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Authors

Tal, Gil, PhD

Ramadoss, Trisha

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Assessing the Market for Used Electric Vehicles in California

Gil Tal, Ph.D., Director

Trisha V. Ramadoss, Ph.D. Candidate

Electric Vehicle Research Center, University of California, Davis

January 2026



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Resilient and Innovative
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16. Abstract The secondary market for zero-emission vehicles (ZEVs) will play a critical role in decarbonizing transportation and in bringing ZEVs to lower income populations. Yet research into this market remains limited. Thus, in this study, the characteristics of the used ZEV market, its buyers, and the sources and destinations of used ZEVs were explored. The flows of secondhand, pre-owned, or “used” ZEVs in California were quantified by analyzing vehicle registration and transfer information from the Department of Motor Vehicles from 2016 to 2020. Descriptive statistics were used to examine this market, and the sources and destinations of used ZEVs were modeled using linear regression. Several key trends became evident. First, plug-in hybrids appear to be entering the used market at higher rates than battery electric vehicles. Second, there was a net gain of used ZEVs into disadvantaged communities over the study period. Finally, the number of households in the highest income brackets and land use types play a significant role in which census tracts are sources and destinations for used ZEVs. While the highest income bracket does not seem to play a substantive role in either side of the market, the next three income brackets serve to both generate and procure used ZEVs.			
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Table

of

Contents

Table of Contents

Executive Summary 1

Introduction 4

Background..... 5

Methods and Data 7

 Used ZEVs in California..... 7

 Modeling Sources and Destinations of Used ZEVs..... 8

Results 10

 Used ZEV Market Characteristics..... 10

 Dispersion of Used ZEVs..... 12

 Sources and Destinations of Used ZEVs..... 18

Discussion and Conclusion..... 22

References 24

List of Tables

Table 1. Number of used and total ZEVs by top make/fuel types and aggregated by fuel type10

Table 2. Types of ZEVs within the used fleet compared to the flow of used ZEVs into DACs.....15

Table 3. Linear regression coefficients for the number of ZEVs sourced by census tract18

Table 4. Linear regression coefficients for the number of ZEVs gained by census tract (standard errors are shown in parentheses).....20

List of Figures

Figure 1. Number of new and used ZEVs in California..... 7

Figure 2. Portion of new ZEVs that became used ZEVs, by vehicle make, initial registration year, and fuel type.
..... 11

Figure 3. A Sankey diagram showing initial and final owners of ZEVs with original owner registration transfers
between 2016 and 2020..... 12

Figure 4. Distribution of net gain of used ZEVs within census tracts in California by fuel type 13

Figure 5. Flow of used ZEVs between census tracts in California..... 14

Figure 6. Spread of net gain of used ZEVs within DAC and Non-DAC census tracts..... 14

Figure 7. The market for used electric vehicles in California shows some dispersion of vehicles from “source” to
“destination” census tracts 16

Figure 8. Used ZEV net gain in census tracts across three regions 17

List of Acronyms

ACS	American Communities Survey
BEV	Battery Electric Vehicle
EV	Electric Vehicle
DAC	Disadvantaged Community
DMV	Department of Motor Vehicles
FCEV	Fuel Cell Electric Vehicle
ICEV	Internal Combustion Engine Vehicle
PEV	Plug-in Electric Vehicle
PHEV	Plug-in Hybrid Electric Vehicle
ZEV	Zero Emission Vehicle

Executive Summary

Executive Summary

California's market for pre-owned or "used" zero emission vehicles (ZEV) has grown in recent years but it must grow further if the state's ambitious 2035 ZEV adoption goals are to be met. To date, scant research has been conducted on the used ZEV market. To address knowledge gaps, our study explored California's used ZEV market, sociodemographic characteristics of buyers, and the sources and destinations of used ZEVs. Our assessment of the on-road ZEV fleet provides useful information about the used ZEV market and its environmental benefits. The buyers of used ZEVs are the first generation of ZEV owners to acquire this new technology without the full support of vehicle manufacturers. It is reasonable to expect manufacturers will continue to provide over-the-air software updates to vehicles' subsequent owners, however, vehicle warranties may expire and people buying ZEVs in private-party transactions may not have a prior service relationship with an automobile dealership.

The ZEV designation encompasses vehicle types that emit nearly zero pollutants and includes battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and fuel cell electric vehicles (FCEVs). This study focused primarily on BEVs and PHEVs with limited analysis on FCEVs. Policy and regulatory questions addressed in this project include: (1) meeting California's goals for ZEV sales through the effect of the used ZEV market on new ZEV markets, (2) criteria pollutant and greenhouse gas emissions, (3) renewable energy development, and (4) environmental justice.

To create a full inventory of ZEVs, we determined the number of vehicles in the fleet, accounted for vehicle retirement, and identified census tracts that were sources and destinations of used ZEVs. We assessed the fleet of used ZEVs in the state by analyzing vehicle registration and transfer information from the California Department of Motor Vehicles from 2016 to 2020. We examined this market by using descriptive statistics and modeled the sources and destinations of used ZEVs using linear regression.

Some key findings are:

- PHEVs enter the used market at higher rates than BEVs. During the study period, 24% of the registered PHEVs entered the used market as compared to 11% of registered BEVs. Used market entry rates of the top BEV makes are typically somewhat lower than PHEVs. For a given BEV make, 7% to 23% of the vehicles registered between 2016 and 2020 eventually entered the used market, while this figure is 29% to 39% for a PHEV make. Among PHEVs, only Toyota's rates were comparable to BEVs.
- Most used ZEVs are exchanged between individuals, though there is notable movement from entities to individuals. Residents of disadvantaged communities (DACs) gained 2.5% of the used ZEV fleet, particularly non-Tesla BEVs. However, DAC status by itself was not a factor that significantly affected the number of used ZEVs flowing into or out of a census tract between 2016 and 2020, according to the logistic regression model. This suggests that other factors—such as income, ethnicity, population characteristics, or rent prices—might better explain this rate flow into DACs.

- Trends indicate that households in the highest income bracket (>\$200k), especially Asian households, are less active in the used ZEV market. The next three highest income groups (\$150-200k, \$125-150k, \$100-125k) are more engaged. These three groups likely benefited from incentives unavailable to the highest earners.
- Rural areas gained more used PHEVs, while urban areas saw an increase in non-Tesla BEVs.
- A robust secondary market for used ZEVs depends on buyers of new ZEVs who regularly update their household fleets. Further research is needed to understand the impact of factors such as leasing, incentives, and vehicle supply on the used ZEV market.

Contents

Introduction

Adoption of zero-emission vehicles (ZEVs) will be critical in achieving decarbonization goals within the transportation sector, especially in car-dependent countries like the United States. Supply-side policies in multiple US states, such as California's Advanced Clean Cars II (1), will ensure a full fleet transition to ZEVs in the coming decades.

Studies have shown that early adopters of new ZEVs are more affluent. They tend to be highly educated, higher-income homeowners with many vehicles (2, 3). A much broader market must be cultivated to complete the transition to ZEVs. Yet research into the emerging pre-owned or "used" ZEV market remains limited, with only a few studies examining the characteristics of the buyers in this market (4–7). The used ZEV market has expanded considerably in the years since these studies were conducted, necessitating a fresh look at this topic.

There are no recent studies examining sources of used ZEVs, who the first owners of these vehicles are, where these vehicles go, and/or the overall supply of used ZEVs. Our study has expanded the scope of the literature on used ZEVs by exploring the following questions:

- What are the characteristics of ZEVs that enter the used car market?
- Which types of neighborhoods generate used EVs?
- Which types of neighborhoods obtain used EVs?

We characterized the fleet of used ZEVs in California with 2016 to 2020 California Department of Motor Vehicles (DMV) owner registration transfer data then examined market characteristics. We applied the definition of ZEVs used in California policy which includes plug-in electric vehicles (PEVs), like battery electric and plug-in hybrid vehicles (BEVs and PHEVs), and fuel cell electric vehicles (FCEVs). Because FCEVs are a minor part of the fleet and that is not expected to change in the near-term, only limited analysis is performed on them. For other ZEVs, we investigated dispersion with descriptive statistics and linear regression models that assessed the number of used ZEVs that originated from, and/or flowed into, a census tract.

This study was limited to census tract-level sociodemographic and spatial data. The insights we gleaned are relevant to many policy and planning decisions.

Background

California's Advanced Clean Car II regulations (1) will ensure that all new vehicles sold in many US states by 2035 will be ZEVs. Multiple studies have focused on early adopters of new ZEVs, finding they tend to be more affluent and educated homeowners (2, 3). Yet relatively little is known about buyers of used ZEVs. It is important to understand this market to understand the equity implications of ZEVs and the transition to a full fleet of ZEVs, which will require that many people purchase used ZEVs.

Used ZEV buyers are more likely to have a lower income, or identify with a minority group, and/or reside in a Disadvantaged Community (DAC). Low-income households tend to own fewer vehicles and are more likely to purchase them used (8). This pattern continues in ZEVs. Muehlegger and Rapson (4) find low-income and minority buyers are more likely to buy their ZEVs used, if they purchase ZEVs at all. People in DACs are also more likely to buy used ZEVs than new ZEVs. Using a combination of survey and DMV data, Canepa and others (9) found that, in 2016, there was a higher proportion of used ZEVs compared to new ZEVs in DACs. However, the authors note that people buying ZEVs in DACs, whether new or used, tend to be unrepresentative of their DAC neighborhoods due to having higher incomes, higher levels of education and/or higher rates of home ownership than the DAC average.

The used market, which is about three times larger than the new vehicle market in the US (10), will need to transition from internal combustion engines to ZEVs in order to decarbonize the entire vehicle fleet. This process will be gradual. In California, more than 1.5 million ZEVs have been cumulatively sold as of March, 2023 (11), and many of these have entered the used vehicle market. Tankou and others (12) projected that the stock of used ZEVs could surpass the stock of new ZEVs by the early 2040s. ZEVs may be especially attractive to used vehicle buyers as these buyers are more sensitive to the price of gasoline (13) and to total cost of ownership. The cost of used ZEVs is expected to reach parity with that of used conventional vehicles soon. Bauer and others (8) estimated that the average BEV will cost less than the average gasoline vehicle by 2030 while Tankou and others (12) estimated that this could happen as soon as 2025.

Muelegger and Rapson (4) analyzed trends from transaction-level data on every PHEV or BEV purchased in California from 2011 to 2015. They found only mixed evidence that buyers identifying as Black, Hispanic, Indigenous, or other minority ethnicities, either traveled farther to buy, or paid more for, used plug-in vehicles (PEVs). Tal and others (6) analyzed DMV records from 2017 and found that used PEVs made up a higher share of all PEVs in areas with few PEVs overall, and that used PEVs are slightly less spatially concentrated than new PEVs. Turrentine and others (7) investigated the motivations of, and vehicle use by, those who purchased used PEVs with a survey of people identified as used ZEV owners based on 2015 DMV records.

The used ZEV market has changed dramatically since these early used ZEV studies, especially with the large volume of Tesla BEVs that entered the market starting in 2018. This study has extended previous research in this topic in several ways. We examined where used ZEVs came from, where they end up, and the characteristics of used ZEVs and their buyers.

Methods and Data

Used ZEVs in California

The data for identifying potential used ZEVs was acquired from the California Department of Motor Vehicles (DMV). It includes registration records for all ZEVs registered in the state between 2016 and 2020. Registration records include partial vehicle identification numbers, census tracts in which vehicles are registered, odometer readings, date of odometer readings, and evidence of transfers but no personal identification information. DMV registration records are taken from October during a given record year. For example, records from 2016 contain registrations recorded between October 2015 and October 2016.

This analysis considered the subset of new ZEVs purchased or leased in California that showed evidence of entering the used car market between 2016 and 2020. ZEVs that were purchased in this period new and showed evidence of ownership transfer after multiple years were assumed to have entered the used ZEV market. Of these vehicles, 82.4% (58,620 out of 71,100 vehicles) were registered in a different census tract in their latest year compared to the first year of registration.

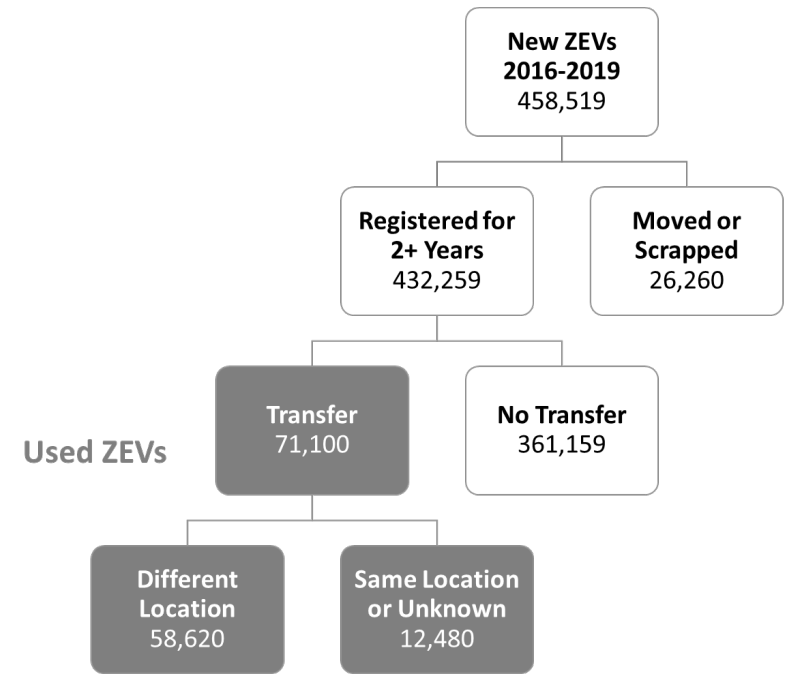


Figure 1. Number of new and used ZEVs in California.

Used ZEVs are assumed to be the subset of new ZEVs registered for multiple years in California between 2016 and 2020 that showed clear evidence of vehicle ownership change.

The total number of new ZEVs in California was determined by identifying unique ZEVs registered between 2016 and 2019 with model years newer than 2014 and odometer readings of less than 15,000 miles at time of first registration. This threshold was chosen to ensure leased vehicles were included in the number of new ZEVs.

Only vehicles registered for at least two years were examined for ownership or lease transfer. Thus, vehicles registered for the first time in 2020 were excluded from this analysis. Of this sample, 16.5% were determined to have had registration transfers based on new transfer dates and higher odometer readings in the latest year compared to the first year of registration. This sample of “used” ZEVs had discontinuance rates similar to those of PHEV and BEV owners estimated by Hardman and Tal (14). This means that our sample size was reasonably close to the used ZEV market, as discontinued ZEVs would likely be a source for the used ZEV market. Of the 458,519 ZEVs purchased new from 2016 to 2019, 71,100 vehicles are estimated to have entered the used market by 2020 (Figure 1).

Modeling Sources and Destinations of Used ZEVs

We model the number of used ZEVs sourced from ($N_{sourced}$) and gained by (N_{gained}) each census tract using the subset of vehicles that transferred ownership and moved to different census tracts ($N = 58,620$). Because DMV registration records do not include ownership data, we use tract-level vehicle (v), sociodemographic (x) and other variables (t) as explanatory variables. Coefficients are estimated separately for different types of ZEVs (f), with FCEVs excluded due to low sample size. Tesla owners are known to deviate from typical ZEV buyers, so separate coefficients are estimated for these BEVs. The specifications of both models are provided below.

$$N_{sourced} = \sum_f \beta_{0,f} + \beta_{v,f}v + \beta_{x,f}x + \beta_{t,f}t$$

$$N_{gained} = \sum_f \beta_{0,f} + \beta_{v,f}v + \beta_{x,f}x + \beta_{t,f}t$$

Variables were mainly gathered from the 2015 to 2019 American Communities Survey (ACS) (15) to match the spatial level of the used ZEV data. Additional data identifying DACs were gathered through CalEnviroScreen 3.0 (16), which is appropriate for our 2016 to 2020 period of analysis. Several variables were tested in each model.

Vehicle Variables

Total new ZEVs and total vehicles in each tract were examined. Total new ZEVs registered by type, including non-Tesla BEV, Tesla BEV, or PHEV, in each tract from DMV records were included in “source” and “destination” models. In the source model, the coefficient represented the average value of new ZEVs that later transferred ownership and moved out of a tract. In the destination model, the coefficient represented social influence, in which purchases of new ZEVs within a census tract influence additional purchases of used ZEVs (17). The aggregate number of vehicles was an explanatory variable included in both models. This variable represents the total number of vehicles in a census tract and was taken from ACS data.

The Used ZEV destination model included the additional term “Nearby Used ZEVs.” This variable calculated the total number of used ZEVs that were sourced from all tracts within 50km of a given census tract. This variable represents the supply of used ZEVs near a census tract.

Sociodemographic Variables

Variables such as income, ethnicity, age, and education were obtained from the ACS and tested in “source” and “destination” models. The “number of households by income range” and “ethnicity” subgroups were included in both models. Four income ranges were defined: \$100,000 to \$125,000, \$125,000 to \$150,000, \$150,000 to \$200,000, and over \$200,000. Lower income ranges were tested but ultimately excluded from the models because of low statistical significance across all ZEV types. The ACS categories for ethnicity were collapsed into three: Asian, White Not Hispanic, and All Other Races. The last category included the number of households that identify as Hispanic, Black, Indigenous, another race, or two or more races and were grouped together to improve statistical significance. Median age and percent of population with advanced degrees (Master’s, Doctorate, or professional school degrees) were also included in the used ZEV source model, as these two factors are known to correlate with initial ZEV adoption (18).

Other Tract Variables

Tract status as a DAC was included in “source” and “destination” models. DAC designations were developed as a result of California Senate Bill 535. They are defined through CalEnviroScreen (CES), a tool that uses around twenty indicators to develop a score that indicates vulnerability to pollution. CalEnviroScreen 3.0 was updated in June 2018 and identifies census tracts in the top quartile of CES scores as DACs. The tool identified 2,007 tracts of the 8,057 tracts in California as DACs, accounting for 2.8 million households of the state’s 13 million households (16).

Population changes and median rent from the ACS were included in both models. A proxy for population change was taken by comparing the 2015 to 2019 ACS population estimates to 2013 to 2017 ACS population estimates for each tract.

Finally, tract land use designation was included in the used ZEV destination model. The classifications of tracts was developed by Salon and others (19) and includes five categories ranging from least to most dense: Rural, Rural-In-Urban, Suburb, Urban, and Central City.

Results

Used ZEV Market Characteristics

Here, we identify the number of used and total vehicles for different leading ZEV make and fuel types. As of 2020, PHEVs comprised the majority of, and were overrepresented in, the used ZEV population. They comprised about 58% of used ZEVs but 38% of total ZEVs. When considering vehicle manufacturers and drive trains, Tesla BEVs had the highest frequency in the used ZEV population, followed by PHEVs from BMW, Chevrolet, and Ford (Table 1).

Table 1. Number of used and total ZEVs by top make/fuel types and aggregated by fuel type.

Make	Fuel Type	Used	Total	Percent Used
Tesla	BEV	12,398	167,513	7%
BMW	PHEV	11,374	39,780	29%
Chevrolet	PHEV	10,596	27,180	39%
Ford	PHEV	9,877	34,214	29%
Nissan	BEV	3,976	20,571	19%
Chevrolet	BEV	3,229	32,361	10%
FIAT	BEV	2,783	12,901	22%
Toyota	PHEV	2,731	32,631	8%
Volkswagen	BEV	2,654	11,742	23%
Audi	PHEV	2,227	6,327	35%
Aggregated BEV		28,501	249,632	11%
Aggregated PHEV		41,567	175,547	24%
Aggregated FCEV		1,032	7,080	15%
Total		71,100	458,519	16%

Further delving into the relationship between used ZEVs and the total ZEV fleet, we can examine the portion of different makes and fuel types that enter the used ZEV fleet by initial registration year (Figure 2). We find that BEVs from Tesla, Nissan, Chevrolet, and FIAT followed similar trajectories with 25% to 35% of new vehicles of each make from 2016 entering the used ZEV population by 2020. Toyota PHEVs followed a similar trend as

BEVs. A much higher percentage of BMW, Chevrolet, and Ford PHEVs entered the used fleet, with around 50-60%, of new vehicles from 2016 entering the used population by 2020. PHEVs appear to enter the used ZEV market at higher rates than BEVs.

FCEVs are excluded from the vehicle make analysis due to a small fleet size (Table 1), making up just 1.5% of the total ZEV fleet during the study period.

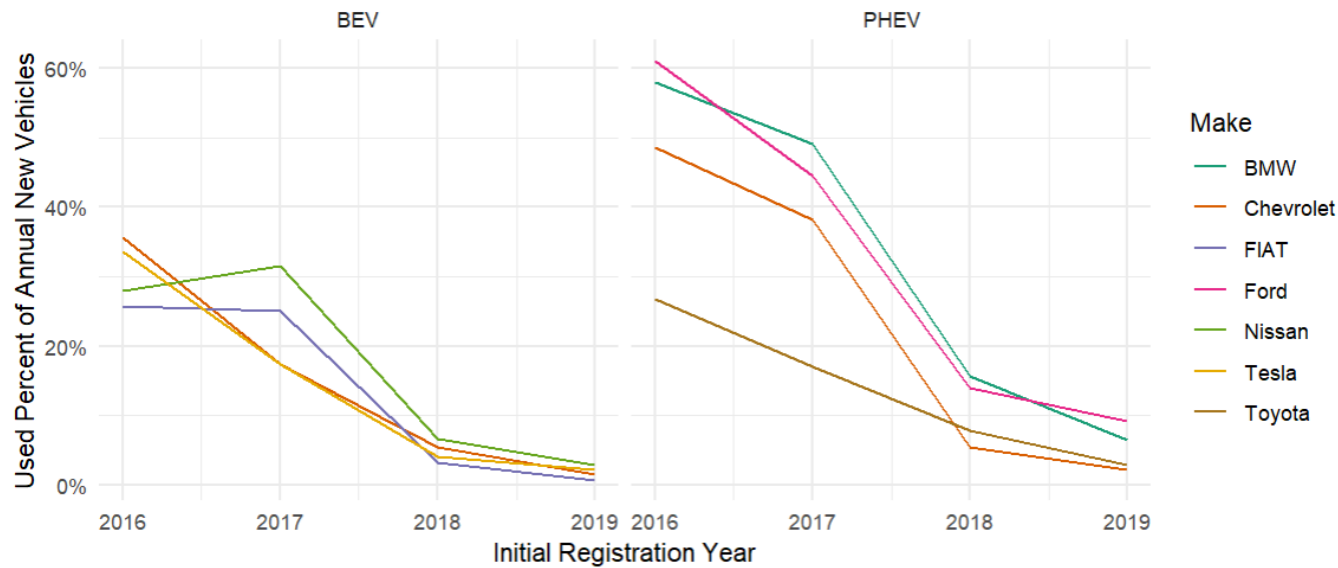


Figure 2. Portion of new ZEVs that became used ZEVs, by vehicle make, initial registration year, and fuel type.

Vehicles comprising the used population were overwhelmingly transferred by individuals to other individuals rather than individuals transferring vehicles to, or purchasing vehicles from, entities such as companies. A minority of vehicles belong to individuals without Californian identification cards or driver’s licenses (indicated by * in Figure 3). The second largest flow of used vehicles is from entities to individuals.

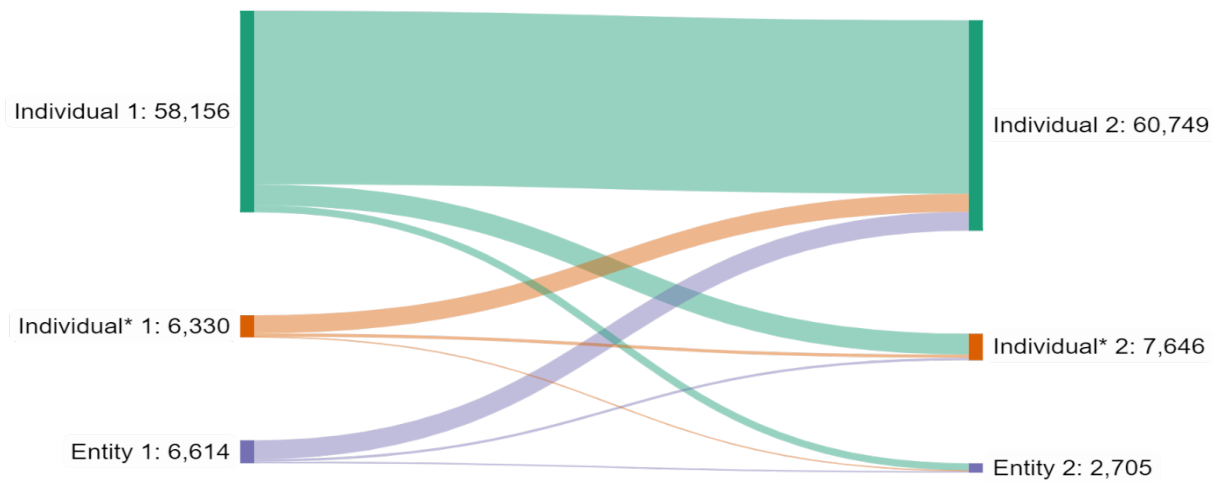


Figure 3. A Sankey diagram showing initial and final owners of ZEVs with original owner registration transfers between 2016 and 2020

Dispersion of Used ZEVS

Most of the used ZEV population is comprised of vehicles that move to new census tracts (58,620 of 71,100 vehicles). Focusing on this subset, we see two key trends: diffusion of ZEVs to more census tracts and ZEV transfer to DACs.

As ZEVs changed ownership between 2016 and 2020, they became increasingly dispersed around the state. The 58,620 vehicles started in 6,551 tracts and flowed into 7,412 tracts with overlap. Most tracts had a minimal net gain of used ZEVs—the difference between vehicles that flowed into the tract and vehicles sourced to other tracts—with a median of one ZEV gained. The interquartile range of net used ZEV gain was between three vehicles gained to one vehicle sourced out. A closer look at the distribution of net gain by fuel type can be seen in Figure 3.

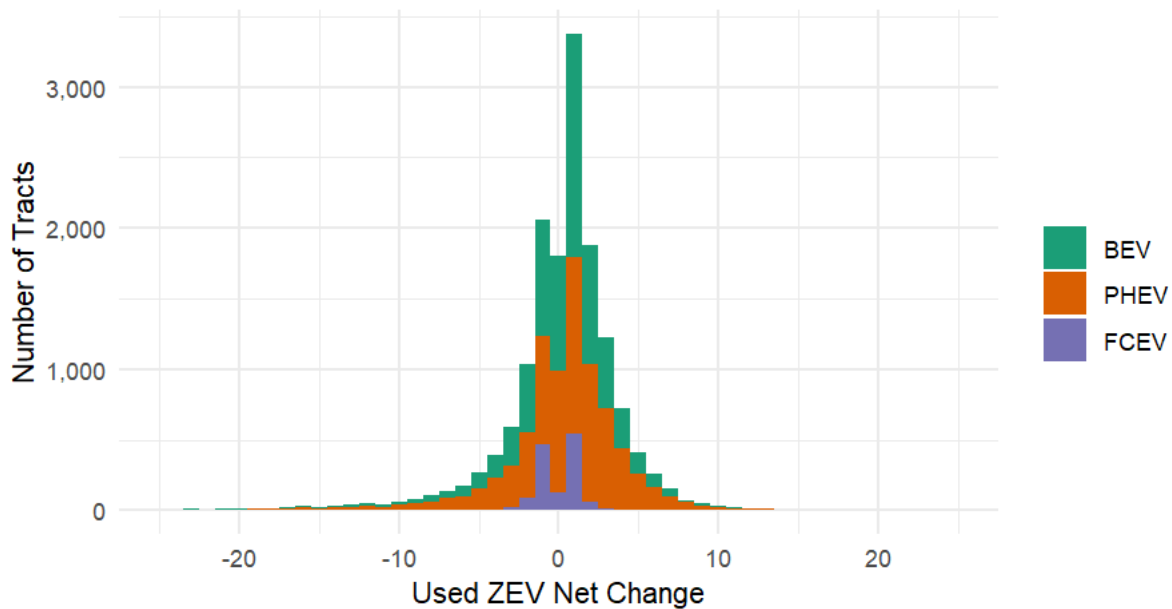


Figure 4. Distribution of net gain of used ZEVs within census tracts in California by fuel type.

An additional 129 tracts have a net loss of 25 vehicles or more and an additional 10 tracts have a net gain of 25 vehicles or more.

We also identified a net gain of used ZEVs in DACs. DACs gained an additional 1,783 ZEVs, or 2.5% of the used ZEV fleet, between 2016 and 2020 (Figure 5). Of the 58,620 ZEVs that transferred between census tracts, 46,519 ZEVs moved within non-DAC tracts and 1,000 ZEVs moved within DAC tracts. However, a greater number of ZEVs were transferred from non-DAC tracts to DAC tracts than vice versa. Nevertheless, the distributions of net gain in DAC and non-DAC tracts are similar (Figure 6). Compared to the entire fleet of used ZEVs, a higher fraction of non-Tesla BEVs and a lower fraction of Tesla BEVs flowed into DACs (Table 2).

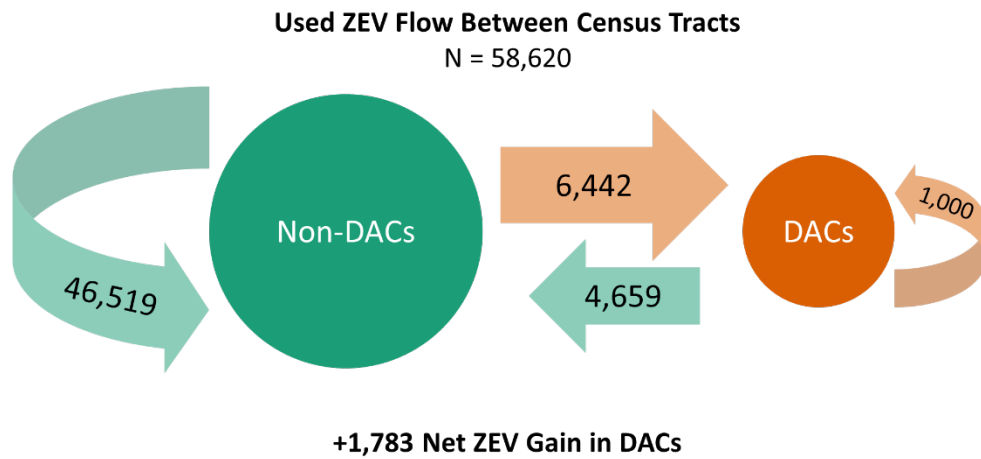


Figure 5. Flow of used ZEVs between census tracts in California.

Arrows are labelled with the number of vehicles that transferred within and between non-DAC and DAC Census tracts.

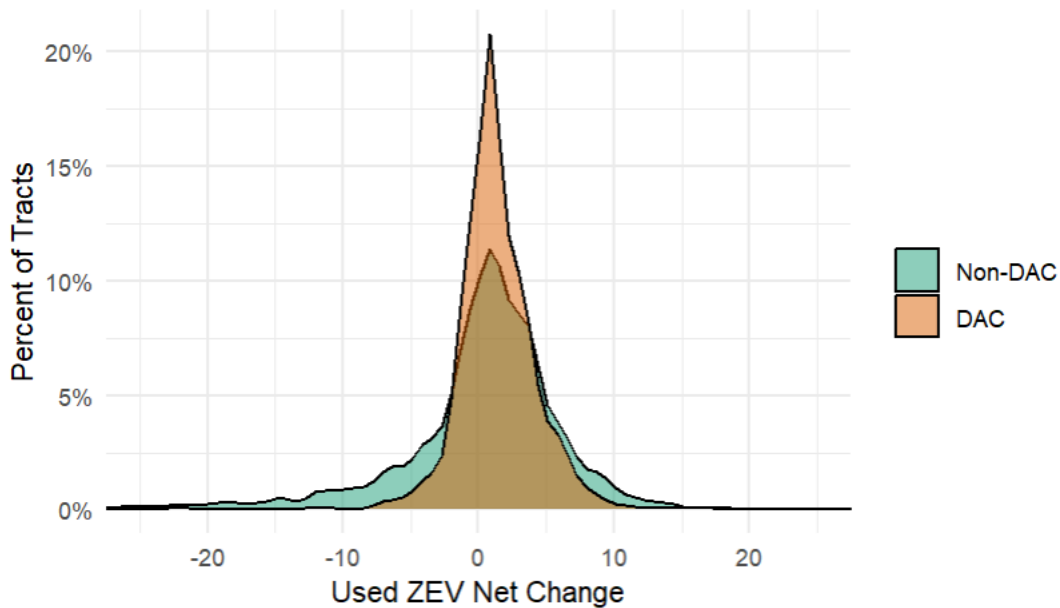


Figure 6. Spread of net gain of used ZEVs within DAC and Non-DAC census tracts.

Table 2. Types of ZEVs within the used fleet compared to the flow of used ZEVs into DACs.

ZEV Type	Used ZEV Fleet		Used ZEVs Flow into DACs	
	Total	Percent	Total	Percent
BEV	28,501	40%	786	44%
Non-Tesla	16,103	23%	573	32%
Tesla	12,398	17%	213	12%
PHEV	41,567	58%	913	51%
FCEV	1,032	1%	84	5%
Total	71,100	100%	1,783	100%

We used the results of our analysis to create a depiction of used ZEV net gain in census tracts across California (Figure 5 and Figure 6). Predictably, tracts near the urban clusters of San Francisco/San Jose and Los Angeles/Long Beach had a high density of tracts that sourced used ZEVs. Areas in rural counties in northern California had low or zero net gain of used ZEVs. The San Joaquin Valley, an area with some of the worst air quality in the US, had a slight net gain of used ZEVs.

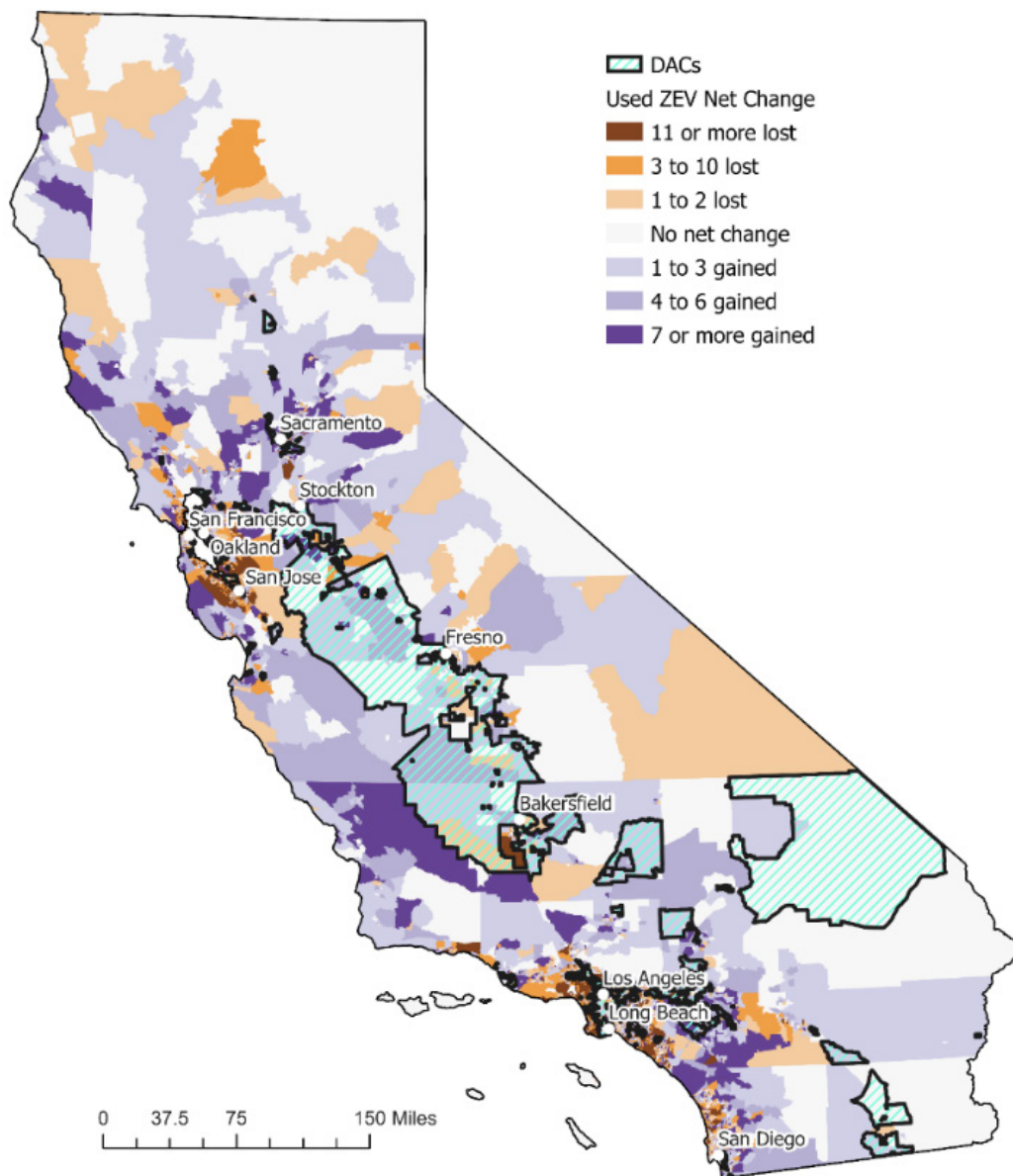


Figure 7. The market for used electric vehicles in California shows some dispersion of vehicles from “source” to “destination” census tracts.

Tracts are highlighted in shades of orange to indicate a net loss of used ZEVs while purple is used to indicate a net gain of used ZEVs. Disadvantaged communities as identified by CA SB 535 are outlined and cross-hatched.

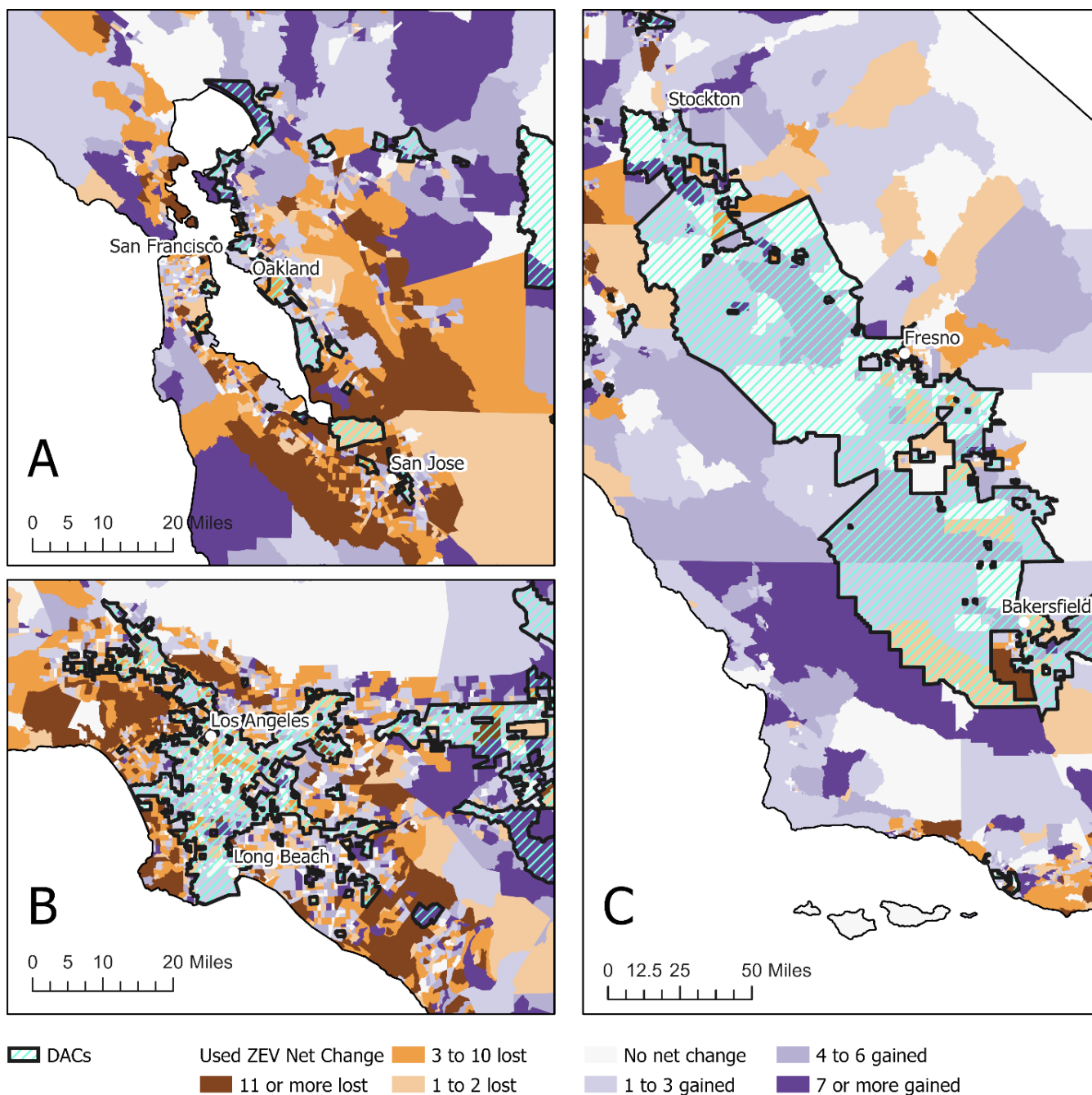


Figure 8. Used ZEV net gain in census tracts across three regions in California.

The San Francisco Bay Area (A), the Los Angeles area (B), and the San Joaquin Valley (C) are shown. Tracts are highlighted in shades of orange to indicate a net loss of used ZEVs while purple is used to indicate a net gain of used ZEVs. Disadvantaged communities as identified by CA SB 535 are outlined and cross-hatched.

Sources and Destinations of Used ZEVs

In the final part of this study, we modeled used ZEVs that originated from and relocated to a census tract, estimating two separate linear regression models (Table 3 and Table 4). FCEVs were excluded from this analysis because of small sample sizes.

Used ZEV Sources

Coefficients were estimated for the number of used ZEVs that originated from a census tract (Table 3).

Table 3. Linear regression coefficients for the number of ZEVs sourced by census tract (standard errors are shown in parentheses).

	BEV, non-Tesla	PHEV	BEV, Tesla
Total New ZEVs Registered	0.135*** (0.002)	0.189*** (0.003)	0.162*** (0.002)
Aggregate Vehicles, thousands	-0.483*** (0.060)	-0.577*** (0.090)	-1.071*** (0.092)
Households (in Thousands) By Income Range & Ethnicity			
\$100-125k, Asian	11.551*** (1.483)	-	8.497*** (2.290)
\$125-150k, Asian	-	-	11.158*** (2.725)
\$150-200, Asian	3.984*** (1.360)	4.936** (2.256)	-3.983* (2.126)
>\$200k, Asian	-10.323*** (0.719)	-7.661*** (1.095)	-21.922*** (1.124)
\$100-125k, White Not Hispanic	3.573*** (0.890)	3.221** (1.370)	5.160*** (1.350)
\$125-150k, White Not Hispanic	-	4.687*** (1.659)	5.285*** (1.588)
\$150-200, White Not Hispanic	-	-2.944** (1.361)	4.852*** (1.303)
>\$200k, White Not Hispanic	1.248*** (0.396)	-1.870*** (0.652)	-9.547*** (0.648)
\$100-125k, All Other	4.627*** (1.082)	5.875*** (1.586)	5.486*** (1.645)
\$125-150k, All Other	-	-	-
\$150-200k, All Other	-	-3.264* (1.876)	5.950*** (1.874)
>\$200k, All Other	-	-6.754*** (1.970)	-3.988** (1.852)
All Other Sociodemographics			
Median Age, decade	-	-	-0.254** (0.111)
Advanced Degrees, %	-0.038*** (0.007)	-	-0.085*** (0.010)

	BEV, non-Tesla	PHEV	BEV, Tesla
All Other Tract Characteristics			
DAC	-	-	-0.713*** (0.236)
Population Change, thousands	1.628*** (0.369)	2.000*** (0.565)	-2.313*** (0.567)
Median Rent, thousands USD	-	-	-0.538*** (0.166)
Constant	-0.630*** (0.180)	-	-1.982*** (0.280)
Observations	12,977		
R ²	0.681		
Adjusted R ²	0.679		
Residual Std. Error	4.116 (df = 12,917)		
F Statistic	467.229*** (df = 59; 12,917)		

Note: *p< 0.05; **p< 0.01; ***p<0.001

On average, 13.5% of non-Tesla BEVs, 16.2% of Tesla BEVs, and 18.9% of PHEVs initially registered in a tract later became used vehicles that left that tract. Additionally, the greater the aggregate number of vehicles in a tract, the fewer ZEVs that tract sourced.

Income and ethnicity are correlated with the number of used ZEVs leaving a tract across different ZEV types. For the most part, the more households per tract in the highest income bracket, the fewer ZEVs are sourced from that tract. This pattern is seen across all ethnicities for Tesla BEVs and PHEVs. However, it is only seen in the number of Asian households in the highest income bracket for non-Tesla BEVs. Households in the next three highest income brackets were correlated with more used ZEVs of all types and across all ethnicities, except for White Not Hispanic households in the second highest income bracket, which correlated with fewer sourced used PHEVs.

Tracts with higher median ages generated fewer Tesla BEVs for the used market. Additionally, tracts with a higher percentage of the population holding postgraduate degrees generated slightly fewer non-Tesla and Tesla BEVs for the used market.

Used Tesla BEV trends consistently deviated from other used ZEV trends. We speculate that this most likely resulted from the low share of leased—as compared to purchased—Tesla vehicles (20). For example, DACs generated fewer Tesla BEVs while there was no statistical relationship between DACs and used PHEVs or non-Tesla BEVs. Similarly, tracts that experienced population growth over the given time period generated more non-Tesla BEVs and PHEVs but fewer Tesla BEVs. Lastly, tracts with higher median rents generated fewer used Tesla BEVs.

Used ZEV Destinations

Coefficients were estimated for the number of used ZEV gained by a census tract (4).

Table 4. Linear regression coefficients for the number of ZEVs gained by census tract (standard errors are shown in parentheses).

	BEV, non-Tesla	PHEV	BEV, Tesla
Total New ZEVs Registered	0.023*** (0.001)	0.048*** (0.002)	0.125*** (0.002)
Aggregate Vehicles, thousands	-	0.381*** (0.055)	-0.410*** (0.108)
Nearby Used ZEVs, thousands	0.523*** (0.039)	0.161*** (0.014)	-0.338*** (0.086)
Households (in Thousands) By Income Range & Ethnicity			
\$100-125k, Asian	3.162*** (0.900)	5.611*** (1.382)	8.709*** (2.546)
\$125-150k, Asian	-	-	9.548*** (2.980)
\$150-200, Asian	-	-	-
>\$200k, Asian	-2.721*** (0.424)	-4.630*** (0.610)	-19.276*** (1.212)
\$100-125k, White Not Hispanic	2.397*** (0.531)	3.780*** (0.772)	2.520* (1.483)
\$125-150k, White Not Hispanic	1.956*** (0.616)	2.613*** (0.940)	3.803** (1.736)
\$150-200, White Not Hispanic	-	6.244*** (0.771)	6.774*** (1.426)
>\$200k, White Not Hispanic	2.276*** (0.225)	1.767*** (0.352)	-14.829*** (0.695)
\$100-125k, All Other	-	-	3.143* (1.803)
\$125-150k, All Other	-	-	-
\$150-200k, All Other	1.624** (0.727)	4.753*** (1.069)	9.566*** (2.059)
>\$200k, All Other	1.433* (0.753)	4.941*** (1.120)	-
Land Use			
Rural	0.571*** (0.216)	0.830*** (0.298)	-2.046*** (0.629)
Rural-In-Urban	0.652*** (0.209)	0.858*** (0.292)	-2.679*** (0.617)
Suburb	0.695*** (0.194)	-	-2.647*** (0.560)
Urban	0.867*** (0.191)	-	-2.585*** (0.552)

	BEV, non-Tesla	PHEV	BEV, Tesla
All Other Tract Characteristics			
DAC	-	-	-
Population Change, thousands	0.875*** (0.221)	2.478*** (0.321)	-
Median Rent, thousands USD	-0.239*** (0.065)	-	-
Constant	-	-	1.954*** (0.718)
Observations	12,977		
R2	0.544		
Adjusted R2	0.541		
Residual Std. Error	3.487 (df = 12,908)		
F Statistic	226.307*** (df = 68; 12,908)		

Note: *p< 0.05**p< 0.01***p<0.001

The number of ZEVs of a particular type registered in a tract directly influenced the influx of used ZEVs into that tract, especially for Tesla BEVs. This may hint at the social influence of neighborhood vehicle purchases. Unexpectedly, as the number of vehicles in a tract increased, more PHEVs but fewer Tesla BEVs flowed into the tract. The same trend was observed for used ZEVS sourced by surrounding tracts. More used non-Tesla BEVs or PHEVs leaving nearby tracts correlated to more of the same type of used vehicles entering a tract, but more Teslas leaving nearby tracts correlated with fewer Teslas entering a tract.

Income and ethnicity showed mixed effects on the destinations of used ZEVs. For both non-Tesla BEVs and PHEVs, more Asian households in the highest income category correlated with fewer used ZEVs entering the tract. In contrast, this relationship was either insignificant or positively correlated for all other income and ethnicity subgroups. Similar patterns held for Tesla BEVs with one exception: more White Not Hispanic households in the highest income bracket correlated with fewer used Tesla vehicles entering a tract.

All land use types, relative to the densest designation Center City, had more used non-Tesla BEVs entering with tracts with the second-densest designation, Urban, attracting more of these used vehicles. For PHEVs, Rural and Rural-in-Urban tracts attracted more used vehicles than more urban tracts. Finally, fewer Teslas flowed into all types of tracts, almost uniformly, as compared to Center City tracts.

There was no significant correlation between DAC status and attracting used ZEVs. Population growth in a tract led to more non-Tesla BEVs and even more PHEVs entering. Higher median rent resulted in fewer non-Tesla BEVs coming into the tract.

Discussion and Conclusion

Used ZEVs will be essential for allowing lower-income households access to ZEVs—which is in turn essential to fully decarbonizing transportation. While considerable research has been conducted on first-time adopters of new ZEVs, the study of used ZEVs has been limited. Our research expands the current literature by examining the generation and flow of used ZEVs and the characteristics of these vehicles and their buyers.

In analyzing the types of ZEVs in the used market from 2016 to 2020, several trends emerge. PHEVs appear to have entered the used ZEV market at higher rates than BEVs, with an aggregate average of 24% of all PHEVs registered compared to 11% of all BEVs registered ultimately entering the used market. The rates of vehicles entering the used car market were similar across the top four BEV makes and lower than most of the top PHEV makes. Three of the top four PHEV makes exhibited comparable higher rates of entering the used market, between 29%-39%, except for Toyota PHEVs, which had rates similar to BEVs, at 7%-23%.

We gained insights into the buyers of these vehicles. In the used ZEV market, most vehicles were exchanged between individuals, and there was a lesser flow from entities to individuals. Furthermore, residents of disadvantaged communities (DACs) gained 2.5% of the used ZEV fleet. The used ZEVs flowing into DACs compared to the entire used ZEV fleet consisted of slightly more non-Tesla BEVs (32% vs. 23% of the used ZEV fleet) and slightly fewer Tesla BEVs (12% vs. 17% of the used ZEV fleet). Notably, DAC status did not yield statistically significant results in the used ZEV destination model, hinting that other factors might better explain the flow of used ZEVs into DACs. This suggests that other factors—such as income, ethnicity, population characteristics, or rent prices—might better explain this rate flow into DACs.

Finally, we see clear trends in the sources and destinations of used ZEVs. Several variables impact the number of used ZEVs coming from or entering a census tract in 2016–2020. The highest income bracket, those making over \$200,000, did not participate substantively in the used ZEV market, either by generating used ZEVs for other tracts or gaining used ZEVs from other tracts. This was especially true for the highest income Asian households. In contrast, the next three highest income brackets—\$100,000 to \$125,000, \$125,000 to \$150,000, \$150,000 to \$200,000—generated and attracted many used ZEVs of all types, regardless of ethnicity. The highest income groups were not eligible for incentives aimed at new ZEV purchases for at least a portion of the study period, while lower income groups were likely eligible. Lack of incentives does not appear to have impacted who gains or creates used ZEVs. Additionally, land use type seems to play a role in where used ZEVs end up. Rural areas tended to gain used PHEVs more than urban areas did. Meanwhile, urban areas gained more non-Tesla BEVs.

The establishment of a successful secondary market for used ZEVs relies heavily on buyers of new ZEVs who are motivated to electrify their entire vehicle fleet. These buyers actively participate in the secondary market by regularly updating their vehicles. More research is needed into used ZEVs sources and the impacts of incentives, leased vs. purchased vehicles, and vehicle supply on the decision to replace a ZEV or purchase a

used ZEV. While this analysis provides an aggregate perspective on the origin and destination of used ZEVs, delving into individual-level characteristics of these households requires additional analysis.

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