.80, α = 0.81)	I rarely trust new ideas until I see whether most people around me accept them.			0.718	0.50
	I am usually one of the last people in my group to accept something new.	0.086	0.000	0.742	
	I must see other people using new innovations before I will consider them.	0.082	0.000	0.708	

	I often find myself skeptical of new ideas.	0.097	0.000	0.653	
Used products preferences (CR = 0.729, α = 0.72)	Acquiring vehicles as used is a better match for my household than acquiring them new.			0.765	0.493
	I can afford to buy more because I pay less for used and second-hand products.	0.034	0.000	0.621	
	Just because a vehicle is new doesn't mean it is worth paying a higher price over a used one.	0.040	0.000	0.686	
Environmental concerns (CR = 0.793, α = 0.79)	I am very certain that there is solid evidence the average temperature on Earth has been getting warmer over the past several decades.			0.721	0.621
	Powering a car with electricity poses less environmental risk than powering it with gasoline	0.036	0.000	0.753	
	There is an urgent need to replace gasoline and diesel fuels with other sources of energy.	0.067	0.000	0.838	

Table 12 presents the multinomial logit estimates of household characteristics associated with different types of PEV ownership. The results reveal distinct socio-demographic and attitudinal profiles across new, used, and non-PEV households. We will discuss the results in the subsequent sections.

Table 12 Multinomial logit estimates of household characteristics associated with owning a new PEV, a used PEV, both, or no PEV.

Household groups	**(1)**	**(2)**	**(3)**	**(4)**

Variables	New PEV	Used PEV	Used and new PEV	No PEV
ln(household income)	0.373***		0.323*	0.141
	(0.117)		(0.174)	(0.137)
Gender	-0.225*		-0.363*	0.149
	(0.135)		(0.207)	(0.154)
Age	0.0124**		0.00280	-0.0221***
	(0.00503)		(0.00773)	(0.00541)
Education (years)	0.0239		-0.00899	-0.00414
	(0.0269)		(0.0395)	(0.0315)
Household size	-0.0589		0.146*	-0.0698
	(0.0656)		(0.0883)	(0.0738)
Number of vehicles	-0.0644		0.551***	-0.611***
	(0.0780)		(0.102)	(0.0994)
Private parking (dummy)	0.134		0.474	-0.533**
	(0.253)		(0.503)	(0.249)
DAC	-0.125		-0.0311	0.0971
	(0.144)		(0.221)	(0.160)
Neighbors with PEVs (5%-10%)	-0.0801		0.437	-0.885***
	(0.201)		(0.345)	(0.207)
Neighbors with PEVs (10%-20%)	-0.0342		0.412	-0.928***
	(0.205)		(0.345)	(0.222)
Neighbors with PEVs (20%-30%)	0.335		0.582	-0.939***
	(0.221)		(0.367)	(0.251)
Neighbors with PEVs (more than 30%)	0.765***		0.775*	-1.055***
	(0.265)		(0.415)	(0.335)
Innovation resistance	-0.0293		-0.0270	0.202***
	(0.0515)		(0.0767)	(0.0561)
Used products preferences	-0.881**		-0.472***	-0.552***
	(0.0484)		(0.0665)	(0.0542)
Environmental concerns	0.138*		0.500***	-0.721***
	(0.0831)		(0.140)	(0.0844)
Constant	-4.328**		-7.235***	2.203
	(1.391)		(2.121)	(1.588)
Observations	2,268	2,268	2,268	2,268
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

In a complementary analysis (not shown), household vehicle miles traveled (VMT) and commute distance were added as predictors of PEV ownership type. Neither variable showed a statistically significant effect, and including them reduced the sample size due to missing observations. The final model, reported in Table 12, therefore excludes these variables and provides more stable estimates across a larger sample.

10.4. Discussion

The present study examined differences between buyers of used and new vehicles in California to gain a better understanding of buyers of used vehicles, including buyers of PEVs, in comparison to buyers of new vehicles and non-PEVs. While most prior studies have limited the analysis to a simpler classification of used vehicle buyers (e.g., used versus new), our analysis offers a comprehensive grouping to account for the complexity of used vehicle buyers among Californian households. Leveraging all possible combinations between vehicle type and fuel type, we identified 62 household vehicle combinations, which were then assigned to four main groups. These groups were then subjected to further analysis, including descriptive statistics of key variables to understand differences between their socio-demographic and -economic characteristics, travel behavior and attitudes (as measured by three principal components extracted by the PCA). We run a MNR to examine the likelihood of being in one of these groups as a function of these key variables and the three principal components. Here we limit the discussion of the results to some of the key findings.

10.4.1. Analysis of Mean Group Differences

In questions related to charging infrastructure, used-PEV owners were moderately confident in charging availability (means ≈ 3.7), close to new-PEV owners but higher than no-PEV households. A similar pattern emerged for perceptions of charging time: While all PEV owners rated this issue closer to neutral, used-PEV owners were slightly more concerned than new-PEV owners but still notably less skeptical than non-owners. Charging speed has been considered a barrier to PEV adoption, yet only a small proportion of PEV owners reported to be dissatisfied with charging speed in a prior report examining the experiences of PEV owners (Plug In America, 2023).

For range and cost perceptions, used-PEV owners again represented a middle ground. Regarding driving range, they expressed somewhat more concern than new-PEV owners but substantially less than non-owners.

On purchase price, all groups agreed BEVs are more expensive than ICE vehicles, which aligns with research that has shown that the purchase price of BEVs remains a key concern of owners (Dadashzada et al., 2025). Used-PEV owners rated this concern less strongly than non-owners, suggesting cost perceptions evolve with exposure and purchase experience in the used market. Operating cost perceptions highlight another clear gap between PEV owners and non-owners. Although all groups rated this statement below the neutral midpoint, indicating that most respondents do not believe BEVs cost more to operate, the no-PEV group was far less convinced than BEV owners (mean = 3.5 vs. ≈ 2.1).

Perceptions of safety and reliability showed consistent divides: non-owners viewed ICE vehicles as safer and more reliable (means ≈4.0-4.5), while all PEV groups disagreed (≈2.5-2.8). The differences were large and highly significant. Among the owner groups, used-PEV households expressed slightly higher agreement than new-PEV owners, suggesting that second-hand buyers retain more caution toward BEV reliability, possibly due to concerns about battery degradation and warranty coverage.

Perceptions of environmental and technological aspects were broadly positive across all groups, though with notable differences in emphasis. All groups agreed that BEVs are environmentally beneficial, but non-PEV households expressed the weakest agreement, while no significant differences were found among the three PEV-owning groups. Environmental considerations were stated as one of the most important purchase considerations of PEVs (Plug In America, 2025). In contrast, perceptions of technology readiness revealed meaningful variation across all groups. Although PEV owners generally viewed BEV technology as mature and market-ready, used-PEV owners rated it significantly lower than both new-PEV and dual-ownership households. This pattern suggests that while ownership experience increases technological confidence, used-PEV owners remain somewhat more cautious, possibly reflecting their exposure to older vehicle models or concerns about aging technology.

Model availability was one of the few items with limited differentiation: all groups agreed that BEV options remain limited, including used-PEV owners, who experience these constraints more directly. The strongest contrasts appeared for driving experience, where used-PEV owners closely matched new-PEV owners in rating BEVs as offering a superior driving experience (means ≈5.5-5.7), while no-PEV respondents remained unconvinced (≈3.8).

10.4.2. Multinominal Logistic Regression Analysis

Household income is positively associated with owning a new PEV and, to a lesser extent, with owning both new and used PEVs, indicating that higher-income households are more likely to participate in the new-vehicle segment of the electric market. Prior research has shown that an increase in income reduced the likelihood of purchasing used PEVs (Chakraborty et al., 2024). Studies have also found the purchase and ownership of used vehicles to be a financial burden for buyers (Klein et al., 2023).

Female respondents are less likely to own new and mixed PEV fleets (used and new), while age has an opposite effect: Older respondents are more likely to own a new PEV but less likely to have no PEV at all. Education does not appear to play a significant role once income and other factors are controlled for. Prior research has shown that buyers of used ICEVs were lower-educated and to have no college degree than buyers of new ICEVs (Chakraborty et al., 2024; Zou et al., 2020).

Differences between groups also emerge in household composition and vehicle stock. Larger households are somewhat more likely to own used PEVs, possibly reflecting the presence of multiple drivers or vehicles serving different roles within the household. The total number of vehicles is strongly associated with used-PEV ownership, suggesting that second-hand PEVs often enter as additional, rather than replacement, vehicles.

Neighborhood context plays a key role in adoption. Living in areas with higher shares of PEV-owning neighbors substantially increases the likelihood of owning either a new or a used PEV, emphasizing the importance of social exposure and peer effects. Conversely, households in areas with low PEV penetration remain much more likely to be non-adopters.

Attitudinal factors show some of the strongest associations. Environmental concern is positively related to both new and used PEV ownership, suggesting that environmental concern is a key driver for PEV adoption. Preferences for used products is linked to lower adoption, which is counterintuitive as one would expect that individuals preferring to purchase used are more likely to acquire used PEVs. As expected, higher innovation resistance is also linked to lower adoption, meaning that individuals resisting technological innovations are less likely to adopt PEVs. In line with our expectations, used-PEV owners tend to express stronger environmental motivation than non-adopters but are also more likely to exhibit cost-conscious behaviors consistent with their preference for used products.

10.4.3. Conclusions

In this study we find significant differences between buyers of used and new vehicles in California. This study offers new insights into the diversity of household vehicle ownership in California by going beyond the traditional binary classification of new versus used vehicles. Overall, the results suggest that new and used PEV owners share some common environmental and social characteristics but differ in socioeconomic status and vehicle ownership context. Used-PEV owners appear to represent a more economically diverse group - one that bridges early adopters and the broader mainstream market. Policy efforts to broaden PEV adoption should target the used vehicle market more explicitly, especially through tailored messaging, incentives, and infrastructure improvements to address affordability and practicality concerns.

11. What is the Use Pattern (Miles, Charging behavior) of used PEVs?

To assess the similarities and differences between used and new PEVs, we begin by examining the Department of Motor Vehicles (DMV) dataset on light-duty vehicle (LDV) ownership patterns at the household level. For this analysis, we use the most recent DMV dataset available, which was obtained after completion of the survey and includes vehicles registered through most of 2023, including some 2024 model-year vehicles.

The dataset comprises 25.3 million vehicles which, based on registration addresses, were traced to 12.5 million registered addresses corresponding to privately owned vehicles. For the purposes of the following analysis, these addresses are used as proxies for households and are hereafter referred to as households.

The DMV dataset includes 23,988,355 internal combustion engine vehicles (ICEVs, including hybrids), 959,249 battery electric vehicles (BEVs), 335,388 plug-in hybrid electric vehicles (PHEVs), and 13,368 fuel cell electric vehicles (FCEVs).

By comparison, the most recent data published on the California Energy Commission (CEC) dashboard indicate that by the end of 2024 there were 1,453,994 BEVs and 432,000 PHEVs on the road. In addition, PEV sales in 2025 are estimated to exceed 420,000 vehicles. Based on these figures, we estimate that the total PEV population in California by the end of 2025 is approximately 2.1 million vehicles, compared with the 1.3 million vehicles represented in our analysis.

Table 13 presents the distribution of light duty vehicle ownership among California households. Approximately half of all households that own light duty vehicles own only one vehicle, while the majority of vehicles, about 19 million out of 25 million, are owned by households with multiple vehicles. The DMV dataset further indicates that by the end of 2023, 8.80 percent of households owned at least one electric vehicle. This household level share is higher than the electric vehicle share of the overall light duty vehicle population, which is 5.2 percent as shown in Table 13. This difference reflects the fact that more than half of households own more than one light duty vehicle.

Table 13 Distribution of Household LDV and PEV Ownership in the DMV Dataset.

N of LDVs in the HH/ N of PEVs in the HH	**1**	**2**	**3**	**4**	**5+**	**Total**
0	47.74%	23.85%	11.68%	5.67%	4.63%	*93.57%*
1	1.91%	1.89%	1.06%	0.52%	0.41%	*5.79%*
2		0.22%	0.17%	0.10%	0.09%	*0.58%*
3			0.02%	0.01%	0.01%	*0.04%*
4				0.00%	0.00%	*0.00%*
Total	*49.65%*	*25.96%*	*12.93%*	*6.30%*	*5.14%*	*100.0%*

Figure 26 shows that more than half of the households in the dataset own only used internal combustion engine vehicles, while 16.9 percent own only new internal combustion engine vehicles. With respect to plug in electric vehicles, 6.1 percent of households own a new PEV, 1.9 percent own a used PEV, and 0.4 percent own both new and used PEVs. Overall, the ratio of new to used ownership is much higher for ICEVs, whereas most PEVs are relatively new and are still owned by their original purchasers. As expected, Figure 27 shows that as the number of vehicles in a household increases, the probability of owning multiple ZEVs also increases—especially when the household's vehicles are newer.

Figure 24 Household Vehicle Basic Composition in the DMV Data.

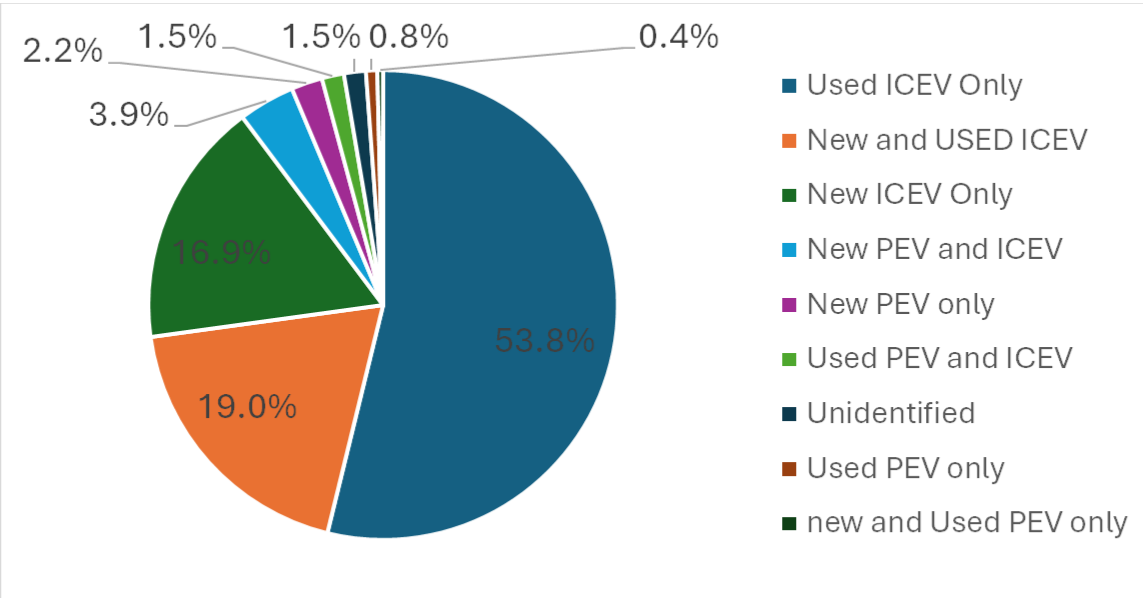
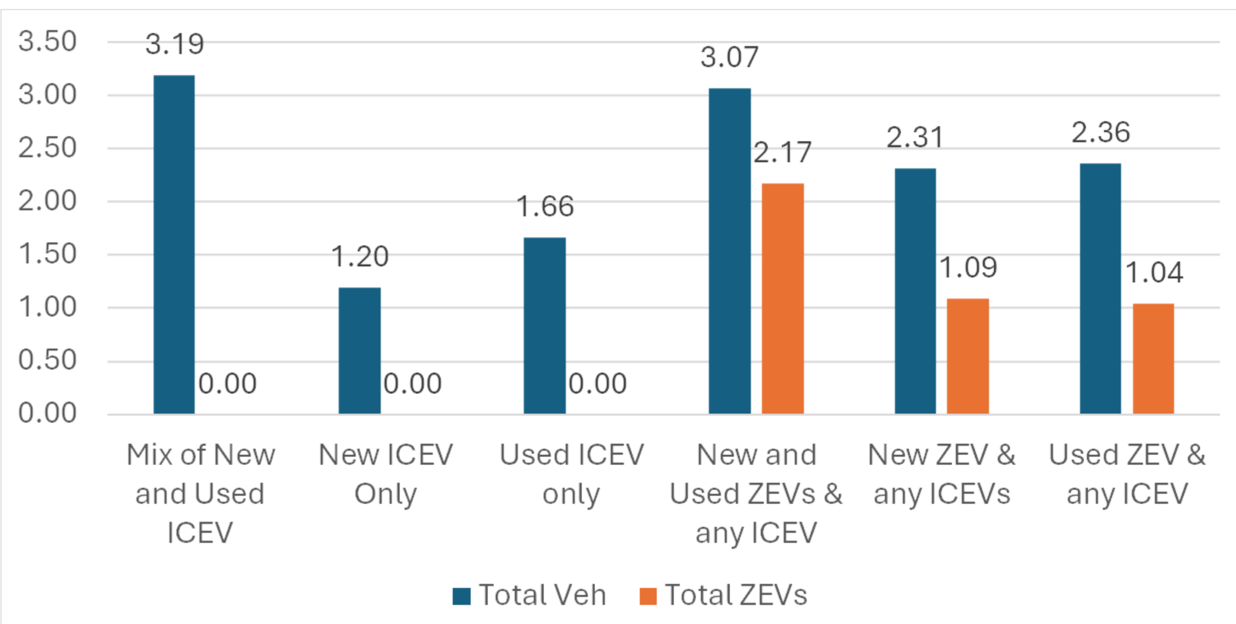


Figure 25 Household Vehicle Basic Composition in the DMV Data.



Light duty vehicle usage is usually measured as annual VMT and, although it is supposed to be a simple arithmetic calculation dividing the total miles driven by a vehicle as measured by the odometer by the time the vehicle is on the road, in reality it is very difficult to obtain reliable and relevant data. New vehicles that have only been on the road for a few months may bias annual VMT estimates, while older vehicles with many years on the road may better reflect average usage but may also capture atypical periods such as COVID 19.

Reporting of odometer readings by owners is often inaccurate, and reporting of time on the road is commonly rounded to years or model years, which may bias results for newer vehicles. In our survey, buyers of new vehicles were asked for the purchase date by month and the current odometer reading. Buyers of used vehicles were asked for the odometer reading at purchase, the current odometer reading, and the time of purchase. For vehicles purchased more than five years prior to the survey, we only collected estimated annual VMT. For all questions, we included a self-reported estimate of data accuracy in order to exclude low accuracy responses.

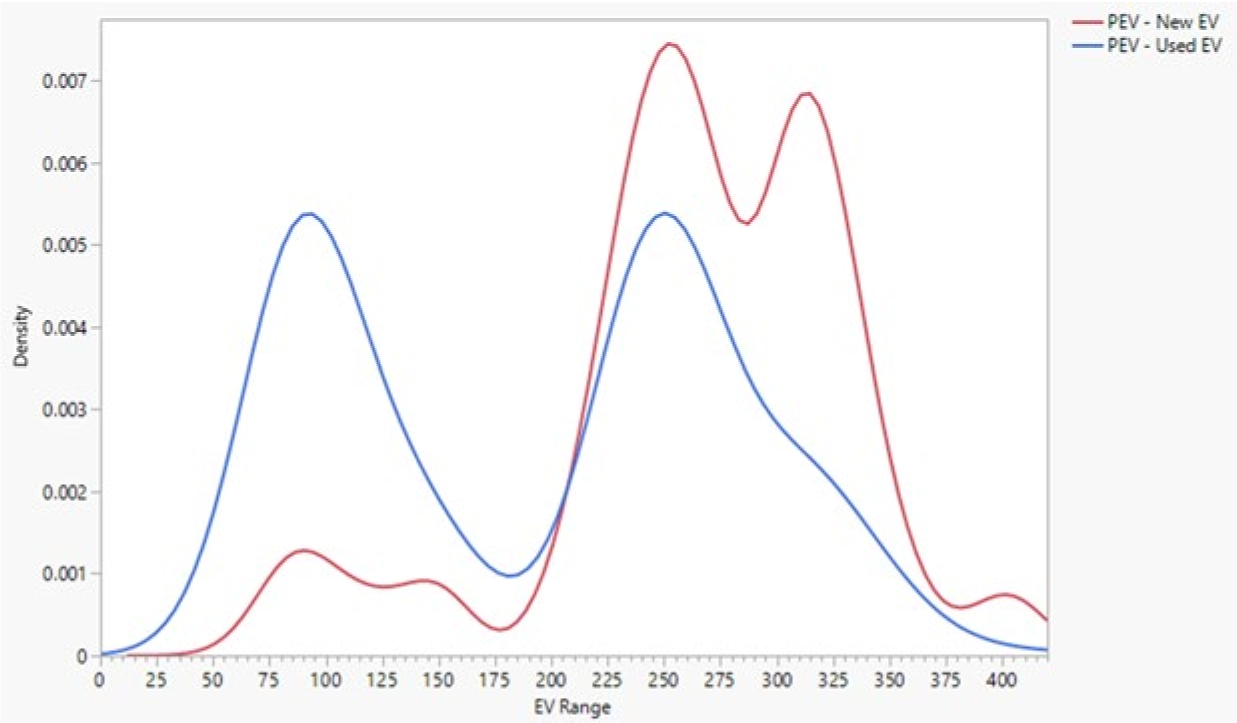
Table 14 presents annual VMT for 1854 vehicles with complete and reportedly accurate data. We observe lower VMT than reported in previous studies of 8000 to 10100 miles per year, with insignificant differences across technologies. This may partially reflect the impacts of COVID 19 and changes in driving and commuting patterns in the post COVID period.

Table 14 Annual VMT by Technology.

Level	**Number**	**Mean**	**Std Dev**
BEV	914	9626	6990
Gasoline	525	9499	7711
Hybrid	126	10095	6542
Plug-in Hybrid	289	8901	6388

We explore the charging behavior of PEVs across four main groups, new and used BEVs and new and used PHEVs, subject to sample size limitations for each question. A new PEV is defined as one owned by the original buyer and, in some cases, may be older than a used PEV. Nevertheless, Figure 28 examines the EPA range of BEVs and identifies three clear groups. BEVs with less than 100 miles of range are now mostly owned by second owners rather than original owners. BEVs with a range of 200 to 250 miles are popular among both original owners and the secondary market. BEVs with a 300-mile range are newer to the market and, at this time, are owned only by first buyers.

Figure 26 EPA range for new and used BEVs.



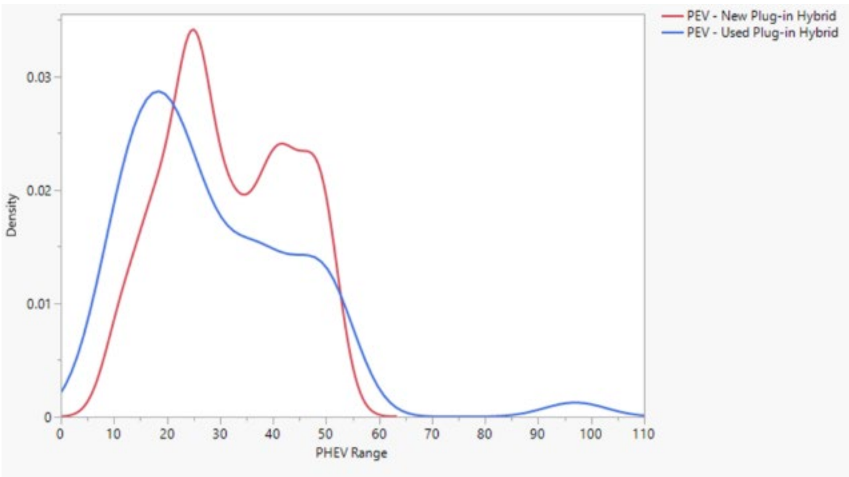
PHEVs exhibit patterns similar to BEVs but with shorter range. Most PHEVs with a 10 to 15 mile range are now owned by the secondary market, while PHEVs with a range of 20 miles or more are popular in both the first and secondary markets, with a larger share among new users for PHEVs with a 40 mile or greater range.

11.1. Short-Range PHEVs are only in the Used Market

shows EPA range for new and used PHEVs.

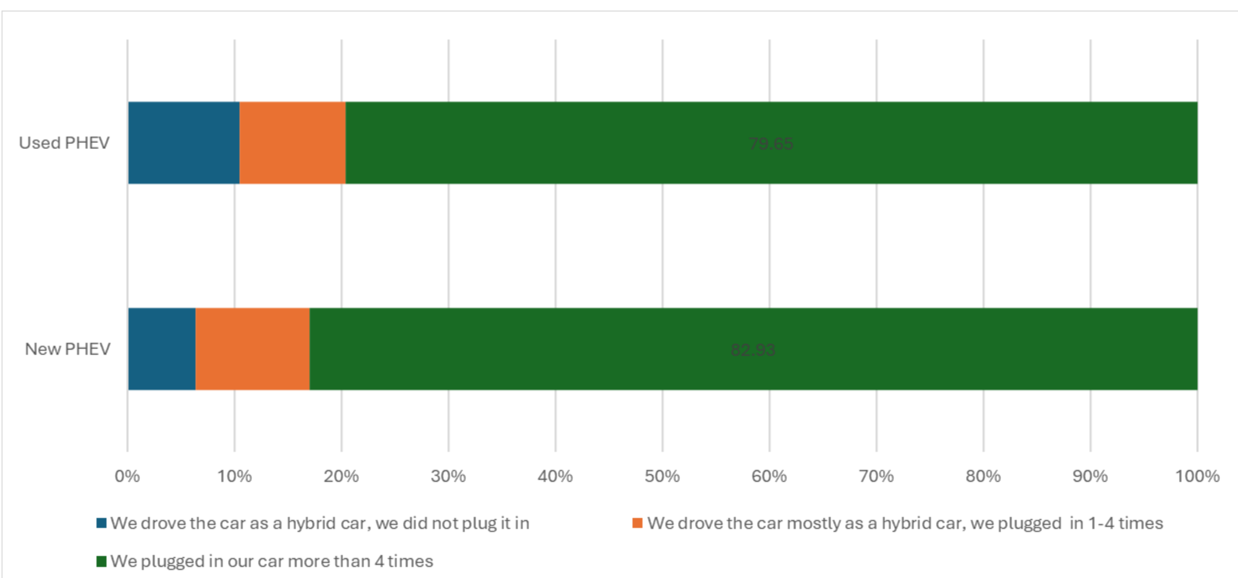
Figure 29 shows EPA range for new and used PHEVs.

Figure 27 EPA range for new and used PHEVs



Previous research by the UC Davis EV Research Center suggests that some PHEV users do not charge their vehicles and instead drive them mostly as hybrids. This behavior is correlated with not having home charging and with PHEV range. In this study, Figure 30 shows that buyers of used PHEVs charge their vehicles at a similar rate, with about 80% of used PHEV owners charging regularly compared to 83% of new PHEV owners.

Figure 28 PHEV charging behavior.



11.2. BEV Charging Behavior

Using the dataset from**Error! Reference source not found.**, we created four BEV categories, distinguishing between new and used vehicles by ownership status as first owner or subsequent owner, and between short and long range BEVs defined as having less than or more than 150 miles of range. For some analyses, we also separated Tesla's from other BEVs.

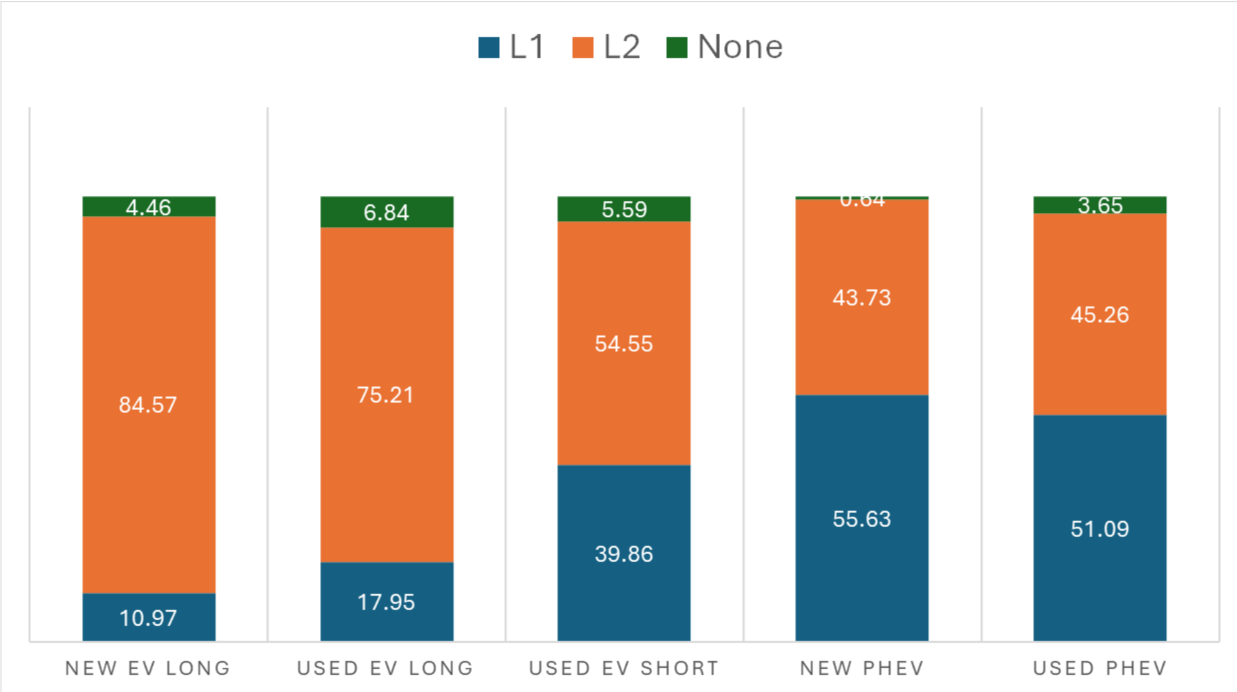
We collected three sets of data on (1) home charging behavior and the ability to charge at home, (2) fast charging using DCFC in the last 30 days, and (3) a detailed charging diary reporting charging events over the last 7 days, starting from the day the survey was completed and including the previous 6 days. The diary includes charging location such as home, work, and public locations, time of day, and charging level L1, L2, or DCFC. Similar to previous sections, we asked about the accuracy of the reporting, acknowledging that the survey respondent may not be the only user of the BEV and may therefore have incomplete information.

Out of 1948 respondents who completed the charging frequency questions, 305 respondents, or 15.7%, reported "Very Inaccurate" in response to the question "s5q8a. How accurate would you say your responses were in the previous question about when and where your {carmain} was charged for the last 7 days?" These responses were excluded from the analysis.

Home charging availability is presented in Figure 31 and is based on questions about charging at home during the last week. For users who did not charge at home at all, a follow up question asked whether they could charge at home and at what level. We report results for only five groups, as the short-range new BEV category had fewer than 20 responses and is therefore not reported.

The first important comparison is between long range new BEVs and used BEVs. Both groups primarily use L2 charging at home but used BEVs have a much larger share of respondents with no home charging availability, 6.8% compared to 4.5%, as well as a larger group of users who rely on L1 charging. Short range BEVs, which are mostly early generation Nissan Leaf models, and both new and used PHEVs also rely on L1 charging at home, but in these cases L1 charging may not be a limiting factor.

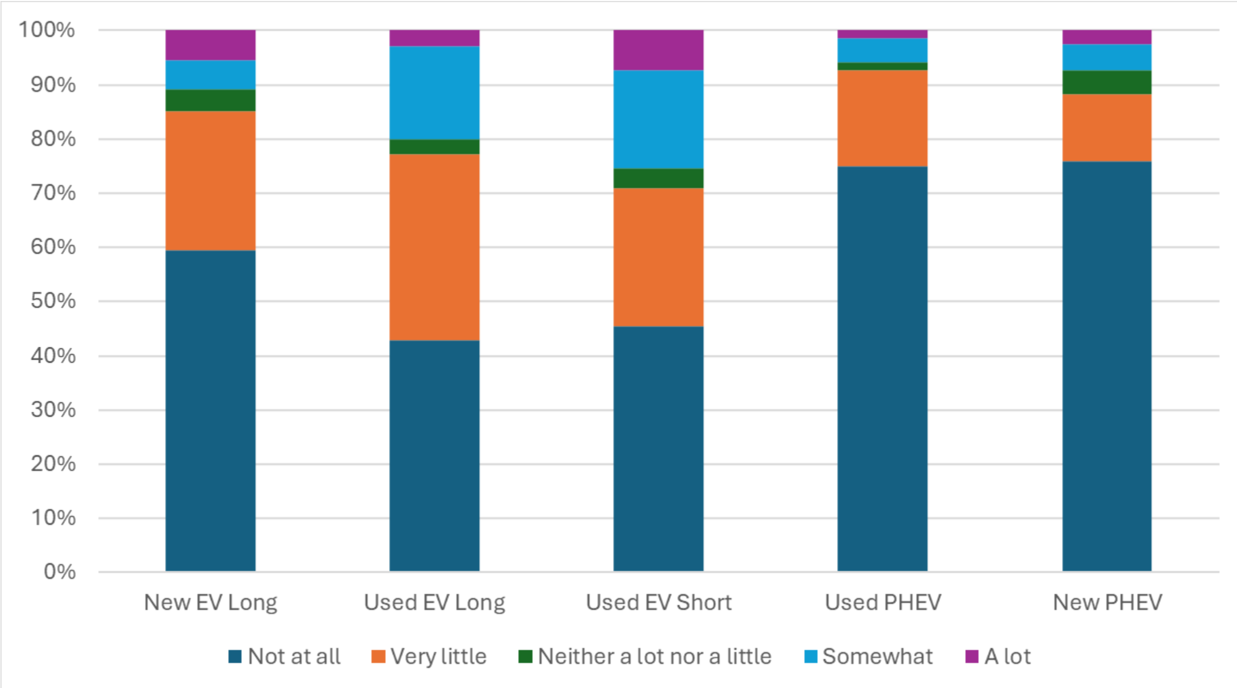
Figure 29 Home charging availability.



For PHEVs, it is interesting to note that almost all new owners reported having home charging, compared to 3.7% of used buyers who reported having no home charging. In both cases, this share is much lower than the nearly 20% who reported not charging at all, which may also reflect some users who have access to home charging but choose not to use it.

We asked the subset of respondents who have only L1 charging at home whether not having a faster L2 charger limit how much they drive their PEV. Figure 32 shows that even for PHEVs, which do not have a strict range limitation, a small share of 1% to 3% reported that not having a faster home charger limits their use, most likely because they rely on another vehicle or are trying to maintain a high utility factor.

Figure 30 Does not having a level 2 (240 V) charger at home limit how much you drive your {carmain}?

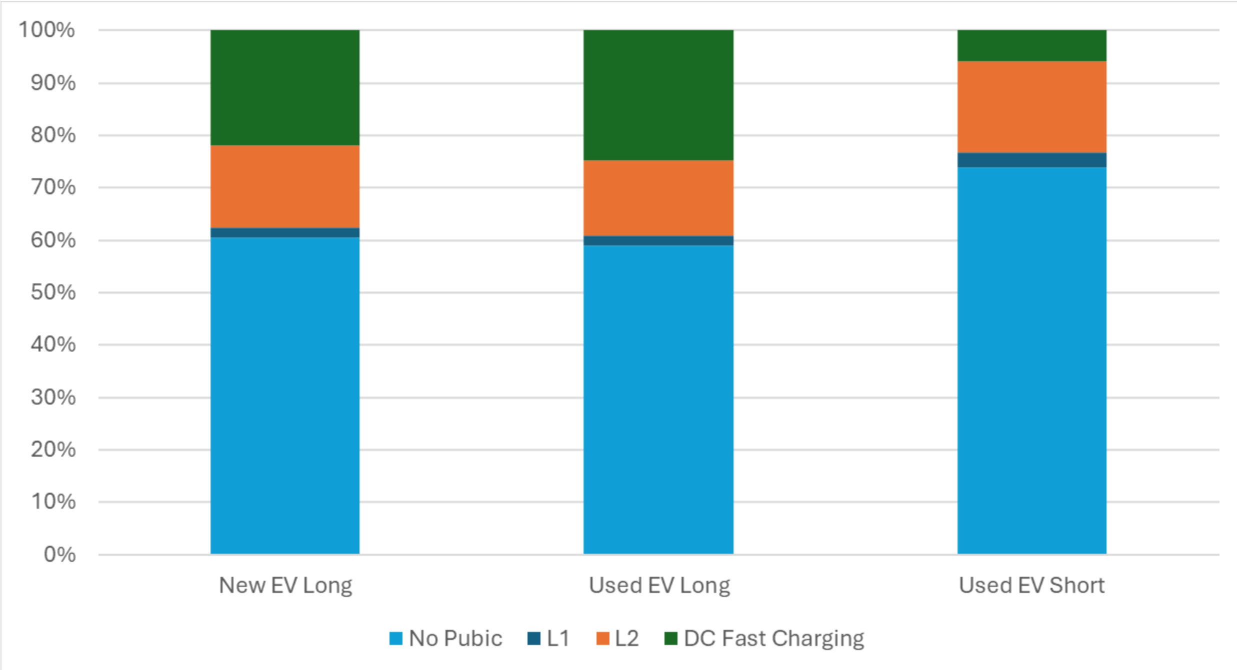


For BEVs, we observe a somewhat higher impact. Short-range used BEVs show greater limitations, and among long range BEVs, 20% of used BEV owners reported some level of limitation or higher, compared to 10% of new BEV owners.

The other side of home charging is presented in Figure 33 for BEVs only. We asked, "In the last 7 days, what level charger was used for this car away from home?" and found that 60% of long range BEVs, both new and used, charged only at home, compared to 74% of used short range BEVs who charged only at home.

About 14% to 17% of BEVs used L2 charging away from home, while 22% of new long range BEVs and 25% of used long range BEVs used DCFC at least once in the last 7 days. For used short range BEVs, which mostly rely on CHAdeMO chargers, only 6% used DCFC in the 7 days prior to the survey.

Figure 31 In the last 7 days, what level charger was used for this car away from home?



12. What is the Impact of New and Used Incentives on the Market?

We designed a survey experiment to test the effect of different incentives on the decision to purchase a PEV. The incentive was shown to all survey respondents and respondents were randomly assigned to see different levels of HOV lane access, state rebates, and federal tax credits. When respondents saw the various incentives, they were asked to consider whether they would choose a PEV or not in this scenario. The experiment includes the following incentive dimensions and levels:

- State incentive dimensions levels: $0, $1,250, $2,500, $5,000
- Federal dimension levels: $0, $3,750, $7,500, $10,000
- HOV dimension levels: Carpool Lane access (Yes), No carpool lane access (No)

Respondents are randomly shown a vignette set shown in Table 16 and asked “Thinking back to when you chose your {carmain}, if you were able to make the decision again and the following scenario applied what would you decide?”. Respondents could choose the same vehicle, a different BEV/PHEV, a gasoline vehicle, a hybrid vehicle, no vehicle, or none of these options. For this analysis, we create a binary variable for choosing a PEV or not choosing a PEV and restrict analysis to respondents who own a BEV and PHEV and control for whether respondent’s main vehicle was purchased new or used. We create a binary logistic regression model to investigate the influence of state incentives, federal incentives, and HOV lane access on the probability of choosing a PEV. The independent variable is the vehicle chosen (1=PEV 0=other) while incentive levels and whether the main car was purchased new or used are independent variables.

Table 15 shows results of the model. The results show that relative to the baseline of no HOV lane access having HOV lane access is positively related to choosing a PEV. For the state rebate, only a $5,000 rebate was positively related to choosing a PEV. For the federal EV tax credit only the $7,500 and $10,000 incentives are positively related to choosing a PEV. Whether the vehicle is used or new is not related to the decision of whether responds would or would not choose a PEV in this experiment, suggesting new and used car buyers respond similarly to PEV incentives.

Figure 34 shows the predicted probabilities of choosing a PEV for each incentive level. HOV lane access increases the probability of choosing a PEV from 0.9 with no HOV lane access to 0.94 with HOV lane access. A $5,000 state incentives increases the probability of choosing a PEV from 0.9 to 0.95. Both a $7,500 or a $10,000 federal tax credit increase the probability of choosing from 0.87 with no credit to 0.95 with the credit.

Considering a scenario where no HOV lane access, no state rebate, and no federal tax credit is available the probability of choosing a PEV is 0.79. In a scenario where HOV lane access is available, along with a $5,000 rebate, and a $7,500 or $10,000 tax credit the probability of choosing a PEV is 0.97. This suggests that the impact of there being no incentives available to encourage the purchase of a PEV would have a significant impact on PEV purchase decisions by those who have already adopter a PEV. Based on the results of this model around 21% of PEV buyers would not choose a PEV if they got neither HOV lane access, a state incentive, or a federal tax credit compared to only 3% of buyers if these incentives were available.

Table 15: Binary logistic regression results where the dependent variable is 1=choosing a PEV.

Term	Estimate	Std Error	Prob > X^2

Intercept	2.63933296	0.0979146	<.0001*
HOV[Yes]	0.32295871	0.0828203	<.0001*
State rebate[US$5,000.00]	0.40329033	0.1614793	0.0125*
State rebate[US$2,500.00]	-0.2273897	0.1316738	0.0842
State rebate[US$1,250.00]	0.08978959	0.1461593	0.5390
Federal credit[US$10,000.00]	0.32966852	0.1605187	0.0400*
Federal credit[US$7,500.00]	0.43180795	0.166613	0.0096*
Federal credit[US$3,750.00]	-0.0746189	0.1388828	0.5911
Used vehicle (1=used, 0=other)	-0.0400456	0.0872615	0.6463
Observations	2212		
Log likelihood	582.9		
R^2	0.04		

Figure 32: Mean probabilities of choosing a PEV with and without HOV lane access, for various state incentives, and various federal incentive values (*<0.1, **<0.5, ***<0.01).

Table 16: Vignette number, dimensions, and dimension levels.

Vignette	**HOV**	**State rebate**	**Federal credit**
1	Yes	$0	$0
2	No	$5,000	$3,750
3	Yes	$2,500	$7,500
4	No	$1,250	$10,000
5	No	$2,500	$10,000

6	Yes	$5,000	$0
7	No	$1,250	$3,750
8	Yes	$0	$7,500
9	No	$0	$0
10	Yes	$2,500	$3,750
11	No	$5,000	$7,500
12	Yes	$1,250	$10,000
13	No	$5,000	$10,000
14	Yes	$1,250	$0
15	No	$0	$3,750
16	No	$2,500	$3,750
17	Yes	$1,250	$7,500
18	Yes	$2,500	$10,000
19	No	$0	$7,500
20	Yes	$0	$10,000
21	No	$5,000	$0
22	Yes	$2,500	$0
23	Yes	$5,000	$3,750
24	No	$1,250	$7,500
25	Yes	$0	$3,750
26	No	$2,500	$0
27	Yes	$5,000	$10,000
28	No	$2,500	$7,500
29	No	$1,250	$0
30	Yes	$5,000	$7,500
31	Yes	$1,250	$3,750
32	No	$0	$10,000

13. How many Cars Leave California and Where To?

13.1. Introduction

To examine the effect of state-level incentives for new PEVs on the volume of used PEVs imported from California, we combine descriptive spatial analysis with a fixed-effects panel regression framework, using annual state-level data from 2016 to 2023. The descriptive component of the analysis uses state-level vehicle registration data to map variation in total LDV fleet size, PEV adoption rates, and the share of each state's PEV fleet that originated in California. This spatial variation helps establish key patterns in market size, adoption trends, and regional dependence on California as a source of used EVs.

13.2. Econometric Strategy

To formally estimate the relationship between new PEV incentives and the volume of used PEVs imported from California, we employ two econometric strategies using state-year panel data from 2016 to 2023. Our dependent variable is the natural logarithm of the number of used PEVs registered in each state-year that were originally registered in California, based on vehicle registration data from S&P Global.

We begin with a set of cross-sectional regressions estimated separately for each year. This year-by-year approach allows us to explore how the association between new vehicle incentives and used PEV imports evolved over time. Each annual model takes the following form:

$$\ln(UsedPEVs_s) = \beta_0 + \beta_1 \cdot IncentiveDummy_s + \mathrm{X}_s \cdot \beta + \varepsilon_s$$

where s indexes states; $IncentiveDummy_s$ is a binary variable equal to 1 if the state offered a financial incentive for new PEV purchases in that year; X_s includes controls such as total LDV fleet size, ZEV sales, state population, per capita income, and share of commuters; and ε_s is an error term.

We then estimate a two-way fixed-effects panel model pooling all eight years, which allows us to control for unobserved state-level heterogeneity and general national shocks:

$$\ln(UsedPEVs_{st}) = \beta_0 + \beta_1 \cdot IncentiveDummy_{st} + \mathrm{X}_{st} \cdot \beta + \gamma_t + \alpha_s + \varepsilon_{st}$$

where s indexes states, t indexes years (2016-2023), γ_t are year fixed effects, α_s are state fixed effects, and ε_{st} is the error term clustered at the state level. X_{st} again, includes time-varying controls for LDV fleet size, population, income, and ZEV sales.

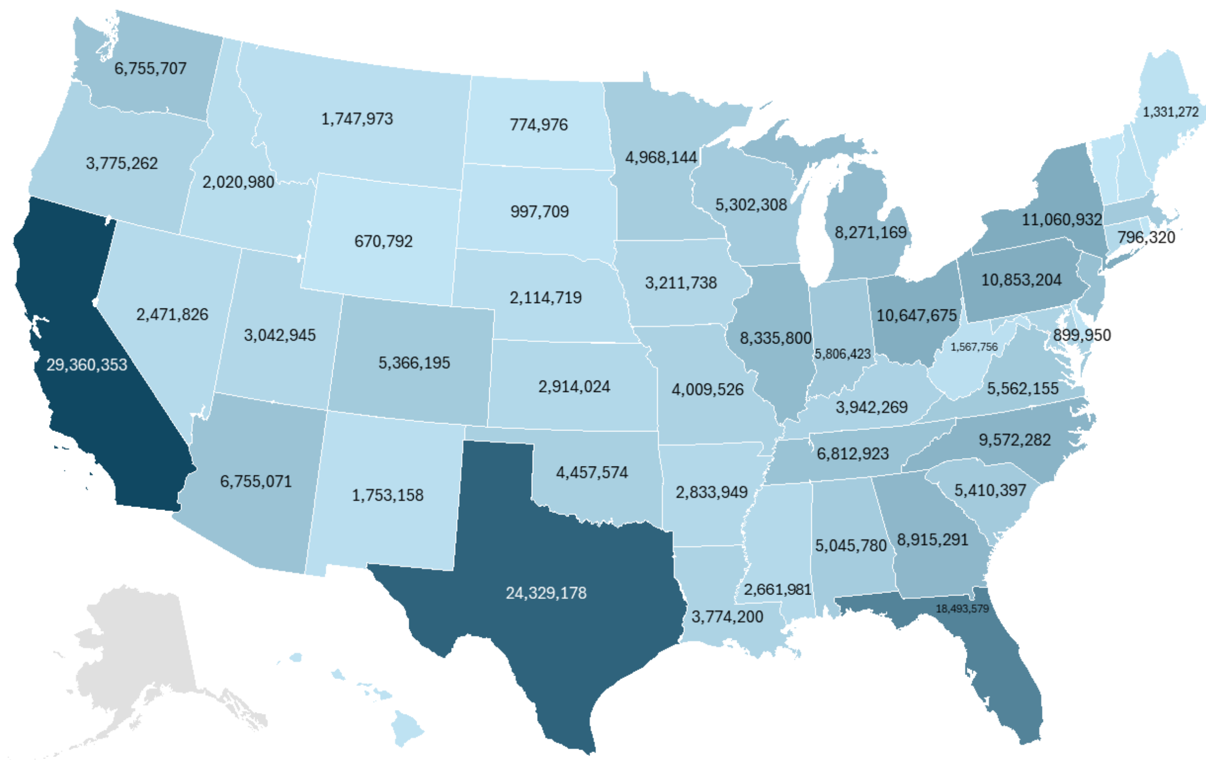
The key independent variable of interest, $IncentiveDummy_{st}$, is constructed using state-level policy data from the US Department of Energy's Alternative Fuels Data Center (AFDC) Laws and Incentives database (See subsection 4.5.4. for further details). All models include robust standard errors clustered at the state level. The year-by-year regressions provide insight into annual dynamics, while the fixed-effects model leverages panel variation to identify broader patterns.

13.3. Results

13.3.1. Descriptive Analysis

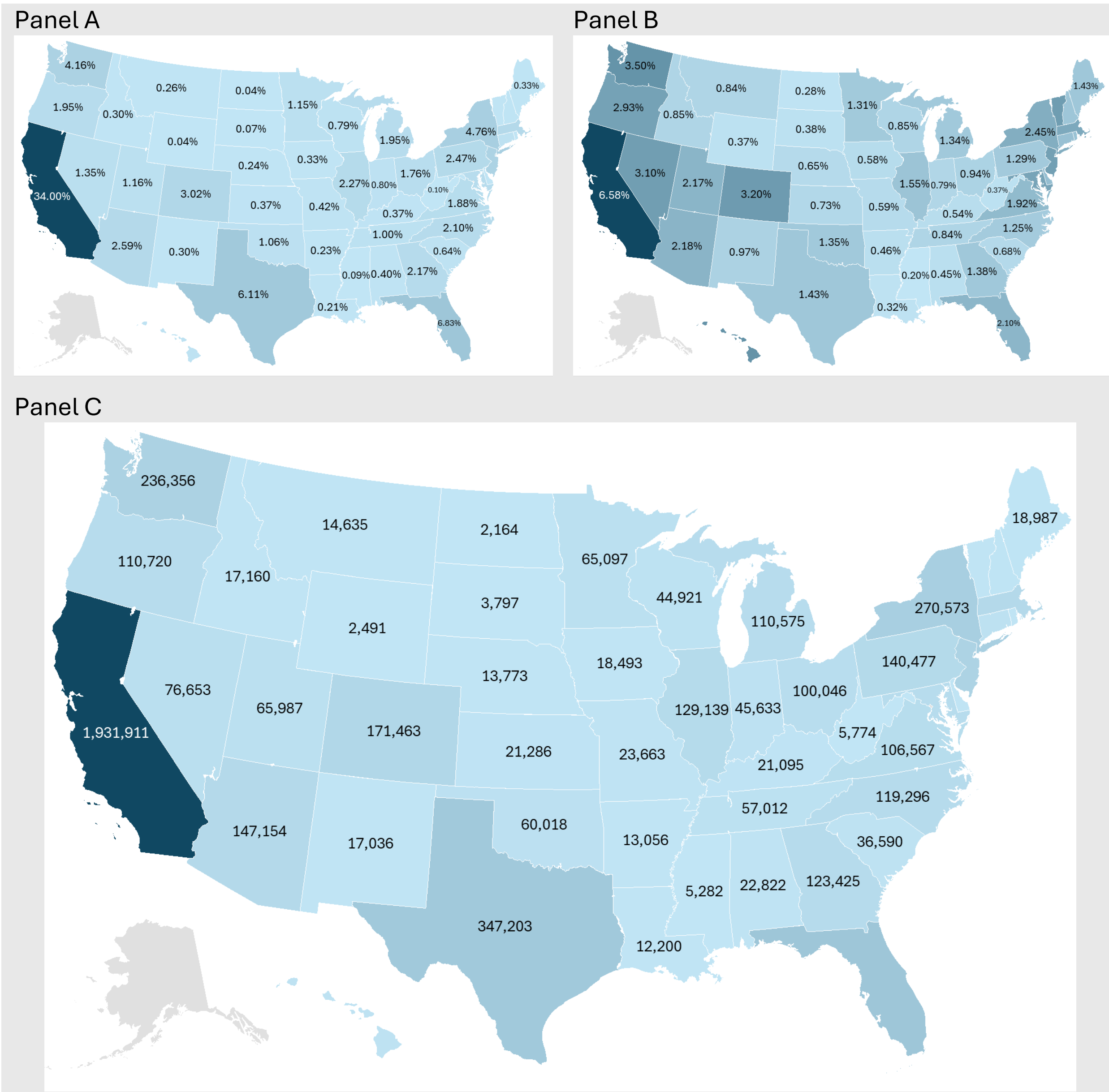
State-level differences in the size and composition of vehicle fleets provide important context for understanding the dynamics of used EV imports. California stands out across all metrics, but its influence plays out differently depending on the measure. Total LDV fleet size varies widely across states (Figure 35). The largest fleets are concentrated in California (29.4 million), Texas (24.3 million), and Florida (18.5 million), reflecting both population and car ownership patterns. Most other states have significantly smaller fleets, with many in the Mountain West and New England under 5 million vehicles. This variation sets the stage for differences in both PEV adoption and market capacity to absorb used vehicles.

Figure 33 Total LDV Fleet by State.



When considering contributions to the national PEV stock, California dominates with 34% of all US PEVs (Figure 36, 18A). No other state contributes more than 7%, and most states remain well below 3%. This imbalance underlines California's unique role as the leading adopter of PEVs and the primary source of vehicles entering the secondary market. Looking at PEV adoption relative to each state's own fleet (Figure 36, 18B), California is again in the lead, with PEVs making up 6.6% of all LDVs. A few Western states – Colorado, Oregon, Arizona, and Washington – also show relatively high penetration rates, in the range of 2-3%. In contrast, much of the central and southeastern US lags behind, with PEVs accounting for less than 1% of the fleet. In terms of absolute PEV counts (Figure 36, 18C), California again leads with nearly 2 million vehicles, followed by states like Texas (347k), Florida (123k), and Washington (236k). This reflects that California not only functions as the nation's primary early adopter of PEV technology but also becomes the largest generator of used PEV supply as first-owner vehicles begin to turn over.

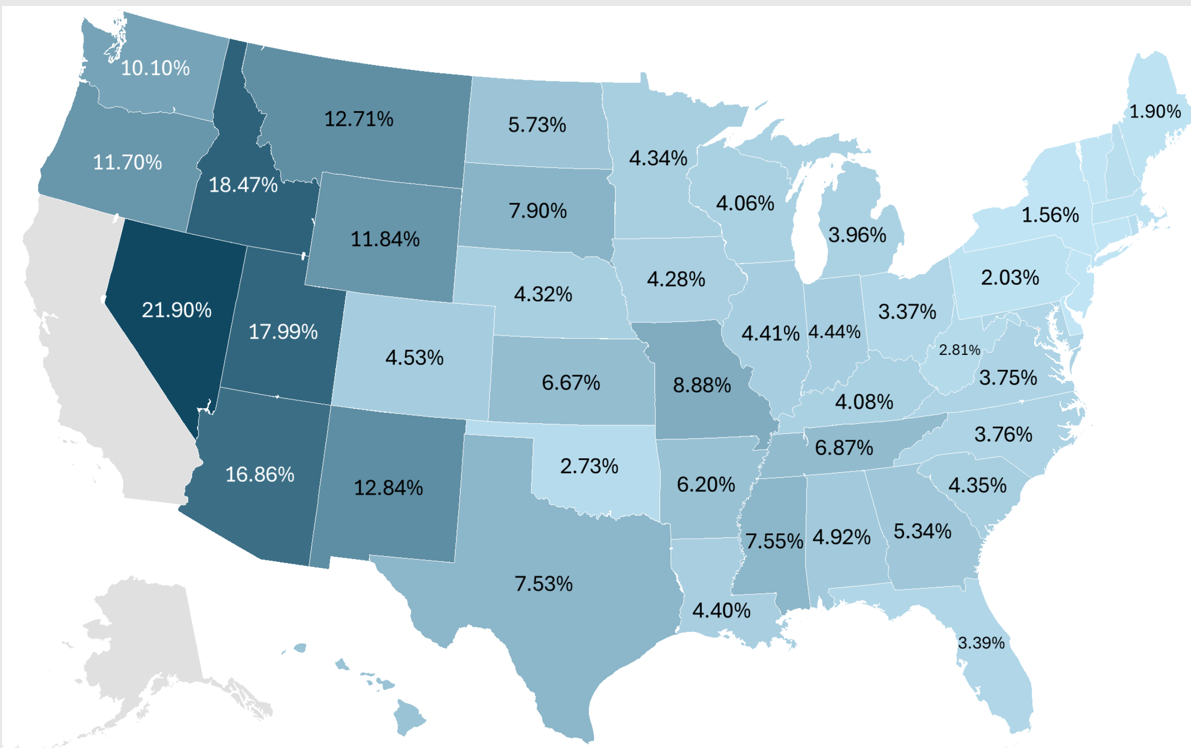
Figure 34 PEV Fleet Size Across States. Panel A: Share of PEVs as a percentage of each state's LDV fleet. Panel B: Each state's contribution to the total US PEV fleet. Panel C: Total number of registered PEVs by state.



Finally, the share of each state's PEV fleet that originated in California reveals meaningful variation (Figure 37). Neighboring states import a disproportionate share of their used EVs from California: 22% in Nevada, 17% in Arizona, and 12% in Oregon. However, these percentages can be misleading in isolation. For example, North Dakota and Texas show similar shares of imports from California (~5-7%), but in absolute terms this translates to over 26k vehicles in Texas and fewer than

150 in North Dakota. A particularly illustrative case is the comparison between Oregon and Nevada. Both have similar sizes of PEV fleets, but Nevada has a much higher share of California-origin vehicles. One plausible explanation is policy: Oregon offers state-level incentives for new EV purchases, while Nevada does not. This suggests that stronger local incentives may suppress demand for used EVs, especially those imported from out of state, a hypothesis explored further in the econometric section below.

Figure 35 Share of PEVs Imported from California.



13.3.2. Econometric Analysis

To examine whether state-level incentives for new EV purchases affect the volume of used EVs imported from California, we estimate a series of regression models using annual state-level panel data spanning 2016 to 2023. All models include a consistent set of 49 states, excluding California itself. The dependent variable in all models is the natural logarithm of the number of used PEVs in each state that were originally registered in California. This specification allows for interpreting coefficients as elasticities or semi-elasticities depending on the functional form of the independent variables.

We begin with a set of year-specific cross-sectional regressions (Table 17, where each column represents a separate regression for a given year. The results reveal a consistent and growing negative relationship between the presence of new PEV purchase incentives and used EV imports from California. This relationship becomes statistically significant starting in 2018 and remains so through 2023, with the magnitude of the effect increasing over time. These results suggest that while such incentives aim to promote new EV adoption, they may also suppress demand for used EVs by increasing the attractiveness and affordability of new models.

In terms of other covariates, the size of the total LDV fleet in a state (measured in millions) is significant and positively associated with used EV imports across all years, indicating that larger vehicle markets absorb more imported EVs. State population, on the other hand, does not appear to be a strong predictor once fleet size is controlled for. Interestingly, per capita income becomes a significant positive predictor of used EV imports only in the later years of the sample. This may reflect a maturing used EV market that increasingly caters to higher-income households, in contrast to the traditional role of used ICE vehicles as an entry-level option for lower-income buyers.

Geographic proximity to California remains a strong and consistent predictor throughout. States that are further away from California (Tiers 3 and 4) import significantly fewer used EVs, highlighting the importance of physical and logistical constraints in shaping interstate vehicle flows. The R-squared values in these yearly regressions are relatively high, ranging from 0.793 to 0.855, indicating that the models explain a substantial share of the variation in used EV imports at the state level.

Table 17 Annual Regression Results Explaining Imports of Used EVs from California (2016-2023).

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
DV: ln(PEVs from California)	2016	2017	2018	2019	2020	2021	2022	2023
New PEV incentive	-0.00326	-0.372	-0.645*	-0.467**	-0.576**	-0.706***	-0.752***	-0.712**
(dummy)	(0.294)	(0.316)	(0.337)	(0.224)	(0.226)	(0.247)	(0.265)	(0.315)
New ZEV Sales	0.317**	0.275**	0.155*	0.133***	0.0560	-0.00147	0.000978	0.00659
(Thousands)	(0.153)	(0.132)	(0.0835)	(0.0488)	(0.0498)	(0.0267)	(0.0157)	(0.0127)
Total LDV Fleet Size	0.386**	0.599***	0.473***	0.471***	0.402***	0.338***	0.325**	0.306**
(Millions)	(0.156)	(0.173)	(0.174)	(0.130)	(0.130)	(0.118)	(0.123)	(0.123)
State Population	-0.216	-0.356**	-0.257	-0.263**	-0.196	-0.104	-0.109	-0.122
(Millions)	(0.131)	(0.155)	(0.154)	(0.112)	(0.119)	(0.108)	(0.0952)	(0.110)
Commute Share (%)	-3.826	6.467	5.882	1.290	-6.145	-7.892	-11.74*	-12.56*
	(6.171)	(6.812)	(7.592)	(5.849)	(5.701)	(6.044)	(5.960)	(6.655)
ln(Per Capita Income)	1.474	0.0329	0.222	0.631	3.036**	3.479***	3.884***	3.962***
	(1.491)	(1.725)	(1.901)	(1.420)	(1.291)	(1.263)	(1.229)	(1.390)
Proximity to California:								
Tier 2	-0.711	-1.072*	-1.211*	-0.694	-0.425	-0.735	-0.717	-0.733
	(0.517)	(0.589)	(0.626)	(0.460)	(0.447)	(0.473)	(0.473)	(0.509)
Tier 3	-2.288***	-2.889***	-2.768***	-2.249***	-2.216***	-2.158***	-1.991***	-2.072***
	(0.577)	(0.613)	(0.655)	(0.511)	(0.488)	(0.518)	(0.527)	(0.567)
Tier 4	-2.433***	-3.170***	-2.963***	-2.526***	-2.397***	-2.470***	-2.404***	-2.346***
	(0.462)	(0.513)	(0.553)	(0.403)	(0.385)	(0.410)	(0.419)	(0.437)
Constant	-8.411	2.347	0.912	-1.081	-22.74*	-26.09**	-29.25**	-29.90**
	(13.18)	(15.42)	(16.96)	(12.67)	(11.68)	(11.54)	(11.55)	(13.26)
Observations	49	49	49	49	49	49	49	49
R-squared	0.808	0.816	0.793	0.855	0.851	0.829	0.833	0.815
Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1								

To validate these patterns in a multiyear setting and account for unobserved heterogeneity across states, we estimate a fixed-effects panel model using the full 2016-2023 data (Table 18). This model includes year fixed effects to account for nationwide trends and unobserved time-varying factors. The results strengthen the pattern observed in the year-by-year regressions: the presence of a new PEV incentive is associated with a statistically significant reduction in used EV imports from California. Other covariates, including the size of the LDV fleet and per capita income, maintain their expected signs, though not all coefficients are statistically significant in the panel model. The year fixed effects are not presented in the table, but they show a clear upward trend from 2017 to 2023, indicating a steady increase in used EV imports from California over time. Overall, these findings suggest that while state-level incentives can boost new EV adoption, they may also have the unintended effect of reducing demand for used EVs, potentially by shifting the attention of prospective buyers toward subsidized new models.

Table 18 Effect of New PEV Incentives on Used PEV Imports from California.

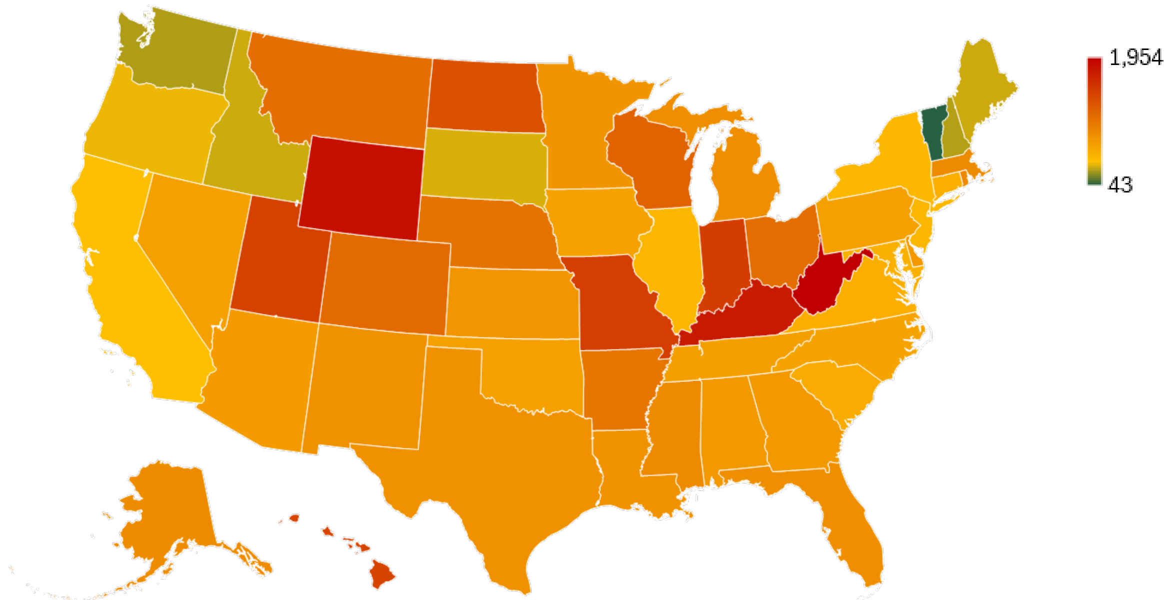
DV: ln(PEVs from California)	**Coefficient Estimates**
New PEV incentive (dummy)	-0.146**
	(0.0621)
New ZEV Sales (Thousands)	0.000271
	(0.00183)
Total LDV Fleet Size (Millions)	0.251
	(0.155)
State Population (Millions)	-0.337
	(0.228)
ln(Per Capita Income)	-1.376
	(1.301)
Year FE	✓
Constant	18.85
	(13.35)
Observations	392
Number of states	49
R-squared	0.871

Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1

13.4. Potential Environmental Implications

Beyond market outcomes, interstate transfers of used EVs from California also raise questions about their potential environmental implications. Because the emissions benefits of EV use depend on the carbon intensity of electricity generation, relocating EVs across states can alter the realized emissions impacts of California's original EV incentive programs. Figure 38 illustrates substantial heterogeneity in grid carbon intensity across US states, measured as annual CO_2 emissions per MWh of electricity generated. While California is among the cleaner grids nationally, many recipient states (particularly in the Midwest and parts of the South) rely more heavily on fossil fuel-based generation and therefore exhibit significantly higher emissions rates.

Figure 36 State Annual CO_2 Total Output Emission Rate (lb/MWh).



To summarize where exported PEVs are ultimately operated relative to California's grid, we construct a weighted relative grid-intensity index, defined as:

$$\text{Relative Intensity Index} = \frac{\sum_s E_s r_s}{\sum_s E_s}$$

where E_s is the number of used PEVs imported from California into state s, and r_s is that state's grid emissions intensity relative to California. Values above one indicate dirtier grids than California, while values below one indicate cleaner grids. Applying this metric to observed interstate flows yields an average relative intensity of 1.79, implying that, on average, exported PEVs from California are operated in states with grid emissions approximately 79% higher than California's.

This finding suggests that, from a grid-emissions perspective, the realized emissions benefits of some California-subsidized EVs may be lower once those vehicles leave the state. At the same time, it should be noted that this calculation is not a full accounting of net emissions impacts. The true climate effect depends on the vehicles these used PEVs replace in destination states, as well as on the counterfactual vehicles that would have been driven in California had the PEVs remained in-state. Because gasoline vehicles displaced in other states may be dirtier than those displaced in California, the net effect is theoretically ambiguous.

A full assessment of environmental impacts would therefore require modeling vehicle replacement patterns and usage in both origin and destination states. We view this analysis as a first-order diagnostic and as motivation for future work that explicitly links vehicle movements, grid emissions, and replacement behavior.

13.5. Discussion

The results presented in Section 3 offer important insights into how new PEV purchase incentives affect the geographic distribution of used PEVs, particularly the outflow from California to other US states. The year-by-year regression results show a growing and statistically significant relationship between the presence of new vehicle incentives and the number of used PEVs imported from California. This relationship strengthens in more recent years, suggesting an increasing role of secondary markets as the PEV stock matures. The panel fixed-effects models further reinforce this finding, indicating that the presence of new PEV incentives is negatively correlated with used PEV imports from California.

From a policy standpoint, this highlights a crucial spillover mechanism: incentives for new PEVs not only shape local adoption but also indirectly increase the pool of used PEVs that may eventually be sold out-of-state. This dynamic can lead to unintended consequences. For example, states like California, which have heavily subsidized PEV adoption, may not fully retain the environmental and economic benefits of those subsidies if the subsidized vehicles are later relocated to states that offered no such support. This raises important efficiency questions. Should neighboring states that benefit from the used PEV inflows co-invest in upstream subsidies? Should originating states design policies that encourage the local retention of used PEVs, especially among low-income buyers?

Programs such as California's Clean Cars 4 All, which offers financial support to low-income households purchasing used PEVs, provide one avenue to reduce this outflow and align considerations of local social equity with environmental policy. Still, from a national or even global perspective, the redistribution of used PEVs can be viewed positively: it supports broader diffusion of clean vehicle technology and provides more affordable entry points for PEV adoption in areas where new PEV purchases remain limited. As Tal et al. (2021) observe, used PEVs are less spatially concentrated than new ones and may serve as an instrument for technology spillovers into underserved markets (Tal et al., 2021).

An additional layer of complexity arises when considering the emissions implications of these cross-state flows. If used PEVs move from states with cleaner electricity grids (e.g., California) to those with higher carbon intensity, the emissions savings per mile decline, reducing the climate cost-effectiveness of the original incentive. This phenomenon may reduce the net environmental benefits of localized PEV subsidy programs and highlights the need for national-level coordination in transportation decarbonization.

Taken together, our findings emphasize the importance of considering the spatial dynamics of PEVs when designing incentive programs. Policies that target only new vehicle purchases may inadvertently reshape the used market in ways that might be economically suboptimal.

13.5.1. Conclusions

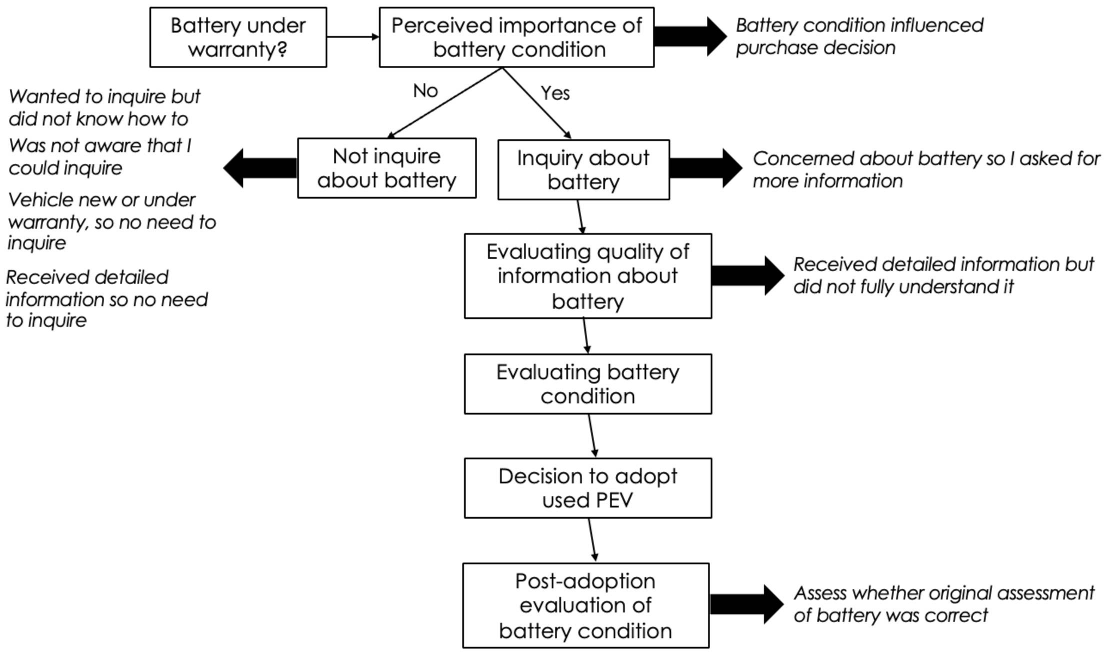
This analysis provides new evidence on the link between new PEV purchase incentives and interstate flows of used EVs. By examining panel data on used PEV imports from California between 2016 and 2023, we find that the presence of state-level incentives for new PEVs are associated with higher volumes of used PEV inflows. These results hold across model specifications and highlight the indirect, spatially diffuse effects of supply-side policies targeted at the new vehicle market.

From a policy standpoint, these findings emphasize the need for coordination in PEV policy design. Subsidies in one jurisdiction may stimulate adoption elsewhere by expanding the pool of available used vehicles – an outcome that is desirable from a national technology diffusion perspective but potentially suboptimal from the viewpoint of the subsidizing state. If policymakers aim to maximize local benefits, they may consider complementary policies to retain subsidized vehicles in-state or target secondary-market buyers more directly. Furthermore, the environmental efficacy of PEV subsidies is not uniform: relocation of vehicles to states with higher grid emissions intensity can erode the climate benefits of the policy. Addressing this issue may require aligning subsidy programs with grid decarbonization efforts or encouraging relocation to cleaner-grid regions.

14. Battery Condition and Used PEV Adoption

The battery condition of a used PEV can be considered a bottleneck to used PEV adoption given the importance of the battery condition for battery health and longevity. To provide a conceptual representation of the relationships between the perceived importance of battery condition and used PEV adoption, we developed a preliminary conceptual framework, as shown by Figure 39.

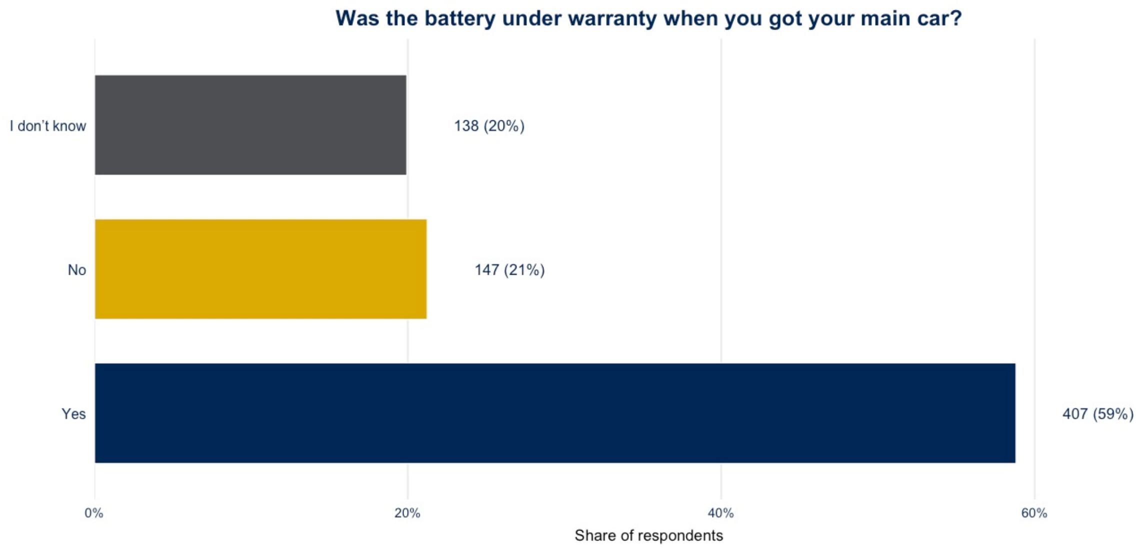
Figure 37 Relationship between assessment of battery condition and used PEV adoption.



Here we assume that the perceived importance of the battery condition triggers consumer's need to inquire about the battery condition. This is a function of whether the battery is under warranty, which is determined by factors, such as car mileage, age, climate, or drivers' charging habits, among other factors. The framework also assumes that even though they consider the battery condition important, they may not inquire about the battery condition, possibly because they do not know how they could inquire about it. It is also plausible that they were not aware of the role of the battery in used PEVs, and therefore did not inquire about it. Once consumers decide to inquire about the battery condition, they can consult different sources of information, such as asking the seller, receiving a battery report from vehicle manufacturers or independent battery testers. In the next stage, they evaluate the quality of the information about the battery condition, followed by the evaluation of the battery condition itself. If the battery condition is aligned with their expectations, they are more likely to make the decision to purchase a used PEV. After the vehicle purchase, consumers can then make a post-purchase evaluation of the battery condition. The following sections are organized around this framework.

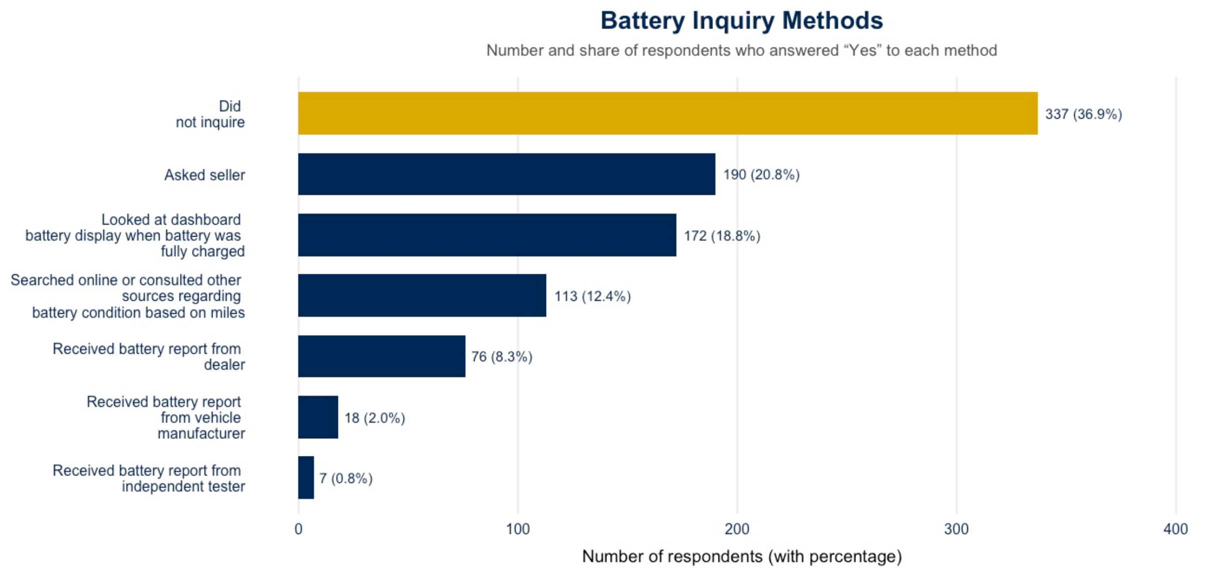
Almost 60% of respondents reported that their battery was under warranty when they acquired it, followed by around of 20% of respondents selecting the response options 'No' and 'I don't know', respectively, as shown by Figure 40. This may suggest that warranty coverage may play a significant role in consumers' confidence when acquiring a vehicle.

Figure 38 Battery under warranty at acquisition.



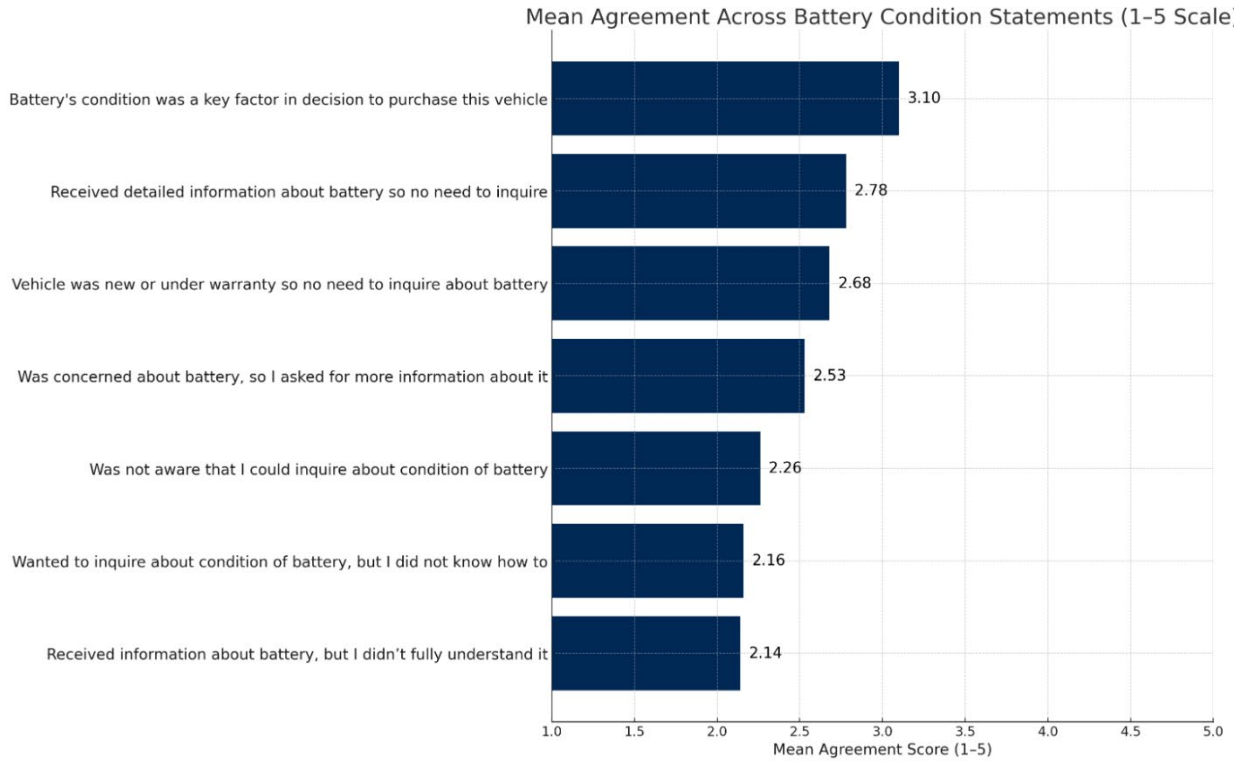
We also analyzed the various ways or methods respondents use to inquire about the battery condition. As shown by Figure 41, more than a third of respondents who answered this question indicated to not inquire about the battery condition, followed by respondents who indicated to ask a seller, looking at the dashboard battery display when the battery was fully charged, and searching online or consulting other sources regarding the battery condition based on miles. The least common inquiry methods are receiving a battery report from an independent tester, followed by receiving a battery report from a vehicle manufacturer. These results suggest that a substantial portion of consumers make purchase decisions without actively verifying the battery's condition, which may increase their exposure to uncertainty or unexpected ownership costs. The fact that many rely primarily on sellers or simple dashboard indicators indicates a dependence on easily accessible - but potentially incomplete and unreliable - information sources. Meanwhile, the low use of independent battery testing or manufacturer-provided reports suggests that more reliable verification channels are either not readily available or not well understood by buyers. Overall, these findings highlight a gap in consumer knowledge and access to standardized battery health information, which could be addressed through improved transparency and education.

Figure 39 Battery inquiry methods.



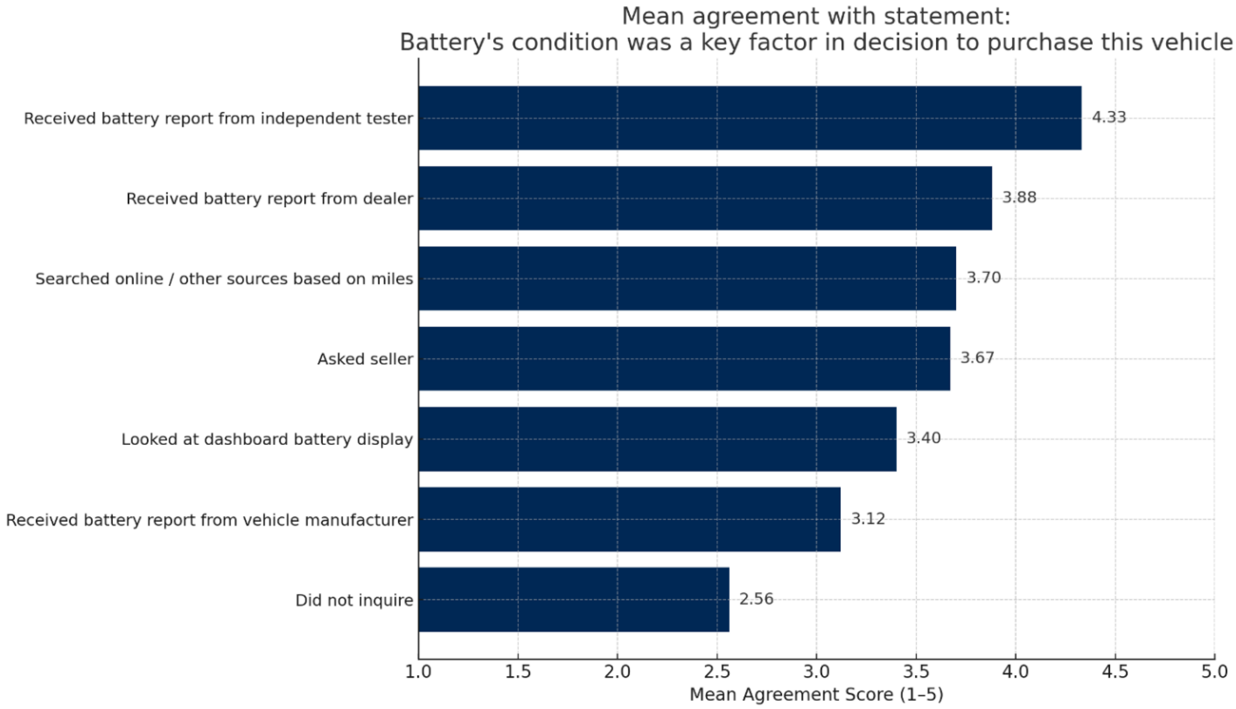
Moreover, we analyzed various statement on the battery condition in used PEVs (see Figure 42). We obtained the strongest agreement for the statement that the battery's condition was a key factor in respondents' vehicle purchase decision (M=3.10, 1=strongly disagree, 5=strongly agree). The second-strongest mean rating was obtained for receiving detailed information about the battery so that there was no need to inquire about it (M= 2.78, 1=strongly disagree, 5=strongly agree), followed by agreement with the statement that the 'Vehicle was new or under warranty so there was no need to inquire about it" (M=2.68, 1=strongly disagree, 5=strongly agree). The lowest mean rating was obtained for receiving information about the battery, but not fully understanding it (M=2.14), implying that confusion or lack of comprehension is less common than simply not seeking additional details. These results suggest that the battery's condition remains a central determinant in used PEV purchase decisions, highlighting the importance of policies that ensure transparent and standardized reporting of battery health. The moderate agreement with statements about receiving sufficient information - either through detailed reports or warranty coverage - indicates that clear and accessible battery documentation can meaningfully reduce the need for additional inquiries. For practitioners, this underscores the value of providing high-quality, user-friendly battery information at the point of sale to enhance consumer confidence. The relatively low agreement with not understanding the information implies that comprehension is less of a barrier than availability, suggesting that efforts should prioritize making battery data more consistently provided rather than substantially simplified. Overall, the findings support policies that promote uniform disclosure standards and encourage dealers and manufacturers to proactively share verified battery condition information.

Figure 40 Mean agreement with statements on battery condition measured on a scale from strongly disagree (1) to strongly agree (5).



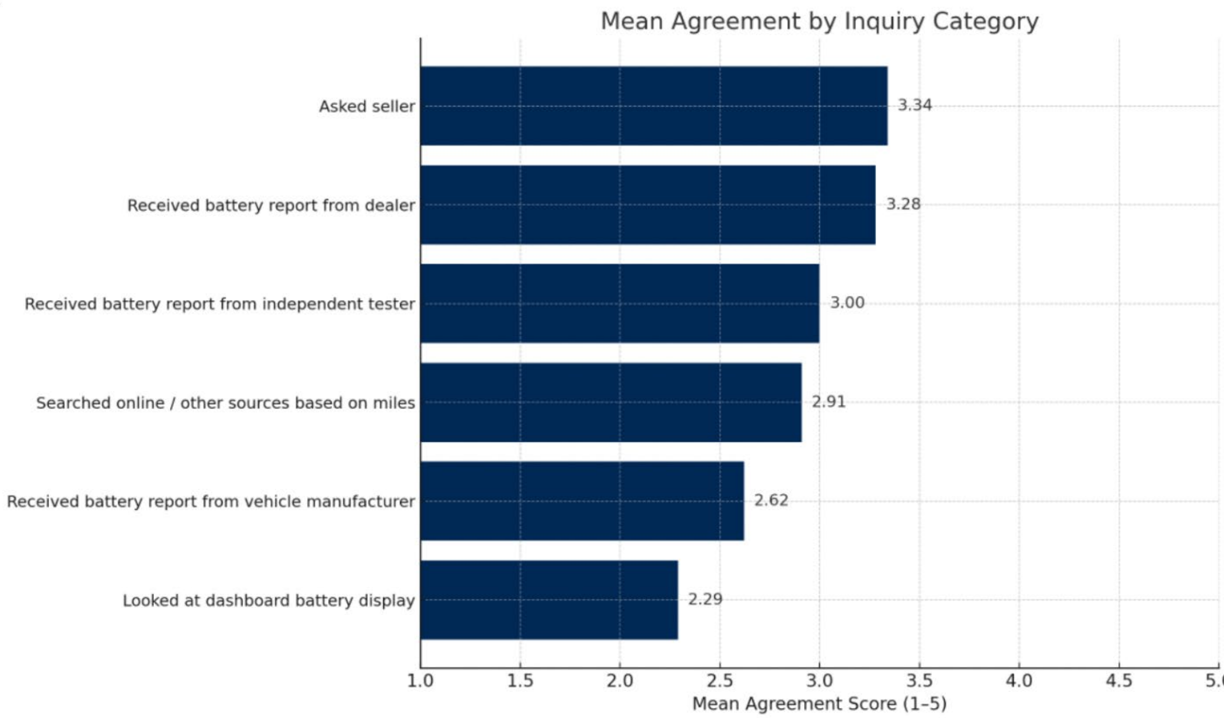
We then performed crosstabulation analyses, crossing these attitudinal questions with the inquiry methods. As shown by Figure 43, respondents who agreed most strongly with the statement that the battery was a key factor in their vehicle's purchase decision were more likely to receive a battery report from an independent tester, followed by receiving a battery report from the dealer, and searching online or consulting other sources based on miles. Those respondents who provided the lowest agreement with this statement were more likely to indicate they did not inquire about the battery condition, followed by receiving a battery report from the vehicle manufacturer. These findings suggest that respondents who view the battery as a crucial factor in their purchase decision tend to engage in more proactive and reliable methods of verification, such as obtaining an independent battery report or seeking detailed information from a dealer or online sources. This pattern indicates a stronger motivation to reduce uncertainty and ensure the vehicle meets their expectations. In contrast, those who place less importance on the battery's condition are more likely to skip inquiries altogether or rely primarily on manufacturer-provided reports, which may reflect higher trust, lower awareness, or reduced perceived risk. Overall, the results highlight meaningful differences in consumer behavior: Individuals who prioritize battery condition invest more effort into verification, while those who do not may be more susceptible to information gaps during the purchase process.

Figure 41. Mean agreement with the statement 'The battery's condition was a key factor in the decision to purchase this vehicle' (By inquiry method).



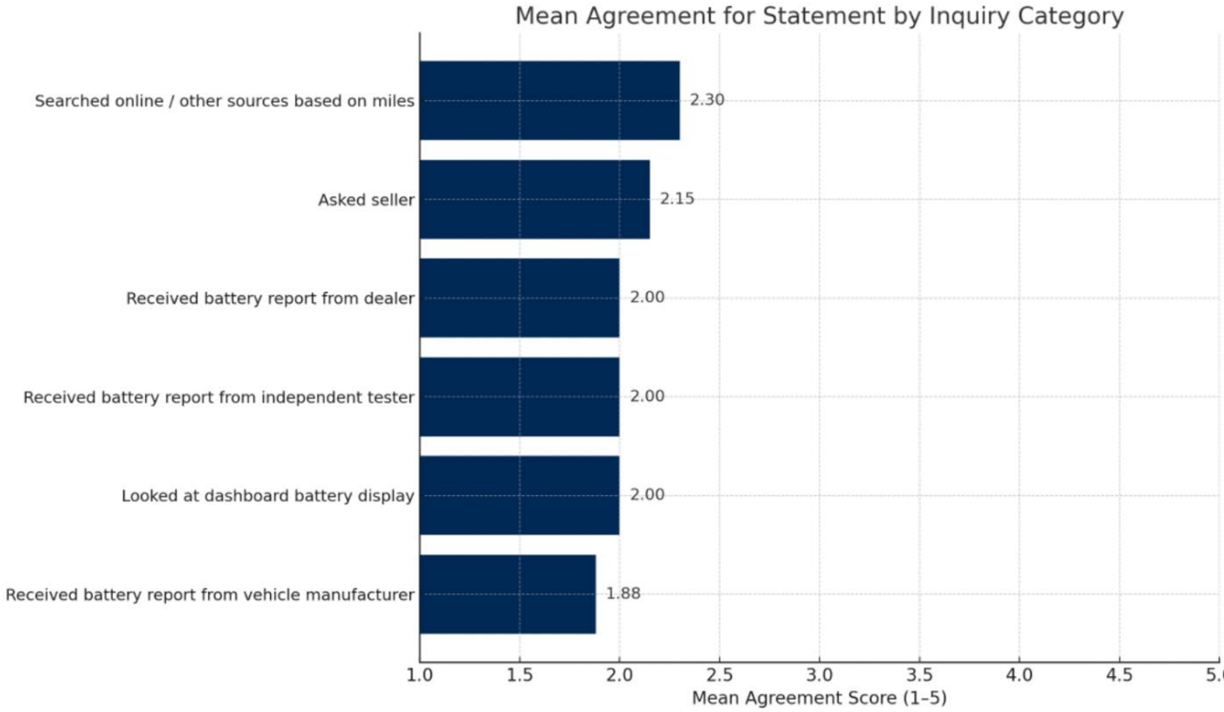
Respondents who provided the strongest agreement with the statement "I was concerned about the battery's condition, so I asked for more information about it" were most likely to ask the seller about it, receive a battery report from the dealer, and from an independent tester. Respondents with the lowest agreement to this question were more likely to look at the dashboard battery display, followed by receiving a battery report from the vehicle manufacturer and searching online or consulting other sources based on miles (see Figure 44). These results suggest that respondents who were most concerned about the battery's condition tended to seek out more detailed and authoritative sources of information, such as speaking directly with the seller or obtaining formal battery reports from dealers and independent testers. This behavior reflects a higher level of caution and a desire to verify battery health through trusted or professional channels. In contrast, respondents who expressed little concern were more likely to rely on quick or surface-level indicators such as the dashboard display, manufacturer-provided reports, or general online information. This pattern implies that lower concern may lead to less thorough inquiry, potentially leaving some consumers with incomplete or less accurate assessments of battery condition. Overall, the findings highlight how perceived risk shapes the depth and reliability of consumers' information-seeking behaviors.

Figure 42. Mean agreement with the statement 'I was concerned about the battery's condition, so I asked for more information about it' (By inquiry method).



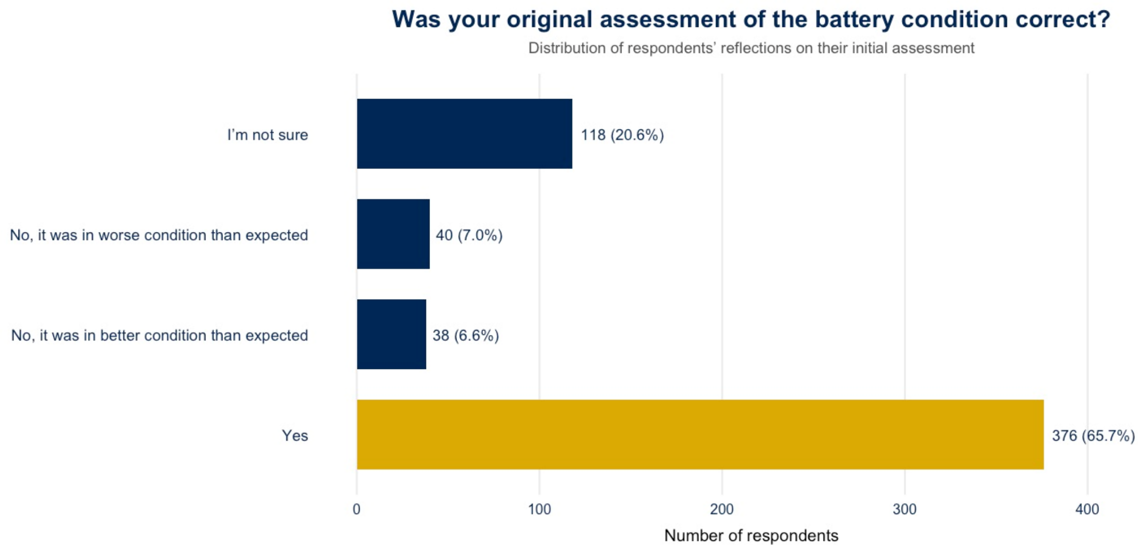
Respondents who agreed most strongly with the statement 'I received detailed information about the battery condition, but did not fully understand it' were most likely to search online or consult other sources based on miles, asked the seller and receive the battery report from a dealer. Respondents with the lowest agreement were more likely to receive a battery report from the vehicle manufacturer, look at the dashboard battery display and receive a battery report from an independent tester, as shown by Figure 45. These findings imply that when consumers receive detailed battery information that they do not fully understand, they compensate by engaging in additional information-seeking behaviors, which aligns with theories of information asymmetry and uncertainty reduction. This pattern suggests that perceived comprehension plays a central role in shaping how consumers navigate complex technical information, reinforcing theoretical models that highlight the importance of cognitive load and interpretability in decision-making. From a practical standpoint, the results indicate that unclear or overly technical battery information may inadvertently drive consumers toward less standardized or less reliable sources, such as online searches or informal inquiries. Meanwhile, respondents who felt they understood the information were more likely to rely on structured assessments such as manufacturer or independent reports, suggesting that providing clearer explanations could reduce unnecessary effort and improve trust in formal battery evaluations. Overall, the findings underscore the need for more transparent, accessible, and user-friendly communication about battery health to support informed consumer decisions.

Figure 43. Mean agreement with the statement 'I received detailed information about the battery condition, but did not fully understand it' (By inquiry method).



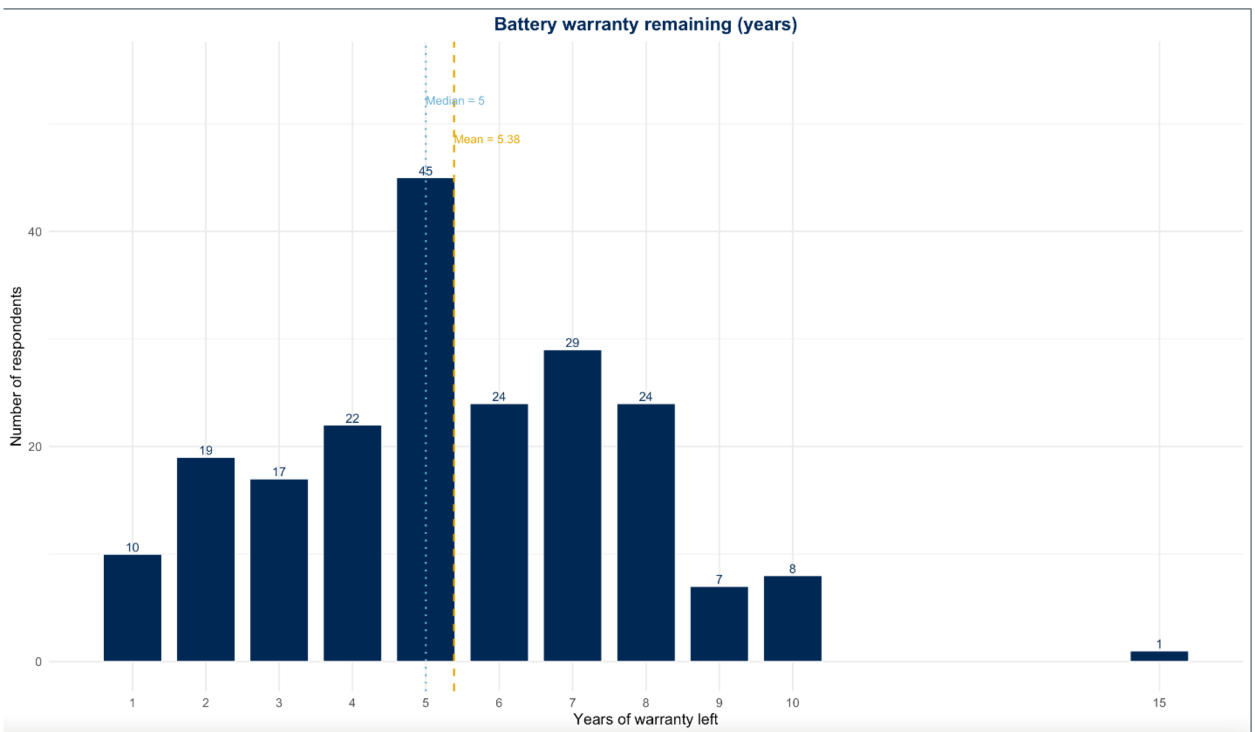
As shown by Figure 46, more than 65% of respondents who inquired about the status of the battery indicated that the original assessment of the battery condition was correct, followed by around 20% of respondents selecting the response option 'I'm not sure', and around 7% indicating that it was in a worse and better condition than expected, respectively. These results suggest that the majority of consumers who inquired about the battery's condition felt that the information they received was accurate, which may indicate that existing assessment methods generally provide reliable guidance. However, the sizeable portion of respondents who were unsure about the accuracy of the assessment highlights gaps in consumer understanding or in the clarity of the information provided. The small percentages who reported the battery being in better or worse condition than expected suggest that misjudgments do occur, even if infrequently, and may carry financial or satisfaction implications for buyers. Overall, these findings point to the need for more consistent, transparent, and comprehensible battery health information to reduce uncertainty and improve consumer confidence.

Figure 44 Original assessment of battery condition.



60% of respondents reported that the remaining battery warranty on their car at the time of the acquisition was between 5-8 years (M = 5.38, SD = 2.38, n = 206), as shown by Figure 47. These results suggest that many consumers acquire vehicles with a substantial amount of battery warranty remaining, which may help reduce perceived financial risk and increase confidence in purchasing used electric vehicles. For practitioners, this highlights the importance of clearly communicating remaining warranty terms, as they appear to play a meaningful role in buyer reassurance. Additionally, ensuring transparency and easy access to warranty information could further support consumer decision-making and potentially increase adoption of used PEVs.

Figure 45 Remaining battery warranty at the time of car acquisition (in years).



We then analyzed differences in warranty at the time of vehicle acquisition between Tesla and non-Tesla owners and found that Tesla owners are slightly more likely to report that their vehicles were under battery warranty at the time of acquisition than non-Tesla owners (78% versus 72%) (Figure 48). Interestingly, the battery warranty at the time of acquisition that was left in years was 4.8 years for the Tesla owners compared to 5.6 years for the non-Tesla owners (Figure 49). The majority of both Tesla and non-Tesla owners report that the condition of the battery was as expected. Tesla owners were slightly more likely to report that the condition was in a worse condition than expected (Figure 50).

Figure 46 Share of vehicles under battery warranty at acquisition

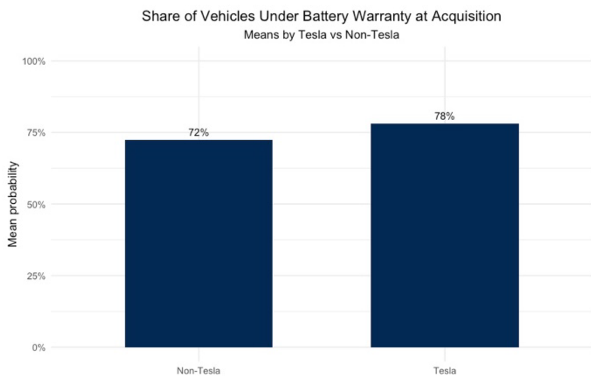


Figure 47 Average remaining battery warranty at acquisition (in years)

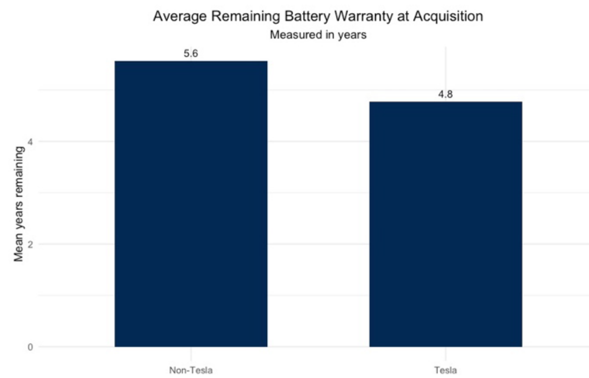
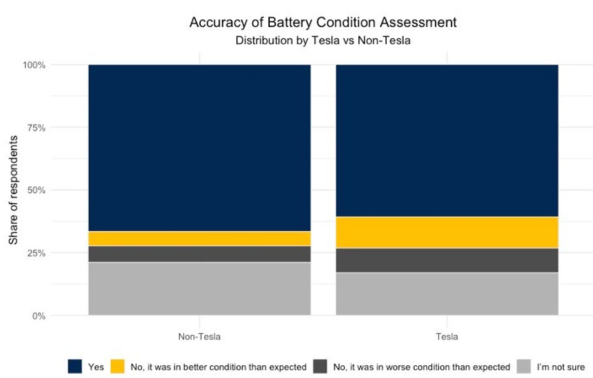


Figure 48 Accuracy of battery condition assessment



15. Policy Discussion

The data and statistical analyses presented in the preceding chapters have significant policy implications, which are discussed in the following section. This discussion addresses the project's main research questions from a comprehensive, overarching perspective, rather than focusing on individual results in isolation.

15.1. What is the Impact of the Used Market on Equity?

Section 8 has shown that the used PEV market has significant equity potential; however, this potential may not yet have fully materialized, as higher-income households are more likely to purchase used EVs. Participation in this market is strongly conditioned by access to home charging, vehicle capability, and affordability constraints.

From an equity perspective, the used vehicle market can lower the upfront financial barrier to electrification, which is critical for households that explicitly identify high purchase prices as a primary obstacle. Many respondents frame price parity—or implicitly, lower prices through used vehicles—as a minimum condition for considering a BEV. This suggests that the used market is a key pathway for extending BEV consideration beyond higher-income households. Furthermore, our data indicate that most California households are not in the market for new vehicles and may not consider one regardless of price parity between new EVs and new ICEVs.

However, the findings also show that access to home charging is a decisive equity filter. Home charging is valued for convenience, time savings, and alignment with daily routines, and respondents without home charging - often due to housing constraints such as limited parking, rental status, or HOA restrictions - are effectively excluded from realizing the benefits of BEVs, including used ones. This creates an equity gap: households most likely to rely on the used market are also more likely to lack home charging access, forcing reliance on public charging that is perceived as insufficient, inconvenient, or unreliable, especially in rural areas.

Vehicle capability further shapes equity outcomes. Many respondents, particularly those considering used BEVs, express concerns about limited range, charging speed, and battery durability, and they specify minimum acceptable ranges, often 350 to 600 miles for ICEV owners, that are rarely met by either gasoline vehicles or BEVs. As a result, availability in the used market often channels buyers toward shorter range BEVs or plug in hybrids, which are viewed as risk reduction technologies rather than full electrification. These buyers also tend to use BEVs in a more limited manner, as suggested by the lower annual vehicle miles traveled of short range BEVs. While the limited supply of long range BEVs supports incremental adoption, it also reinforces a tiered transition in which lower income or more risk averse households are less able to adopt full BEVs that meet all mobility needs.

Cost concerns persist even under price-parity scenarios. Respondents emphasize that price alone is not sufficient if charging, range, reliability, and technology maturity are inadequate. Used vehicles reduce purchase price but do not fully resolve concerns about long-distance travel, emergency preparedness, battery replacement costs, or rising electricity rates. These unresolved risks disproportionately affect households with fewer financial buffers, limiting the equity benefits of the used market.

Our findings in **Section 9** suggest that the used market broadens access to PEVs beyond affluent early adopters, helping to bridge the gap between higher-income new PEV-owners and non-PEV owners. The views of used PEV owners on charging availability, charging time, range, cost, reliability and technology maturity are more positive than the views of non-PEV owners but more cautious than those of new-PEV owners. This implies that direct ownership of used PEVs reduces skepticism, which is critical for more equitable adoption.

Moreover, used PEV owners are less likely to belong to higher income households than new PEV owners, indicating that the used market reduces barriers to entry. While purchase price remains a concern, used PEV owners perceive this barrier as less severe than non PEV owners, suggesting that participation in the used market reshapes cost perceptions and increases the perceived attainability of BEV ownership. Alternatively, these patterns also suggest that education and direct experience with used EVs play a critical role in lowering perceived barriers among prospective adopters.

We also find that higher income strongly predicts new PEV ownership, while used PEV ownership is associated with higher income but also with a more economically diverse set of households, including larger households and those with multiple vehicles. This suggests that used PEVs often enter households as additional vehicles, allowing families with varied needs and budgets to experiment with electrification. At the same time, current market conditions indicate that used EVs differ substantially from used ICEVs in terms of buyer income and vehicle usage. It may therefore take time for changes in used EV supply to be reflected in broader and more representative ownership sociodemographic patterns.

Used PEV owners demonstrate higher confidence in charging infrastructure, operating costs, safety, and the driving experience than non PEV owners, highlighting the role of the used market in reducing informational and experiential inequities. At the same time, some caution remains regarding battery degradation and technology maturity. Despite these benefits, used PEV owners continue to express greater concern about reliability and technology readiness, and the used market does not fully overcome structural barriers such as limited model availability, uneven neighborhood exposure, and gaps in charging infrastructure. In addition, preferences for used products and more cost conscious decision making are associated with lower overall adoption, indicating that financial constraints continue to shape participation. From a policy perspective, reducing knowledge and information gaps to improve the ability of potential used EV buyers to benefit from the technology may be as important as closing charging availability gaps in certain communities and contexts.

Section 10 has shown that nearly one in four PEV-owning households includes a used PEV, either exclusively or alongside a new one. This indicates that the secondary market is impact by familiarty with the new vehciles and mutli EV hosueholds may be large market of the used market. These hosueholds have higfher income than one PEV hosuehold and are not likeley to be part of a DAC.

Annual VMT does not differ significantly across technologies**,** suggesting that once households acquire a used PEV, they use it similarly to new PEVs and ICE vehicles. Likewise, charging behavior among used PHEV owners closely mirrors that of new PHEV owners**,** with roughly 80% charging regularly.

At the same time, the data reveal equity-relevant limitations of the used market. Used PEVs are disproportionately shorter-range, older-generation vehicles, particularly early BEVs and short-range PHEVs that have largely exited the new market. While these vehicles remain usable, they place greater demands on charging access and infrastructure. Used BEV owners are more likely to lack home charging or rely on Level 1 charging, and they report higher levels of driving limitation due to charging constraints - especially for long-range BEVs, where 20% of used owners report some limitation compared to 10% of new owners. This indicates that households relying on the used market are more exposed to infrastructure gaps, which can disproportionately affect renters, lower-income households, and those in multi-unit dwellings.

The charging data also show that used BEV owners rely more heavily on public charging, including DC fast charging, and have less consistent access to home charging. This increases their sensitivity to uneven public charging availability and pricing, thereby reinforcing spatial and socioeconomic inequities that the used market alone cannot resolve. Identifying and addressing charging gaps among used BEV buyers should therefore be a priority to maximize the benefits of these vehicles and to enable market expansion among renters, residents of multi unit dwellings, and urban households.

Findings from the survey experiment in **Section 11** suggest that incentives for both new and used EVs play an equity supporting but incentive dependent role in PEV adoption. A key equity relevant result is that whether a vehicle is purchased new or used is not statistically associated with the likelihood of choosing a PEV once incentives are introduced. New and used vehicle buyers respond similarly to HOV lane access, state rebates, and federal tax credits. This indicates that the used market does not constitute a fundamentally different or less responsive consumer segment; rather, used PEV buyers value and benefit from the same policy instruments as new PEV buyers. Overall, in a higher price environment driven by reduced incentives, we would expect lower levels of sales for both new and used EVs, but not a market collapse. Further research is needed to estimate market shares for new and used EVs under these changing policy and market conditions.

The experiment also shows that incentives substantially promote adoption decisions regardless of vehicle age. In the absence of HOV access and financial incentives, the probability of choosing a PEV drops significantly, implying that roughly one in five PEV buyers would opt out of electrification without policy support. When strong incentives are available (HOV access, a $5,000 state rebate, and a $7,500-$10,000 federal tax credit), the probability increases. This shows that policy support is critical for maintaining participation, especially among buyers who are more likely to rely on used vehicles for affordability reasons.

Section 12 shows that California accounts for roughly 34 percent of all U.S. PEVs and, as a result, supplies a large share of vehicles to the out of state secondary market, with approximately 340,000 PEVs leaving the California market. Neighboring and nearby states, including Nevada, Arizona, and Oregon, import a substantial portion of their PEV fleets from California. These estimates do not include PEVs exported internationally, such as to Mexico, but the analysis suggests that markets with lower incentives for new PEV purchases tend to attract a higher share of used PEVs. While the greenhouse gas implications of these interstate flows depend on the electricity mix of receiving states and may differ only marginally, the effect on the availability of used PEVs within California's secondary market is clear. Policies that incentivize retaining these vehicles in California could benefit both original owners, by increasing resale values, and subsequent buyers, by expanding supply and lowering prices through targeted subsidies.

At the same time, the equity benefits of the used market are not evenly distributed. Econometric results indicate that states offering incentives for new PEV purchases import significantly fewer used PEVs from California. Although such incentives support households able to afford new vehicles, they may unintentionally disadvantage lower income and more price sensitive buyers who depend on the used market. This creates a policy induced equity tension, whereby incentives designed to accelerate adoption of new PEVs may simultaneously reduce affordable access to electrification for households that cannot purchase new vehicles.

Used PEVs exported from California are, on average, operated in states with much dirtier electricity grids (about 79% higher carbon intensity). While this raises environmental justice questions, the equity implications are ambiguous: these vehicles may still replace higher-emitting gasoline vehicles in destination states. However, the climate benefits of California's subsidies may be unevenly realized, while California households - who helped finance these incentives - do not retain long-term access to the vehicles.

Section 13 has shown that battery condition and information asymmetries currently act as equity-limiting bottlenecks. On the one hand, our findings show that many used PEV owners acquire vehicles with substantial remaining battery warranty. This plays a crucial role in reducing financial risk and uncertainty, which is important for cost-sensitive households relying on the used market. However, while warranties help reducing the perceived risk, equity challenges remain in how battery information is accessed, understood, and verified.

More than one-third of respondents did not inquire about battery condition at all, despite recognizing battery health as a key purchase factor. This suggests that some buyers - potentially those with fewer resources, less technical knowledge, or limited access to trusted experts - may proceed without adequate information, increasing exposure to unexpected costs (e.g., battery replacement costs), and potentially leading to dissatisfaction or disappointment and the decision to stop owning or repeating the purchase decision of used PEVs. This can have negative long-term effects on the used PEV market. We also find that the least common inquiry methods were independent battery testing and manufacturer-provided battery reports, which are generally the most reliable. Instead, many buyers relied on sellers or simple dashboard indicators. This reliance on informal or incomplete sources may disproportionately disadvantage buyers who lack bargaining power, technical literacy, or awareness of better verification options.

Overall, we find that the main barriers at present are related more to knowledge and awareness of the topic than to battery degradation. Most PEVs are relatively new, and our sample includes only buyers. As a result, we are unable to observe households that chose to avoid EVs due to concerns about battery wear or degradation.

15.2. Are there Hidden Barriers that will Drastically Reduce the Resale Value of Vehicles?

The results of this report reveal hidden barriers that can reduce the resale value of used PEVs. These are summarized below. We see no drastic reduction of residula values over other vehciles in the study. Potential topics can be:

1) Battery Uncertainty

Uncertainty about battery condition function may function as a major economic penalty in the used market. While the condition of the battery is considered an important factor in individual's PEV purchase decisions, yet more than one third of buyers did not inquire about battery health. When information is sought, it is often informal through seller statements and dashboard displays, which tend to be less reliable than more formal and technical information sources (e.g., battery reports from vehicle manufacturers). This finding implies that even modest uncertainty about battery health can disproportionately reduce resale value because buyers price in worst-case risk.

2) Early-Generation Short-Range BEVs

Older BEVs – especially short-range models – face significant resale challenges because early short-range BEVs are now mostly owned by second owners. These vehicles strongly rely on Level 1 charging, and DC fast charging standards (e.g., CHAdeMO), which are increasingly unsupported. This technological path dependence can contribute to an accelerated depreciation unrelated to vehicle condition, as infrastructure evolves faster than vehicle lifecycles.

3) Incentive-Driven Distortions in the Secondary Market

While incentives strongly increase PEV purchase probability, they can also suppress used vehicle values indirectly because new-vehicle incentives make new PEVs relatively more attractive than used ones. The survey results did not reveal a significant difference in incentive responsiveness between new and used buyers. The focus of incentives on new vehicles reduces demand, contributing to a reductionn in resale prices and an increased likelihood of exporting vehicles out of the state. This is shown by the larger export of used PEVs from California to other status, suggesting that in-state resale demand is weaker than new adoption of used PEVs.

15.3. Are There Policies Needed to Shape this Growing Retail Sector?

(1) Prioritize Expanding Access to Home-Based Charging

Respondents described home charging as essential infrastructure rather than an optional convenience. Concerns related to public charging, including availability, reliability, and the time required to locate functional stations, emerged as significant deterrents. These findings suggest that policies addressing home charging access, particularly for renters and residents of multi-unit housing, may have substantial effects on adoption rates among populations currently underrepresented in the plug-in electric vehicle market.

(2) Battery Information Transparency

The observed information gap regarding battery condition suggests potential value in standardized disclosure requirements. Mandating battery health reporting for used vehicle sales, supporting independent testing and certification programs, and requiring dealers to provide verified condition reports could reduce buyer uncertainty. Consumer education regarding battery degradation and warranty terms may also help address these information gaps.

(3) Public Charging Network Development

Although home charging is preferred by most consumers, public charging infrastructure remains necessary for addressing range concerns, supporting long distance travel, and serving populations without home charging access. Survey respondents expressed concern about charging availability in rural areas, along travel corridors, and during emergencies. Investment priorities suggested by the data include geographic coverage, reliability and uptime, real time availability reporting, and interoperability across charging networks.

(4) Incentive Design for Used Plug in Electric Vehicle Purchases

The demographic profile of used vehicle buyers, characterized by cost sensitivity and higher representation of lower income households, suggests that incentive programs targeting used vehicle purchases may advance equity objectives. Point of sale rebates, financing assistance for credit constrained buyers, and outreach to disadvantaged communities could support adoption among populations underserved by programs focused on new vehicles.

(5) Peer Effects and Social Networks

The association between neighborhood plug in electric vehicle ownership and increased individual adoption likelihood suggests that social influence may be an underutilized factor in market development. Community based programs such as electric vehicle ambassador initiatives, group purchase discounts, and local demonstration events could leverage peer effects to accelerate adoption.

(6) Technology Confidence

Used vehicle buyers express heightened concern about technology maturity, reliability, and service availability. Extended warranties, certified preowned programs for used plug in electric vehicles, improved access to service centers for older models, and clear communication regarding software update policies could help address these concerns.

16. Glossary

Abbreviation	Full Term
ADAS	Advanced Driver Assistance Systems
ANOVA	Analysis of Variance
BEV	Battery Electric Vehicle
CA	California
CR	Composite Reliability
DMV	Department of Motor Vehicles
EPA	Environmental Protection Agency
EV	Electric Vehicle
HH	Household
ICE	Internal Combustion Engine
ICEV	Internal Combustion Engine Vehicle
LDV	Light-Duty Vehicle
LSD	Least Significant Difference
NA	Not Available / Not Applicable
NEM	Net Energy Metering
PCA	Principal Component Analysis
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
RECs	Renewable Energy Certificates
SoCal	Southern California
U.S. / US	United States
V	Volt
ZEV	Zero-Emission Vehicle

17. References

Abdi, H., & Williams, L. J. (2010). Principal component analysis. *Wiley interdisciplinary reviews: computational statistics*, *2*(4), 433-459.

Aigbojie, B., & Osaiga, F. (2010). *Perceived risk in the purchase of imported second-hand cars*. Management Sciences Review, *3*, 2-18.

Akerlof, G. A. (1970). 4. The market for 'lemons': quality uncertainty and the market mechanism. *Market Failure or Success*, *66*.

Asadi, S., Nilashi, M., Samad, S., Abdullah, R., Mahmoud, M., Alkinani, M. H., & Yadegaridehkordi, E. (2021). Factors impacting consumers' intention toward adoption of electric vehicles in Malaysia. *Journal of Cleaner Production*, *282*, 124474.

Axsen, J., & Kurani, K. S. (2012). Who can recharge a plug-in electric vehicle at home? *Transportation Research Part D: Transport and Environment*, *17*(5), 349-353.

Bayus, B. L. (1991). The consumer durable replacement buyer. *Journal of Marketing*, *55*(1), 42-51.

Boelhouwer, A., Van den Beukel, A. P., Van der Voort, M. C., Hottentot, C., De Wit, R. Q., & Martens, M. H. (2020). How are car buyers and car sellers currently informed about ADAS? An investigation among drivers and car sellers in the Netherlands. *Transportation Research Interdisciplinary Perspectives*, *4*, 100103.

Borusiak, B., Szymkowiak, A., Lopez-Lluch, D. B., & Sanchez-Bravo, P. (2021). The role of environmental concern in explaining attitude towards second-hand shopping. *Entrepreneurial Business and Economics Review*, *9*(2), 71-83.

Björnsson, L. H., & Karlsson, S. (2017). Electrification of the two-car household: PHEV or BEV? *Transportation Research Part C: Emerging Technologies*, *85*, 363-376.

Busch, C. (2021). Used Electric Vehicles Deliver Consumer Saving Over Gas Cars. *Energy Innovation: Policy and Technology, LLC*. https://energyinnovation.org/wp-content/uploads/2021/06/Used-Electric-Vehicles-Deliver-Consumer-Savings-Over-Gas-Cars.pdf

Calvo-Porral, C., Orosa-González, J., & Viejo-Fernández, N. (2024). Barriers to online second-hand purchase behavior. *Marketing Intelligence & Planning*, *42*(2), 213-233.

Canepa, K., Hardman, S., & Tal, G. (2019). An early look at plug-in electric vehicle adoption in disadvantaged communities in California. *Transport Policy*, *78*, 19-30.

Carr, Jr., V. H. (1999). Technology adoption and diffusion. The Learning Center for Interactive Technology.

Chakraborty, D., Konstantinou, T., Gutierrez Lopez, J. B., & Tal, G. (2024). Assessing the total cost of ownership of electric vehicles among California households. https://rosap.ntl.bts.gov/view/dot/74409

Chang, T. W. (2023). An indispensable role in promoting the electric vehicle Industry: An empirical test to explore the integration framework of electric vehicle charger and electric vehicle purchase behavior. *Transportation Research Part A: Policy and Practice*, *176*, 103824.

Choo, S., & Mokhtarian, P. L. (2004). What type of vehicle do people drive? The role of attitude and lifestyle in influencing vehicle type choice. *Transportation Research Part A: Policy and Practice*, *38*(3), 201-222.

Cruz-Jesus, F., Figueira-Alves, H., Tam, C., Pinto, D. C., Oliveira, T., & Venkatesh, V. (2023). Pragmatic and idealistic reasons: What drives electric vehicle drivers' satisfaction and continuance intention? *Transportation research part A: policy and practice*, *170*, 103626.

Dadashzada, I., Garza-Reyes, J. A., Roy Ghatak, R., & Gonzalez-Aleu, F. (2025). An investigation into the major barriers to the adoption of electric vehicles in last-mile deliveries for sustainable transport. *The International Journal of Logistics Management*, *36*(3), 906-938.

Dharma, I. K. W. (2023). The Factors that Influence Generation Z's Purchase Intention Towards Imported Secondhand Clothes In Indonesia. *Journal Integration of Management Studies*, *1*(2), 136-145.

Dong, X., Zhang, B., Wang, B., & Wang, Z. (2020). Urban households' purchase intentions for pure electric vehicles under subsidy contexts in China: Do cost factors matter? *Transportation Research Part A: Policy and Practice*, *135*, 183-197.

Encyclopedia of Statistical Science. Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-04898-2_395

Frahm, L. B., Mugge, R., & Laursen, L. N. (2025). Walk a mile in someone's sweaty second-hand shoes: Differences in motivations and barriers for second-hand products. *Resources, Conservation and Recycling*, *219*, 108307.

Ge, Y., Simeone, C., Duvall, A., & Wood, E. (2021). *There's no place like home: residential parking, electrical access, and implications for the future of electric vehicle charging infrastructure* (No. NREL/TP-5400-81065). National.

Guiot, D., & Roux, D. (2010). A second-hand shoppers' motivation scale: Antecedents, consequences, and implications for retailers. *Journal of retailing*, *86*(4), 355-371.

Hair, J.F. (2011). Multivariate Data Analysis: An Overview. In: Lovric, M. (eds) International

Hatt, K., Wilson, B., & Butt, P. (2020). *Benefits and Barriers to Electric Vehicle (EV) Adoption in the City of Guelph*. https://atrium.lib.uoguelph.ca/server/api/core/bitstreams/ef1e6b4c-2893-4a92-a020-ca694028c132/content

He, H., Fan, J., Li, Y., & Li, J. (2017). When to switch to a hybrid electric vehicle: A replacement optimisation decision. *Journal of cleaner production*, *148*, 295-303.

Higueras-Castillo, E., Singh, V., Singh, V., & Liébana-Cabanillas, F. (2023). Factors affecting adoption intention of electric vehicle: a cross-cultural study. *Environment, Development and Sustainability*, 1-37.

Hoogland, K., Kurani, K. S., Hardman, S., & Chakraborty, D. (2024). If you build it, will they notice? public charging density, charging infrastructure awareness, and consideration to purchase an electric vehicle. *Transportation Research Interdisciplinary Perspectives*, *23*, 101007.

Jansson, J. (2011). Consumer eco-innovation adoption: assessing attitudinal factors and perceived product characteristics. *Business Strategy and the environment*, *20*(3), 192-210.

Jensen, A. F., & Mabit, S. L. (2017). The use of electric vehicles: A case study on adding an electric car to a household. *Transportation Research Part A: Policy and Practice*, *106*, 89-99.

Karlsson, S. (2017). What are the value and implications of two-car households for the electric car? *Transportation Research Part C: Emerging Technologies*, *81*, 1-17.

Klein, N. J., Basu, R., & Smart, M. J. (2023). In the driver's seat: Pathways to automobile ownership for lower-income households in the United States. *Transportation research interdisciplinary perspectives*, *18*, 100787.

Koay, K. Y., Cheah, C. W., & Lom, H. S. (2022). An integrated model of consumers' intention to buy second-hand clothing. *International Journal of Retail & Distribution Management*, *50*(11), 1358-1377.

Koay, K. Y., Cheah, C. W., & Lom, H. S. (2023). Does perceived risk influence the intention to purchase second-hand clothing? A multigroup analysis of SHC consumers versus non-SHC consumers. *Journal of Product & Brand Management*, *32*(4), 530-543.

Kurani, K. S., Nordhoff, S., & Hardman, S. (2025). Consumer Resistance to Electric Vehicles: Getting to 100 Percent Zero Emission New Car Sales.

Kurani, K. S. (2018). State of the Plug-In Electric Vehicle Market: Report II. https://escholarship.org/content/qt8rp9h6fb/qt8rp9h6fb.pdf

Kurani, K. S., Caperello, N., & TyreeHageman, J. (2016). New car buyers' valuation of zero-emission vehicles: California. https://escholarship.org/content/qt28v320rq/qt28v320rq.pdf

Lim, M. K., Mak, H. Y., & Rong, Y. (2015). Toward mass adoption of electric vehicles: Impact of the range and resale anxieties. *Manufacturing & Service Operations Management*, *17*(1), 101-119.

Loh, S. W., & Noland, R. B. (2024). Concerns expressed by used electric vehicle owners based on surveying social media. *Transportation Research Part D: Transport and Environment*, *128*, 104086.

Markova, I., & Bayanduuren, N. (2017, January). Conscious consumption: consumer attitudes and behaviors toward second-hand shopping conscious consumption: consumer attitudes and behaviors toward second-hand shopping. In *International Textile and Apparel Association Annual Conference Proceedings* (Vol. 74, No. 1). Iowa State University Digital Press.

Marell, A., Davidsson, P., Gärling, T., & Laitila, T. (2004). Direct and indirect effects on households' intentions to replace the old car. *Journal of Retailing and Consumer Services*, *11*(1), 1-8.

Marell, A., Davidsson, P., & Gärling, T. (1995). Environmentally friendly replacement of automobiles. *Journal of Economic Psychology*, *16*(3), 513-529.

Mashrur, S. M., & Mohamed, M. (2025). Uncovering factors affecting consumers' decisions for pre-owned electric vehicles. *Transportation Research Part D: Transport and Environment*, *139*, 104555.

Maybury, L., Corcoran, P., & Cipcigan, L. (2022). Mathematical modelling of electric vehicle adoption: A systematic literature review. *Transportation Research Part D: Transport and Environment*, *107*, 103278.

Mohamed, M., Higgins, C., Ferguson, M., & Kanaroglou, P. (2016). Identifying and characterizing potential electric vehicle adopters in Canada: A two-stage modelling approach. *Transport Policy*, *52*, 100-112.

Morgan, D. L. (2023). Exploring the use of artificial intelligence for qualitative data analysis: The case of ChatGPT. *International journal of qualitative methods*, *22*, 16094069231211248.

Muehlegger, E., & Rapson, D. (2019). Understanding the distributional impacts of vehicle policy: Who buys new and used electric vehicles?

Mukherjee, S., Datta, B., & Paul, J. (2020). The phenomenon of purchasing second-hand products by the BOP consumers. *Journal of Retailing and Consumer Services*, *57*, 102189.

Padmavathy, C., Swapana, M., & Paul, J. (2019). Online second-hand shopping motivation–Conceptualization, scale development, and validation. *Journal of Retailing and Consumer Services*, *51*, 19-32.

Pallister, J. G., & Foxall, G. R. (1998). Psychometric properties of the Hurt–Joseph–Cook scales for the measurement of innovativeness. *Technovation*, *18*(11), 663-675.

Paradies, G. L., Usmani, O. A., Lamboo, S., & van den Brink, R. W. (2023). Falling short in 2030: Simulating battery-electric vehicle adoption behaviour in the Netherlands. *Energy Research & Social Science*, *97*, 102968.

Pedrosa, G., & Nobre, H. (2018). Second-hand electrical vehicles: A first look at the secondary market of modern EVs. *International Journal of Electric and Hybrid Vehicles*, *10*(3), 236-252.

Peng, Y., & Bai, X. (2023). What EV users say about policy efficacy: Evidence from Shanghai. *Transport Policy*, *132*, 16-26.

Plug In America. (2023). 2023 EV Driver Survey. https://pluginamerica.org/wp-content/uploads/2023/05/2023-EV-Survey-Final.pdf

Plug In America. (2025). 2025 EV Driver Survey. https://pluginamerica.org/wp-content/uploads/2025/06/2025-EV-Driver-Annual-Survey-Report-1.pdf

Prieto, M., & Caemmerer, B. (2013). An exploration of factors influencing car purchasing decisions. *International Journal of Retail & Distribution Management*, *41*(10), 738-764.

Prochaska, J. O. (1991). Assessing how people change. *Cancer*, *67*(S3), 805-807.

Reagan, I. J., Cicchino, J. B., Teoh, E. R., & Cox, A. E. (2023). New and used vehicle buyers' awareness, understanding, and trust in advanced driver assistance systems. *Transportation research part F: traffic psychology and behaviour*, *92*, 44-55.

Roberson, L., Pantha, S., & Helveston, J. P. (2024). Battery-powered bargains? Assessing electric vehicle resale value in the United States. *Environmental Research Letters*, *19*(5), 054053.

Rodrigues, M., Proença, J. F., & Macedo, R. (2023). Determinants of the purchase of secondhand products: an approach by the theory of planned behaviour. *Sustainability*, *15*(14), 10912.

Roux, D., & Guiot, D. (2008). Measuring second-hand shopping motives, antecedents and consequences. *Recherche et Applications En Marketing (English Edition)*, *23*(4), 63-91.

Santos, R. D. O., Gorgulho, B. M., Castro, M. A. D., Fisberg, R. M., Marchioni, D. M., & Baltar, V. T. (2019). Principal component analysis and factor analysis: differences and similarities in nutritional epidemiology application. Revista Brasileira de Epidemiologia, 22, e190041.

Secinaro, S., Calandra, D., Lanzalonga, F., & Ferraris, A. (2022). Electric vehicles' consumer behaviours: Mapping the field and providing a research agenda. *Journal of Business Research*, *150*, 399-416.

Setiawati, C. I., Protopan, S., & Yuliati, A. L. (2019, May). Problematic of Secondhand Car Products in Palembang: Analysis of marketing mix towards purchase decision. In *1st International Conference on Economics, Business, Entrepreneurship, and Finance (ICEBEF 2018)* (pp. 445-450). Atlantis Press.

Shanmugavel, N., Alagappan, C., & Balakrishnan, J. (2022). Acceptance of electric vehicles: A dual-factor approach using social comparison theory and technology acceptance model. *Research in Transportation Business & Management*, *45*, 100842.

Sheykhfard, A., Azmoodeh, M., Das, S., & Kutela, B. (2025). Analyzing purchase intentions of used electric vehicles through consumer experiences: A structural equation modeling approach. *Transport Policy*, *160*, 125-137.

Steren, A., Rubin, O. D., & Rosenzweig, S. (2016). Assessing the rebound effect using a natural experiment setting: Evidence from the private transportation sector in Israel. *Energy Policy*, *93*, 41-49.

Stolz, K. (2022). Why do (n't) we buy second-hand luxury products? *Sustainability*, *14*(14), 8656.

Sun, H., Kim, M., Kim, S., & Choi, L. (2025). A methodological exploration of generative artificial intelligence (AI) for efficient qualitative analysis on hotel guests' delightful experiences. *International Journal of Hospitality Management*, *124*, 103974.

Tal, G., Lee, J. H., Chakraborty, D., & Davis, A. (2021). Where are Used Electric Vehicles and Who are the Buyers? https://escholarship.org/content/qt8125k5tf/qt8125k5tf_noSplash_4d94d3f23191e5f2c2a25128cfe53b61.pdf

Tal, G., Nicholas, M. A., & Turrentine, T. S. (2017). First look at the plug-in vehicle secondary market. https://escholarship.org/content/qt22p191zs/qt22p191zs.pdf

Tal, G., Nicholas, M. A., Woodjack, J., & Scrivano, D. (2013). Who is buying electric cars in California? Exploring household and vehicle fleet characteristics of new plug-in vehicle owners. https://escholarship.org/content/qt70f4r9wc/qt70f4r9wc.pdf

Tankou, A., Lutsey, N., & Hall, D. (2021). Understanding and supporting the used zero-emission vehicle market.

Turrentine, T., Tal, G., & Rapson, D. (2018). The dynamics of plug-in electric vehicles in the secondary market and their implications for vehicle demand, durability, and emissions. https://escholarship.org/content/qt8wj5b0hn/qt8wj5b0hn.pdf

Wang, B., Fu, Y., & Li, Y. (2022). Young consumers' motivations and barriers to the purchase of second-hand clothes: An empirical study of China. *Waste Management*, *143*, 157-167.

Wicki, M., Brückmann, G., Quoss, F., & Bernauer, T. (2023). What do we really know about the acceptance of battery electric vehicles?–Turns out, not much. *Transport Reviews*, *43*(1), 62-87.

Wu, M., Al Mamun, A., Yang, Q., & Masud, M. M. (2023). Modeling the reuse intention and practices of secondhand clothing: Evidence from a developing nation. *Humanities and Social Sciences Communications*, *10*(1), 1-12.

Xu, Y., Chen, Y., Burman, R., & Zhao, H. (2014). Second-hand clothing consumption: a cross-cultural comparison between American and Chinese young consumers. *International Journal of Consumer Studies*, *38*(6), 670-677.

Yan, G., Li, Y., Zhang, T., & Mu, C. (2024). Purchase intention for second-hand luxury goods: An empirical study of Chinese consumers. *Plos one*, *19*(6), e030496

Zahid, N. M., Khan, J., & Tao, M. (2023). Exploring mindful consumption, ego involvement, and social norms influencing second-hand clothing purchase. *Current Psychology*, *42*(16), 13960-13974.

ZEVTC. (2024). Phase-out targets and vans. https://zevtc.org/tracking-progress/phaseout-light-duty/

Zhang, H. E., Wu, C., Xie, J., Lyu, Y., Cai, J., & Carroll, J. M. (2025). Harnessing the power of AI in qualitative research: Exploring, using and redesigning ChatGPT. *Computers in Human Behavior: Artificial Humans*, *4*, 100144.

Zou, T., Khaloei, M., & MacKenzie, D. (2020). Effects of charging infrastructure characteristics on electric vehicle preferences of new and used car buyers in the United States. *Transportation Research Record*, *2674*(12), 165-175.