Where are Used Electric Vehicles and Who are the Buyers?

July 2021

A Research Report from the National Center for Sustainable Transportation

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16. Abstract

Very little research has been conducted on the second (and third, and thereafter) owners of new technologies. For light duty vehicles, the research has been focused on the first owners. In the case of plug-in electric vehicles (PEVs), understanding the secondary market is especially important for many reasons, including the vehicle market development and on-road usage. The second owner is also an adopter of new technology, many times taking greater risk than the original owner by purchasing a vehicle close to, or after, the end of the warranty. Data on vehicle ownership at the zip code level was used to explore the total number of vehicles, the number of electric vehicles (EVs) owned by the original owner, and the number of EVs owned by a second or third owner. Results suggest that in areas with few EVs overall, used PEVs make up a higher share of all PEVs, but a lower share of all vehicles. Used PEVs are slightly less spatially concentrated than new ones, possibly because of a weaker neighborhood effect and possibly because their lower cost makes them accessible to slightly more people. The study finds that at least in this phase of the market development, used PEVs are not trickling down at a high rate, but more research is needed to evaluate the reasons for this phenomenon. Policies that focus on the progression of used PEVs to secondary owners by improving the information provided to used car buyers, reducing the risk of purchasing a new technology, improving the availability of charging, and addressing other barriers, can help communities with low rates of PEV adoption and improve the market growth in the future.

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EXECUTIVE SUMMARY

Very little research has been conducted on the second (and third, and thereafter) owners of new technologies. For light duty vehicles, the research has been focused on the first owners and the last owner were likely to scrap the car. In the case of plug-in electric vehicles, understanding the secondary market is especially important for many reasons, including the vehicle market development, on-road usage, and grid impacts. The growth of the electric vehicle (EV) new car market is highly correlated with the used car market as many of the EV buyers are expected to be repeat buyers (or leasers) and a strong secondary market allows high residual value and the opportunity to buy a new car. The second owner is also an adopter of new technology, many times taking greater risk than the original owners by purchasing vehicle close to, or after, the end of the warranty. Furthermore, the lower price of the used vehicles opens the opportunity for lower income households to adopt the new technology and reduce their transportation operating costs. Understanding the used plug-in vehicle market is especially important in estimating the impact of this technology on disadvantaged communities, households with lower incomes, and communities with higher exposure to air pollution. The locations of the used cars are important for understanding the environmental impact and the electrical demand for charging. Many policies aim to help the original owner installing a home charger, reducing the cost of home electricity, and charging in public locations. The second owner's identity is not always known and in many cases, they are not afforded the same incentives and opportunities that the original owners have access to.

Research focused on new car buyers suggests a strong correlation with socio-demographic characteristics like income and housing type, as owners of detached houses are more likely to have plug-in vehicles. Furthermore, previous studies identified a strong neighborhood effect entailing that areas that already have large numbers of electric vehicles are likely to have higher adoption rates than what would be predicted by socio-demographic characteristics only. The neighborhood effect was observed around the home location but also as a function of the number of EVs a potential buyer is exposed to at the workplace.

We used data on vehicle ownership at the zip code level to explore the total number of vehicles, the number of EVs owned by the original owner, and the number of EVs owned by a second or third owner. We expected the used cars to be owned by households with lower income than the original owners and therefore we expected higher distribution of EVs across different communities. We also expected the neighborhood effect to impact the secondary market similarly to the impact on the new car market, a phenomena that will slow down the adoption of EVs in areas with a low share of new vehicles in general and EVs particularly, and speed it up in areas with higher adoption.

Our results suggest that in areas with few EVs overall, used PEVs make up a higher share of all PEVs, but a lower share of all vehicles. Used PEVs are slightly less spatially concentrated than new ones, possibly because of a weaker neighborhood effect and possibly because their lower cost makes them accessible to slightly more people. We find that at least in this phase of the market development, used PEVs are not trickling down at a high rate, but more research is needed to evaluate the reasons for this phenomenon. Policies that focus on the progression of used PEVs to secondary owners by improving the information provided to used car buyers, reducing the risk of purchasing a new technology, improving the availability of charging, and addressing other barriers, can help communities with low rates of PEV adoption and improve the market growth in the future.

Introduction

With the introduction of a variety of new plug-in electric vehicles (PEVs), including battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), the market share of PEVs in the U.S. has been rapidly increasing year-over-year. The U.S. National Research Council predicts that approximately 13 million electric vehicles (EVs) will be on U.S. roads by 2030, which will account for 4% of the U.S. fleet in 2030 (in the most probable scenario) [1]. Previous studies focus on new PEV distribution, but to the best of our knowledge, no study has addressed the spatial distribution of PEVs in the secondary market, including the impact on disadvantaged communities, infrastructure needs, and energy demand.

However, many government entities in the U.S.—at city, county, state and federal levels—want to accelerate the market penetration of PEVs in all communities to improve the local environment, reduce greenhouse gas emissions (GHGs), and improve mobility. There have been many studies to understand and identify the factors relating to individuals' adoption of new PEVs and a few studies to develop spatial models to estimate and forecast spatial distribution of new PEV market penetration. The most commonly found factors were PEV buyers' socio-demographic variables such as age, gender, level of education, household size, and income, as well as travel patterns including travel distance and duration, and household vehicle composition and vehicle characteristics [2]–[9].

In addition, it is also important to understand where the PEV users are located, so electric vehicle supply equipment (EVSE) can be installed in the right areas and to develop electricity supply plans looking toward a future with higher adoption. The determinants identified above are also important for developing spatial models of PEV market penetration as they help us to understand spatial PEV charging demands [11]. However, an understanding of used PEV market penetration does not currently exist, even though about 55% of plug-in hybrids (PHEVs) and 80% of battery electric vehicles (BEVs) have been leased according to Bloomberg New Energy Finance [12]. These vehicles will be turned over to the used vehicle market quickly because their average lease duration is approximately three years. Therefore, it is critical to understand used PEV market penetration because the buyers of these PEVs are different from brand-new PEV buyers, and the spatial models developed from brand-new PEV data may generate a mismatch between spatial demand and supply of PEV charging infrastructure. This study will fill this research gap and make policy recommendations on the used PEV market. Developing infrastructure and policies to support used PEVs may attract wider groups of people into the PEV market. In addition, this paper will provide new insights to EVSE and energy supply planners to understand an undervalued part of the existing PEV market.

The aim of this paper is to understand who the buyers of second-hand PEVs are and where they are located. The following specific research questions will be addressed:

1) What factors are correlated to the purchase of a used PEV and how does this differ from the purchase of a new PEV or an internal combustion engine vehicle ICEV. This will include investigating socio-demographic factors and the location of car buyers.

2) Are new-PEV-owner to used-PEV-owner flows (including changes in socioeconomic profiles of the buyers, and where the vehicles are sold new and sold used) different between second-hand PEVs and ICEVs?

Data

Considering the PEV market in California, according to the Department of Motor Vehicles (DMV), there were total 264,603 PEVs registered in 2017. Out of the total stock of PEVs in the state, 257,766 (97.4%) were first sold in California and remained in-state. The remaining 6,837 PEVs were first sold in other states and then registered in California. The latter group includes not only cases where the household moved to California from another state but may also include cases of used vehicles bought from another state. However, we cannot identify the scenario where a used vehicle was bought from another state. Therefore, unless mentioned otherwise (have information on the last transfer date in the data), we assume that the PEVs that were first sold in "Other states (OS)" and registered at a later date in California are cases where the first owner of the vehicle moved to California. Given the data on last transfer date, we identified 1,367 "OS" vehicles were transferred or in other words bought "used" by a household. Out of the 257,766 "CA" vehicles, 60,682 were involved in transfers within California.

For the national level, this study uses existing data that has been gathered by the Plug-in Hybrid & Electric Vehicle (PH&EV) Research Center from a variety of DMV records, utilities data and survey results across the U.S. This data contains more than 400,000 EV sales records nationwide. By comparing the second owners with the brand-new PEV buyer group and the second-use ICEV buyer group, it is possible to gain a clearer understanding of who the second-use PEV buyers are, and identify potential factors needed to develop spatial models for second-use PEV market penetration. Table 1 shows the number of used vehicles that were transferred in California each year from 2007 through 2017.

Table 1. Number of PEV transfers year-by-year in California

Year	BEV (#)	PHEV (#)	Total PEV (#)
2007		1	1
2008			-
2009	1		1
2010	1		1
2011	86	8	94
2012	193	103	296
2013	766	569	1,335
2014	1,628	2,022	3,650
2015	4,134	6,238	10,372
2016	8,427	13,406	21,473
2017	10,993	13,830	24,823
Total	**26,229**	**35,820**	**62,049**

We observe in the data that there are some vehicle models that are involved in more transfers/ used vehicle transactions than others. In Table 2, we show the top 10 vehicle models that were transferred or bought as used vehicles by households in California. These transfer rates generally match the popularity of vehicle models for new PEV sales.

Table 2. California PEVs transferred by make and model, top 10

	2011	2012	2013	2014	2015	2016	2017
Nissan Leaf	72	161	332	849	2,087	3,867	4,054
Chevrolet Volt	8	40	219	1,042	3,066	6,085	4,739
Toyota Prius Plug-in		61	273	628	1,670	2,848	3,290
Fiat 500e			14	33	154	686	2,002
Ford C-max Energi			18	114	493	1,328	1,482
Ford Fusion Energi			14	134	606	1,672	2,294
Tesla Model S			100	261	898	1,936	2,087
Toyota Rav 4			22	63	124	371	429
BMW i3				16	281	769	1,711
Ford Focus		3	32	56	167	493	224

Descriptive Analysis

We use two variables to measure the market size of used PEVs in California. First, we consider the share of used PEVs in the total vehicle stock to analyze where the used PEVs are in the state. Second, we consider the ratio of used PEVs to new PEVs to analyze if some areas in California are more likely to adopt used PEVs. Both the analyses are done at the zip code level due to data constraints.

Considering some key socio-demographic characteristics of the zip codes in the top and bottom quantile of the distribution of the two market size measures, we observe that the zip codes with a higher share of used PEVs in the total vehicle stock tend to have a higher median income than those in the bottom quantile. However, when we consider the ratio of used to new PEVs, we observe that area with relatively lower median income may have a higher share of the used PEVs. The relationship between income and the distribution of the two constructs seem to indicate that, like new PEVs, while used PEVs may have penetrated mostly higher income areas so far, the latter can gain market share among lower income groups once they are exposed to the technology. The relationship between income and used PEV market share is also evident from the number of zip codes that have census tracts with disadvantaged community classification (DAC) in the top and bottom quantile of these two constructs. Though we do not observe a major difference in terms of share of renters, zip codes with a higher ratio of used PEVs to all vehicles tend to have a population with higher median age and a higher share of white households, when compared to zip codes that have a high ratio of used PEVs to all PEVs. So, in regions with low PEV adoption overall, the socio-demographics of used PEV buyers more closely matches that of new PEV buyers. In regions with higher PEV adoption, the income and age of used PEV buyers are both lower than that of new PEV buyers.

An analysis of survey data from people who purchased used PEVs, reported by Turrentine, et al. [13], shows that most of them specifically intended to purchase a used PEV and were particularly set on purchasing a PEV as opposed to an ICEV (Figure 1).

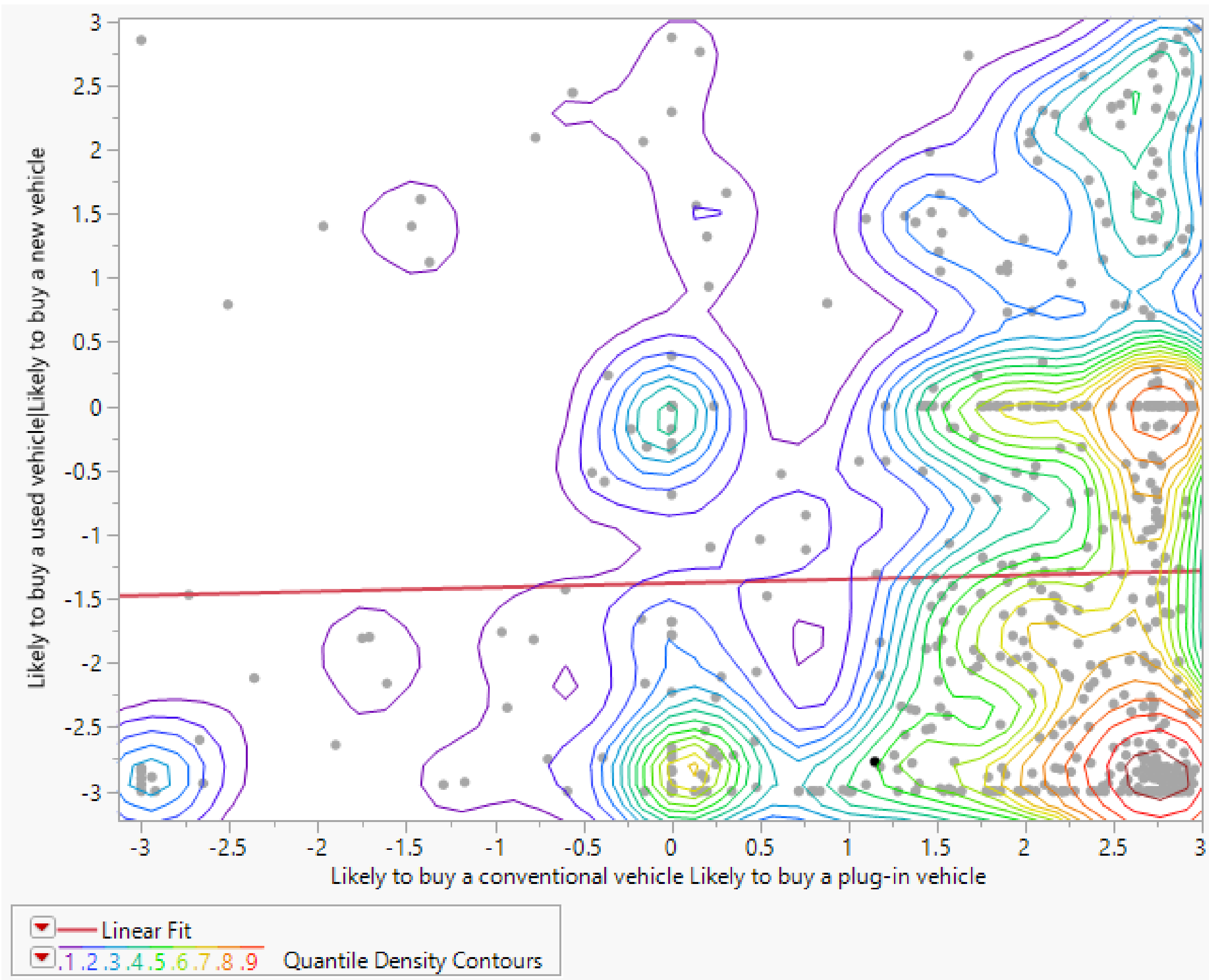

Figure 1. Density map of purchasing intention of used / new vehicles and ICEV / PEV for people who eventually purchased used PEVs

Spatial Analysis

The PH&EV Research Center used the one million vehicle purchase records acquired from Experian Automotive in 2016 to perform spatial analysis of the market for used PEVs for the U.S. and California. These results indicate that the used PEV market may work differently in California than the rest of the country. Nationwide, used PEVs are even more densely concentrated in a few states and regions than new PEVs, but within California, used PEVs are somewhat less densely concentrated than new PEVs, although almost all of them are still in areas with high overall PEV density.

In order to compare the spatial distributions of new and used PEV market, we created two maps at the five-digit zip code level. West coast states (California, Oregon, and Washington) have higher levels of PEV sales in both the new and used market. Although new PEVs were somewhat widely distributed, used PEVs were much more concentrated in a few, mainly urban markets. We also examined state-by-state PEV sales patterns (Figure 2). California has by far the largest PEV market in the U.S. and appears to be a major source of used PEVs sold in other states. The state accounts for about 54.7% of new PEV sales and about 33.2% of used PEV sales. This suggests used vehicles are being exported from California. Washington, New York, and Florida are the second, third, and fourth largest markets for PEVs, respectively. When compared to their new PEV sales, Washington, Florida, Texas, Oregon, and Georgia have substantially more used PEV sales than other states. In contrast, east coast states, including New York, Maryland, and New Jersey, and mid-west states, including Michigan and Wisconsin, have relatively smaller used PEV market [13].

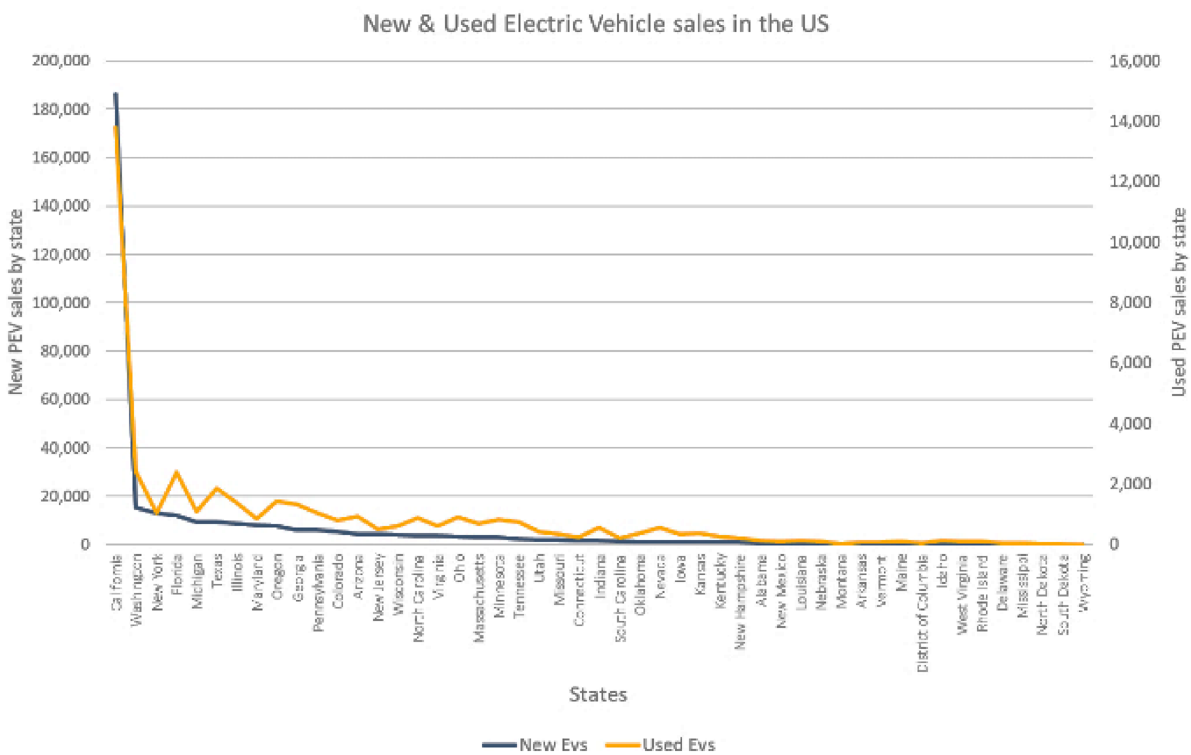

Figure 2. New and used electric vehicle sales in US by state

Spatial Concentration of Used PEV Market in California

California contains the largest share of PEVs of any state, and these vehicles are somewhat widely distributed throughout the state, although they remain much more common in wealthier suburban and urban areas than in rural or less wealthy areas. While used PEVs follow a very similar spatial distribution to new PEVs, they are somewhat less densely concentrated than new PEVs. Used PEVs make up a much larger share of all PEVs in zip codes with relatively few PEVs, but the most used PEVs are still in areas with the largest number of total PEVs.

Analysis of the distribution of new and used PEVs in California as a proportion of all vehicles shows that while all EVs are densely concentrated in a small number of zip codes in particularly dense areas, used PEVs are somewhat less concentrated than new PEVs (Figure 3). Among new PEVs, half are located in the top 15% of zip codes. Among used PEVs, half are in the top 25% of zip codes. For both new and used PEVs, less than 15% of vehicles are in zip codes in the bottom half by PEV density.

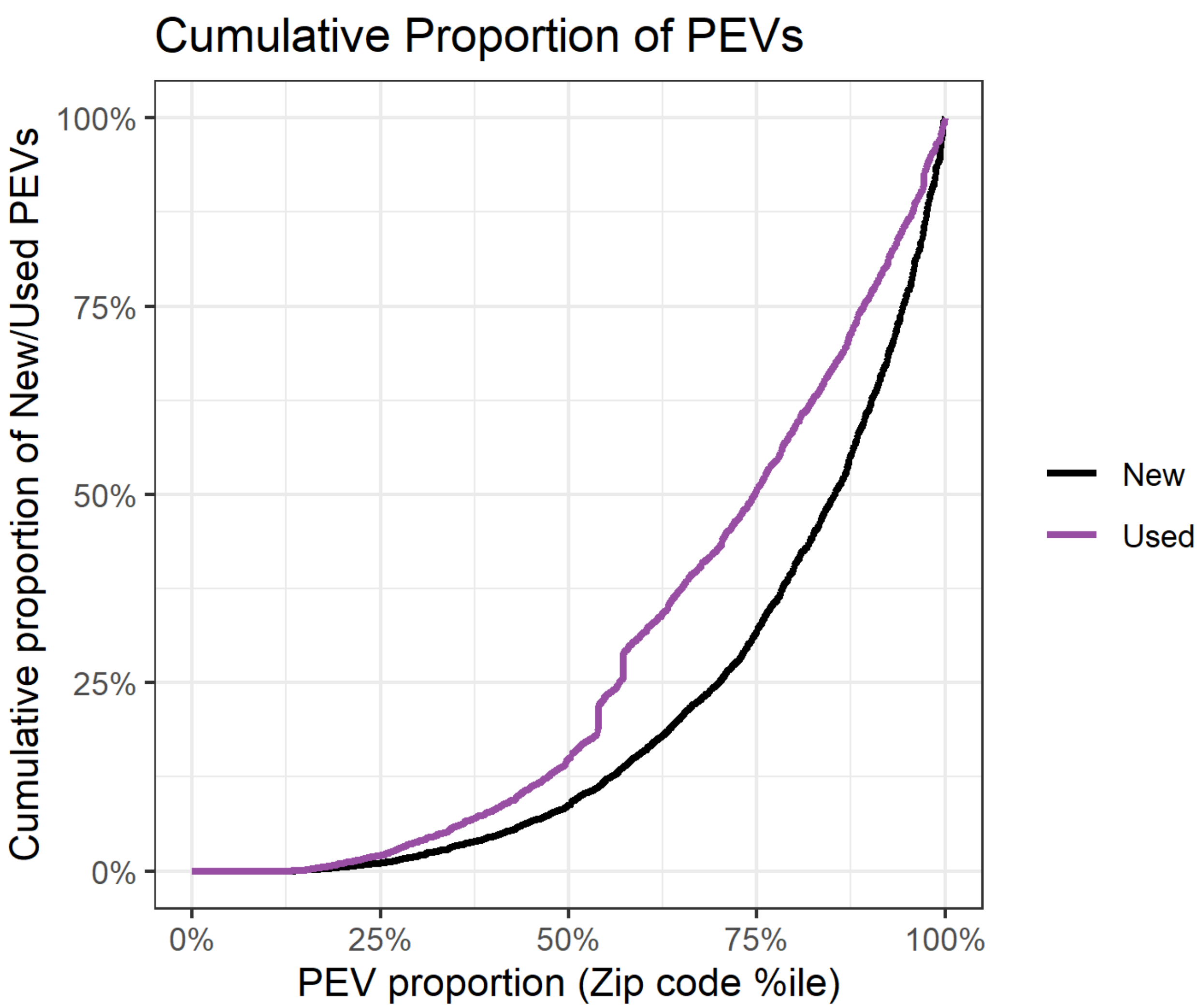

Figure 3. California Cumulative distribution of new and used PEVs by PEV density percentile.

Although used PEVs are less spatially concentrated overall than new PEVs, this does not necessarily indicate that they are a major component of the spread of PEVs to new parts of the state as the fitted line is not based on large enough of a sample size on the right side of Figure

4. Used PEVs are more common in zip codes with few PEVs overall and represent a much smaller fraction in places where they are more common overall.

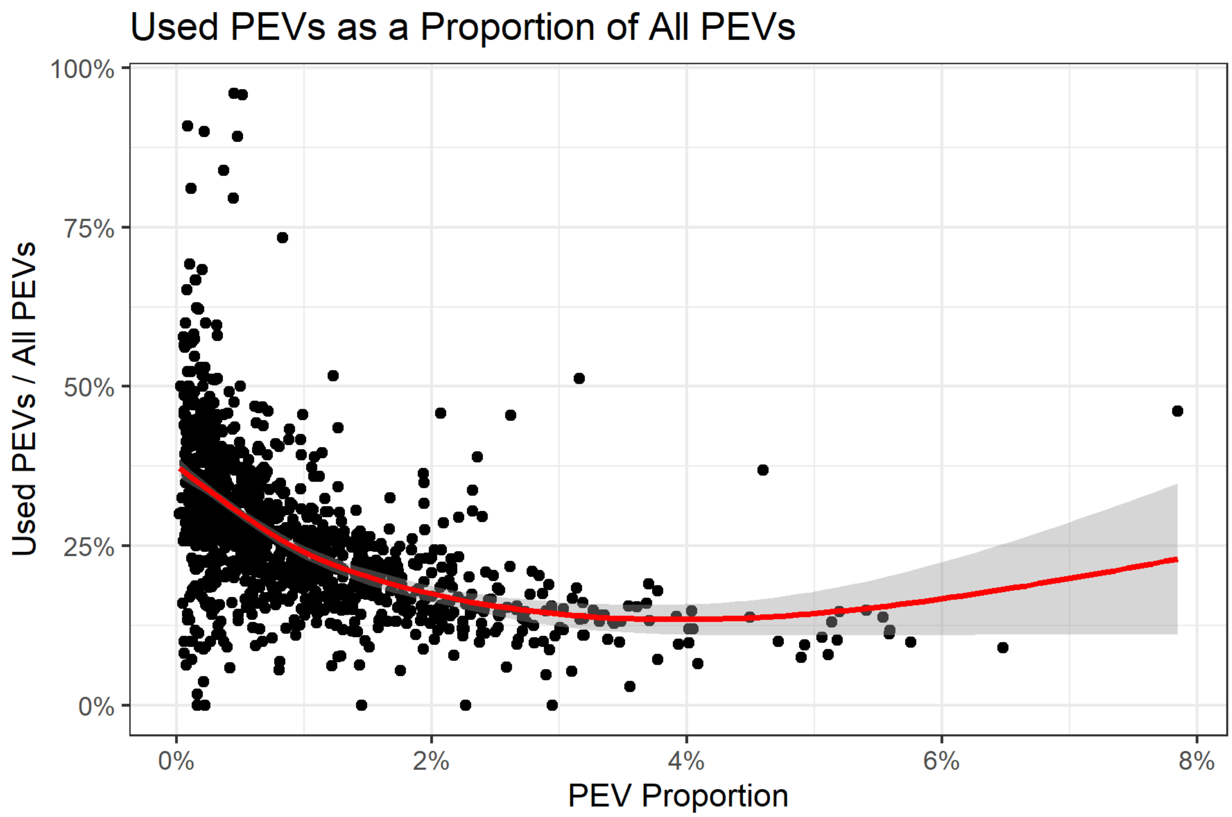

Figure 4. Used PEVs as a proportion of all PEVs as a function of PEV proportion of all vehicles

Spatial Distribution of Used PEV Market

In addition to being concentrated within a few zip codes, EVs are heavily concentrated within the state but may have a slightly weaker neighborhood effect than new PEVs, as shown by a correlogram of EV proportion, a non-parametric spatial method that does not rely on the specification of a spatial weights matrix (Figure 5). While both new and used PEVs have significant spatial autocorrelation, zip-code-level new PEV density has a correlation of over 0.6 with the density in the five nearest other zip codes, indicating that areas with many PEVs are almost exclusively surrounded by other areas with a large share of PEVs and vice versa. Used PEVs show a much less consistent spatial relationship, which indicates that the market penetration of used PEVs is less spatially concentrated and perhaps somewhat more dependent on the supply at a few specific locations than for new PEVs. This spatial relationship decays substantially with distance (each lag corresponds to the next five nearest zip codes) but remains much higher for new PEVs than used ones, such that the fraction of new PEVs in a zip code is more similar to the values from the nearest 40 neighboring zip codes than the fraction of used PEVs is to the nearest five neighboring zip codes. This indicates that new PEVs are much more heavily concentrated in a few specific regions of the state than used PEVs are.

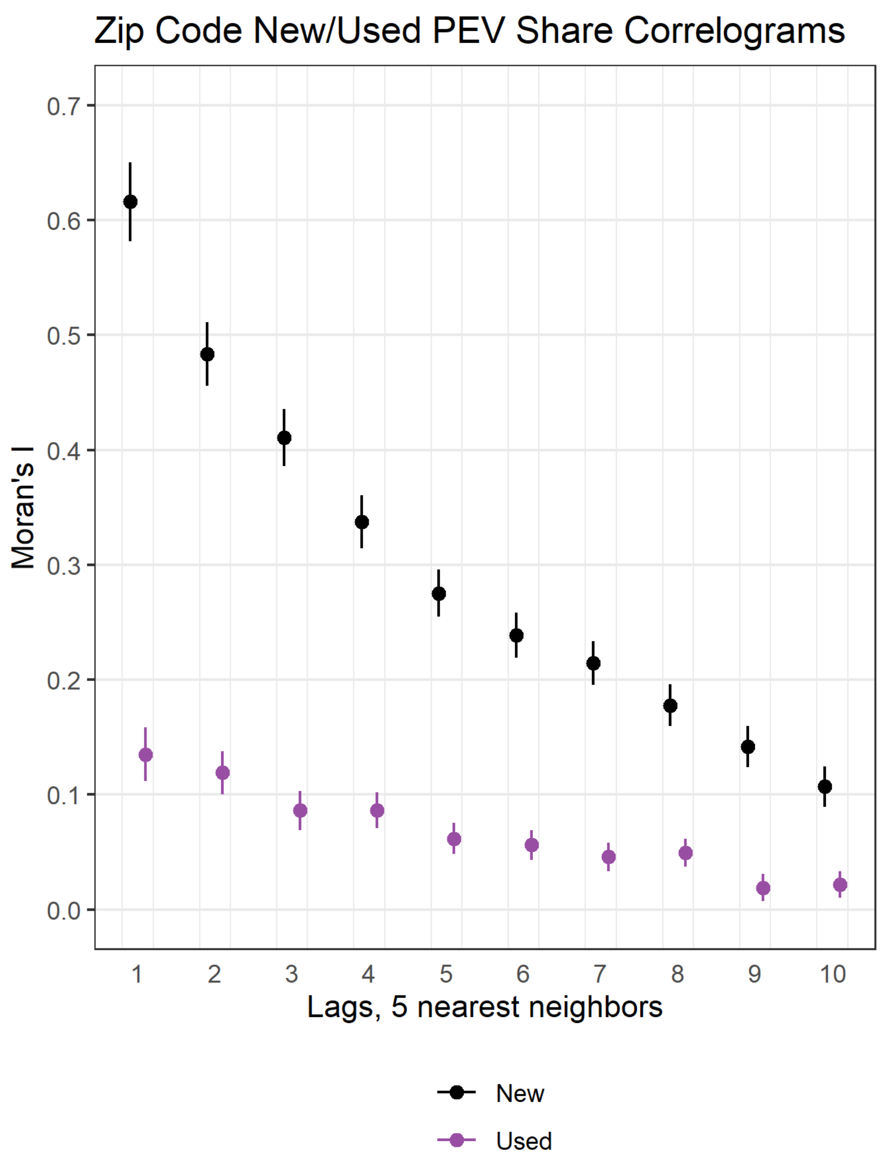

Figure 5. Correlogram of Zip-code-level vehicle share for new and used electric vehicles.

Regional analysis of the spatial distribution of used PEVs indicates that while they generally follow the same spatial distribution as new PEVs, the market for used PEVs may be a significant contributor to the expansion of the PEV market in some specific regions. Regional analysis of the spatial distribution of used PEVs in Northern and Southern California (Figure 8 and Figure 9) generally confirms the findings shown in Figure 3 and Figure 4 that used and new PEVs are heavily concentrated in a few zip codes. Likewise, these maps show zip codes with large shares of used PEVs are generally located near other zip codes with large shares of similar used PEVs.

The maps of used PEV share of all vehicles (Figure 6 and Figure 8) show that used PEVs are heavily concentrated in wealthy urban and suburban areas and are much less common farther from the city center.

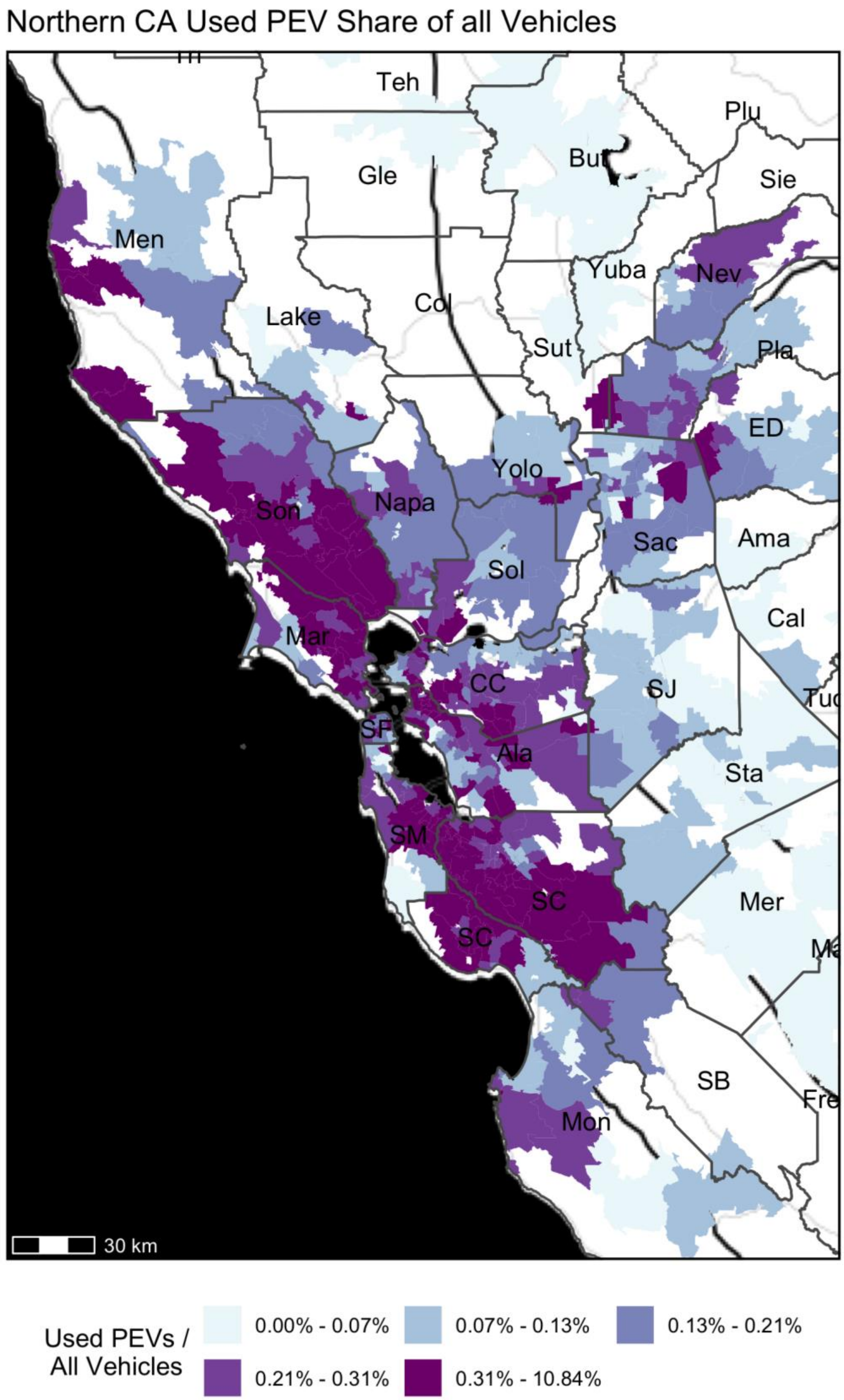

Figure 6. Map of used PEVs as proportion of all vehicles by Zip code, Northern California

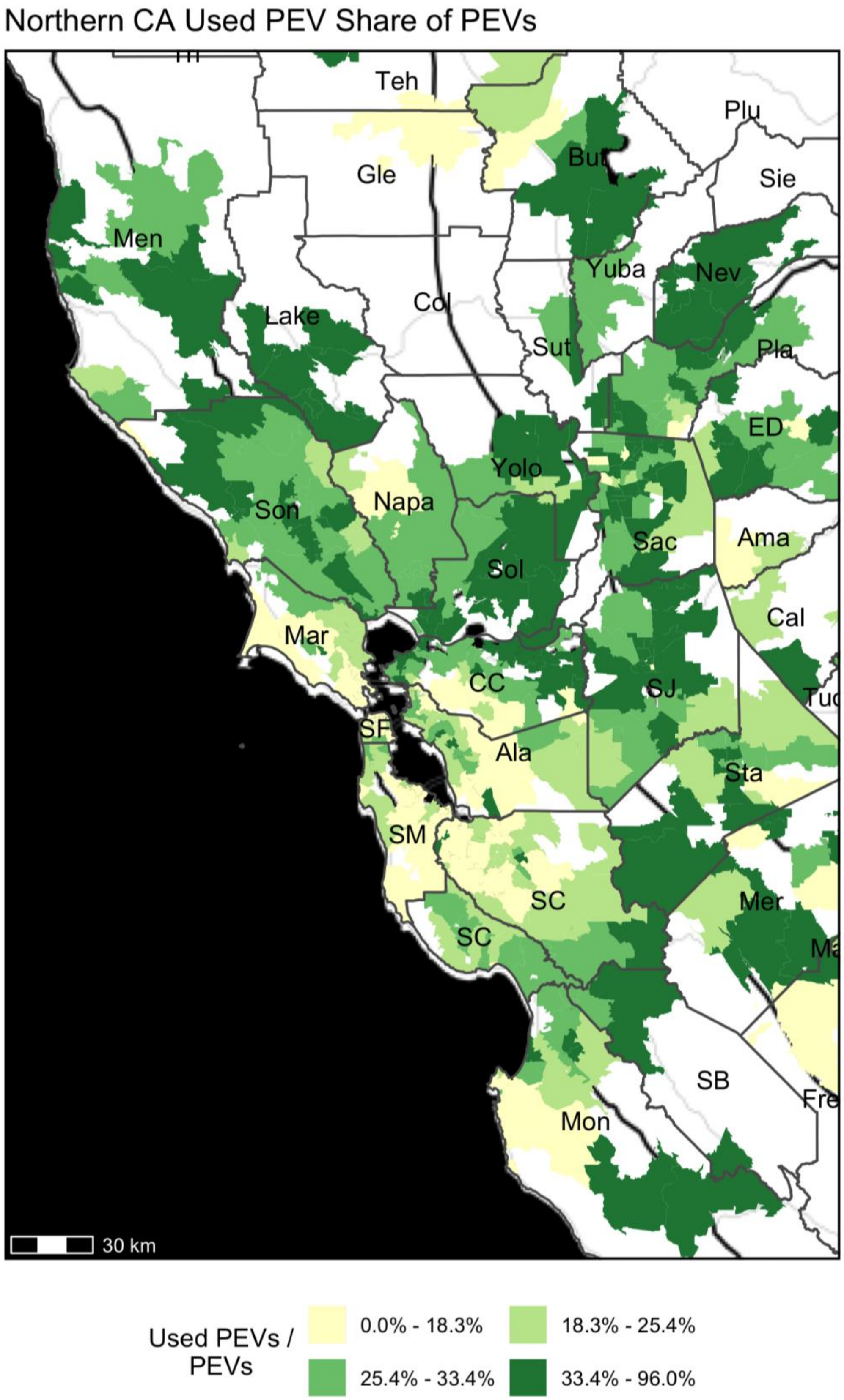

Figure 7. Map of used PEVs as proportion of electric vehicles by Zip code, Northern California

The maps of used PEV share of PEVs (Figure 7 for Northern California and Figure 9 for Southern California) show that used PEVs are relatively more important to the spread of PEVs in areas that are farther from urban centers and wealthy areas. Used PEVs also make up a larger share of all PEVs within parts of Oakland / Alameda County (Ala in the maps of Northern California) and central Los Angeles (LA in the maps of Southern California) that have relatively low PEV shares but are surrounded by areas with extremely high concentration of PEVs. Comparing the two sets of maps indicates one region in which used PEVs appear to have contributed substantially to the overall increase in PEV ownership. In the Sacramento area (counties marked Sac, Yolo, ED, Pla, and Nev), many zip codes are in the top two categories for used PEV share of all vehicles and have used PEVs making up a large share of all PEVs.

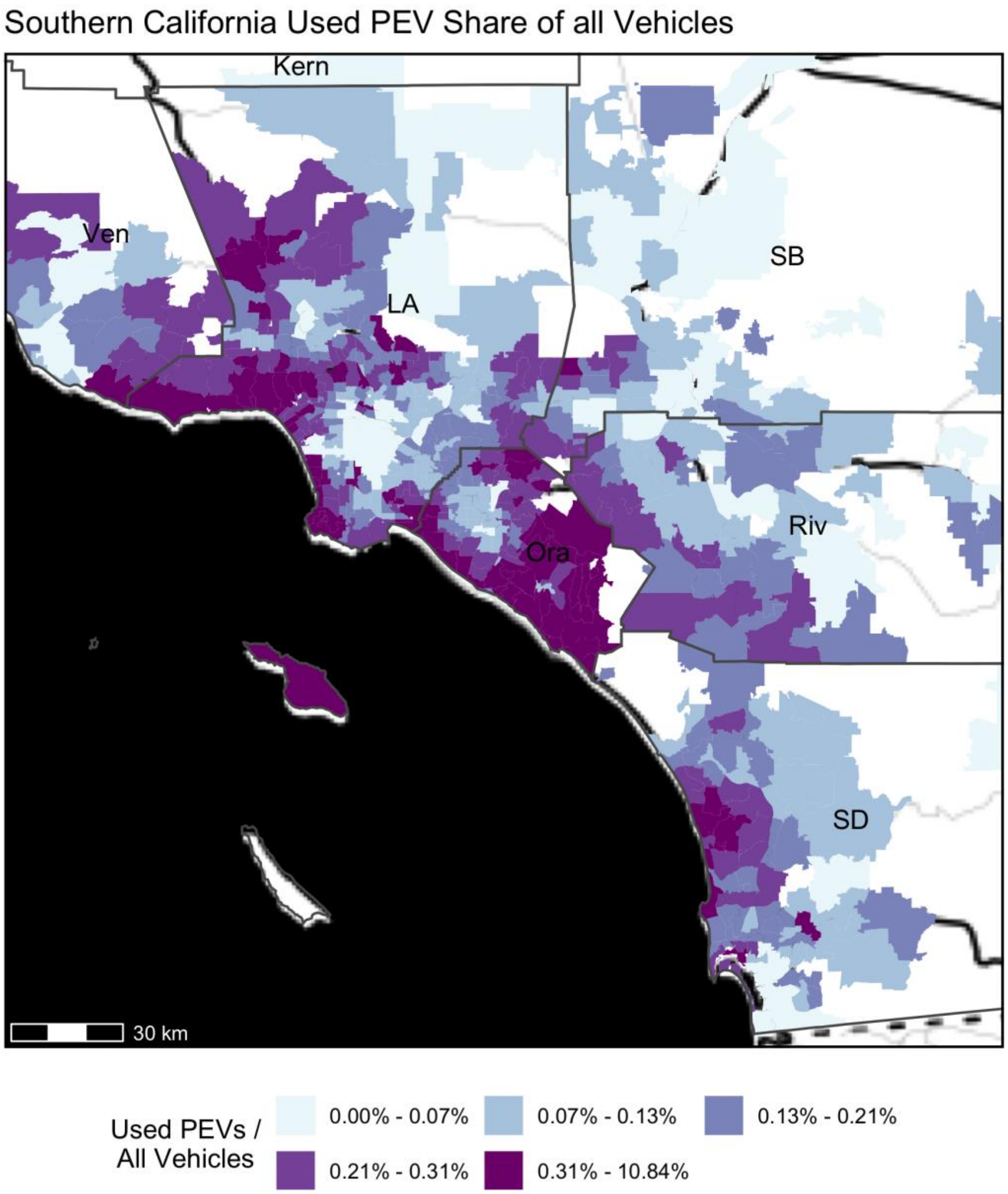

Figure 8. Map of used PEVs as proportion of all vehicles by Zip code, Southern California

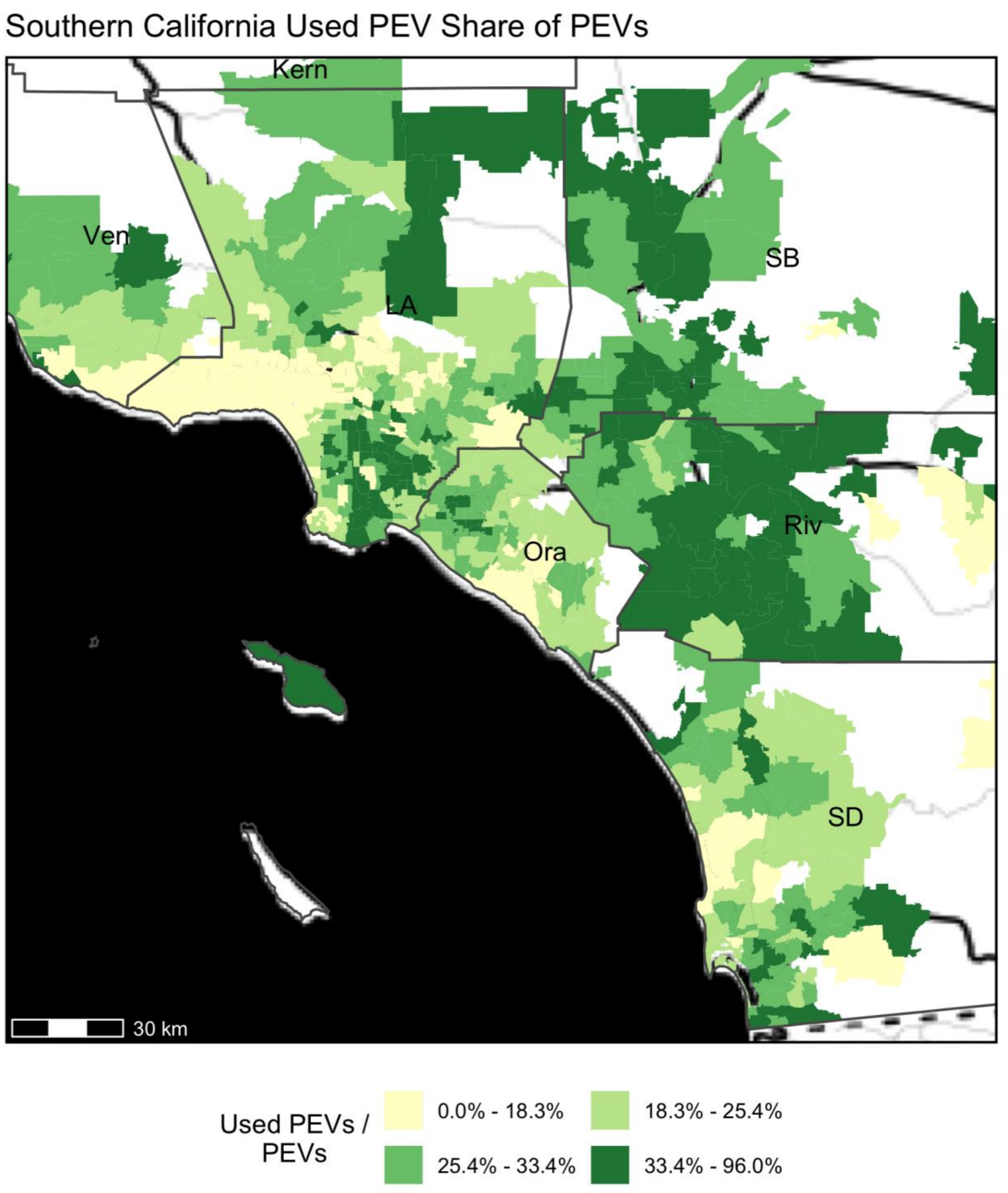

Figure 9. Map of used PEVs as proportion of electric vehicles by Zip code, Southern California

Conclusion

Our initial hypothesis about used PEV was that the lower price would help in higher distribution of those vehicles to more locations and communities with lower average income. Furthermore, we expected the used vehicles to be sold in more regions and states that are not correlated with the ZEV mandates or strong incentives. Overall, this study found that used PEVs are more likely to appear in areas with new PEVs, possibly resulting from the neighborhood effect and the familiarity with the new vehicle technologies. Ownership of housing vs. renting could also partially explain why used PEV adoption largely follows new PEV adoption, i.e., that those that do not own the house they live in are less likely to be able to install chargers or solar panels, and control their home charging cost. Used PEVs are slightly less spatially concentrated than new ones, possibly because of a slightly weaker neighborhood effect and possibly because their lower cost makes them accessible to slightly more people. We find that at least in this phase of the market development, used PEVs are not trickling down at a high rate, but more research is needed to evaluate the reasons for this phenomenon. Policies that focus on the flow of used PEVs can help communities with currently low rates of PEV adoption and control the market growth in the future.

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Data Management

Products of Research

No data was collected.

Data Format and Content

Not applicable.

Data Access and Sharing

The number of new and used EVs per zip code are based on DMV records that are not available to the public.

Reuse and Redistribution

Data for county-level analysis of new PEV sales can be downloaded from https://www.energy.ca.gov/data-reports/energy-insights/zero-emission-vehicle-and-charger-statistics.