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Exploring factors related to future electric vehicle ownership across rural California

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Executive Summary

Adoption of electric vehicle (EV) technology for passenger vehicles is a crucial step in decarbonizing the transport sector. Understanding how vehicle adoption differs across space in urban and rural areas can assist in addressing equity concerns in planning for this emerging technology. This study aims to examine the heterogeneity of sociodemographic characteristics, vehicle ownership, and travel behavior in rural California. Statistical analyses found that a higher proportion of rural residents are homeowners who are lower income and have lower levels of formal education than urban residents. Rural residents also own a higher proportion of ICEVs, and pickup trucks, and vehicles overall tend to be older. A higher proportion of rural residents have a short commute time and a lower proportion of them take public transit to commute to work. This study has practical implications for policy makers and transportation agencies that can use the findings to inform policies relating to infrastructure needs, energy use, and EV adoption across rural California.

Keywords: electric vehicle, rural-urban continuum, heterogeneity, vehicle ownership.

1 Introduction

To reach carbon neutrality by 2050 and limit global warming to well under two degrees Celsius [1], all emitting sectors must adopt zero emissions technologies. In the United States (US), transportation accounts for 27% of greenhouse gas (GHG) emissions, 57% of which come from passenger vehicles [2]. Therefore, adoption of zero emissions technologies is a key step in decarbonizing the transport sector. Currently, the most feasible and effective of these technologies are electric vehicles (EVs), which includes both plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs).

California is at the forefront of ambitious policies and regulations to decarbonize. To achieve an equitable transition to carbon neutrality by 2045, as set out in Executive Order B-55-18, California must provide access to EVs for all communities [3]. Currently, rural areas lag urban areas in EV adoption and public charging infrastructure availability. Rural vehicle owners also face unique barriers and constraints to EV adoption given the greater distances between essential amenities, and a lack of access to public transit [4].

Review of the literature indicates that, at finer spatial scales (local and regional), very little is known about rural vehicle owners, including sociodemographic factors, vehicle characteristics, and travel behavior and even less is known about rural EV owners. Given the diversity of culture, land use, and landscape characteristics across California, a one size fits all approach to policy may not be suitable. To encourage EV adoption in rural California, it is important to first characterize the diversity of rural vehicle owners so that we can understand how current and future EV policies might affect these regions.

This study uses comprehensive datasets of sociodemographic characteristics and travel behavior from the American Community Survey (ACS) and vehicle characteristics from the Department of Motor Vehicles (DMV) to build a complete picture of rural vehicle owners in California. Different definitions of rurality are compared to gain insight into the heterogeneity of vehicle owners across the state. This study aims to understand the following factors and the potential impact on EV ownership and usage:

- Household and vehicle characteristics of rural residents and vehicle owners
- Vehicle ownership and use differences between rural and urban areas.
- The heterogeneity of rural populations through definitions of rurality.

2 Literature Review

American vehicle owners living in rural areas have different travel behaviors and vehicle characteristics compared to urban vehicle owners. This includes higher average vehicle miles traveled (VMT), a higher proportion of internal combustion engine vehicles (ICEVs), and higher rates of ownership of medium and heavy-duty pickup trucks [4] [5] [6] [7]. Much of the literature on vehicle use in rural America focuses on ICEVs or the literature does not make a distinction between different fuel types. Pucher and Renne [5] provided a foundational study on rural mobility using 2001 National Household Travel Survey (NHST) data to compare mobility and vehicle reliance across urban and rural areas of the US. They found that on average, rural households made 5% fewer trips per day than urban households [5]. These numbers varied across income categories with lower income rural households making almost the same number of trips per day as their urban counterparts, while higher income rural households made 15% fewer trips per day than their urban counterparts. Millward and Spinney [6] looked at travel behavior along the rural-urban spatial continuum in Nova Scotia, Canada, found a similar trend with the average number of trips decreasing with increasing rurality. The study used real time data to track vehicle use across the rural-urban continuum over a 48-hour period, thus, it provides important empirical evidence of differences between urban and rural vehicle use. Although rural vehicle owners tend to make fewer trips, average annual VMT is higher for rural residents, indicating that each trip is longer [4].

Available literature on alternative fuel vehicle use often uses VMT as a key metric to measure vehicle use. Using the 2017 NHTS data, Davis [8] looked at VMT differences between EV owners and ICEV owners in California. BEVs were found to have the lowest average annual VMT followed by PHEVs, ICEVs, and hybrid electric vehicles (HEVs). VMT of plug-in hybrid electric vehicles (PEVs) was found to be 30% lower than other fuel types [8]. However, studies that looked at PEVs with longer ranges found that VMT was just as high for BEVs as for PHEVs [9]. Most of the data on electric VMT to date comes from self-reporting in surveys. Therefore, there is little reliable data to draw conclusions from. A panel survey by Chakraborty et al. [7] looked at annual mileage of PEVs across two time points, taking an average across time for more reliable results. Looking across single and multi-vehicle PEV households, the authors found that PEV owners are driving as much as ICEV owners. In multi vehicle households, availability of level 2 charging, and vehicle range were determinants of VMT [7]. Lee et al. [10] identified early adopters as older, retired owners with more than one vehicle in their household. These characteristics are generally associated with lower VMT and as a result may skew the results of studies looking at electric VMT [11]. Although, many studies have looked at the factors that influence VMT, and a subset of those focus on alternative fuel vehicles, no studies have looked at travel behavior of EV owners in rural areas. The current literature on EV travel behavior regards the study areas as spatially homogenous.

Literature on early EV adopters provides insight into the sociodemographic and household characteristics of these vehicle owners. To date, early EV adopters have been mostly highly educated, high income males. Lee et al. [10] conducted a latent cluster analysis on survey data from PEV owners between 2012 and 2017 to characterize the heterogeneity of early adopters of PEV technology in California. The largest group of adopters (47.9%) were the 'high income families' group that is characterized by higher income, middle aged, mostly male, home owning, highly educated households. Although the authors identify heterogeneous groups of EV owners, they regard the study area as homogenous in terms of where these groups are spatially located. However, given the income disparities between urban and rural areas, there may be an additional level of spatial heterogeneity that exists that requires further exploration [12].

Much of the literature focuses on either travel behavior in rural areas or in EV owners, however, very little is known about EV ownership and vehicle use across rural areas. Also, few studies have looked at the variation in vehicle ownership across the rural-urban continuum and the sociodemographic characteristics of these vehicle owners. Understanding the differences in these characteristics across space has important implications for informing transportation policy.

3 Data and Methods

3.1 Data

3.1.1 Urban and rural delineation

A literature review was conducted to identify the various methods which define urban or rural settings in the US. Depending on the definition used for calculating rural populations, up to one quarter of Americans live in rural areas [4] [12]. Defining rural areas is important from a policy perspective as these delineations can determine the distribution of funding and other government resources [12].

Common methods for defining areas across the rural-urban continuum include the use of population or population density estimates, and measures of daily commuting. One of the most widely used definitions is the US Census Bureau definition [12]. The Census Bureau defines urban and rural areas based on population and population density of the most recent census, measured at the block group level. For the 2010 Census, urban areas consisted of densely populated areas with a minimum population of 2,500 people. Urban areas are further classified into two types: a) urbanized areas, which have a population of 50,000 or more people, and b) urban clusters, which have a population of at least 2,500 but less than 50,000 people. For the 2020 Census, an urban area is defined primarily based on housing unit density and must encompass at least 2,000 housing units or at least 5,000 people. Rural areas are all population, housing, and territory not included within an urban area. The US Census Bureau definition follows a land-use concept [13], by identifying urban areas based on how densely settled the area is, which is useful for targeting where support is needed for purposes such as infrastructure planning [14]. For these reasons, this definition was used in this study to understand the overall data trends across rural and urban California.

The US Census Bureau definition entails certain limitations. It is based solely on population density and does not consider other important factors such as geographic, economic, and social characteristics [12]. Furthermore, due to the binary nature of this definition, it does not accurately represent the diverse range of rural communities. By only using such a broad definition, it may be difficult to identify specific needs and allocate resources effectively to address them.

This study also examines the Rural-Urban Commuting Area (RUCA) typology, developed by the U.S. Department of Agriculture (USDA) [15]. This classification uses population density, urbanization, and daily commuting to identify urban cores and adjacent territories that are economically integrated with those cores. The most recent RUCA codes are based on data from the 2010 census and the 2006-2010 ACS. Census tracts are classified in 10 levels or codes based on the size and direction of the primary commuting flows. Levels of 1 to 10 delineate metropolitan (codes 1-3), micropolitan (codes 4-6), small town (codes 7-9), and rural commuting areas (code 10).

Additional typologies exist that define urban and rural areas, such as the Office of Management and Budget (OMB) definition [16], the Rural-Urban Continuum Codes (RUCC) [17], or the Rural Urban Density Code (RUDC) [12]. However, these definitions are mainly based on a county-level designation of rurality or urbanicity which may not provide significant implications for policy analysis and research. Using census tracts as a geographic unit can offer a more detailed geographic pattern of settlement classification and reveal disparities that would have been otherwise overlooked.

3.1.2 Household and vehicle characteristics

Two sources of data were used to examine differences across the rural and urban classifications: 1) the 2017 ACS 5-year estimates for California, and 2) the California DMV for 2020. Using multiple datasets can provide a more comprehensive and nuanced understanding of underlying trends and patterns that may be missed by relying on a single dataset. Table 1 provides an overview of the data used in this study. These datasets were aggregated at census tract level to be compatible with the US Census and USDA definitions of rurality.

Table 1: Data summary table

Data source	American Community Survey (ACS)	Department of Motor Vehicles (DMV)
Unit of analysis	Individual/household	Vehicle
Sample size	39,346,023	24,316,310
Date of collection	2017	2020
Variables used	Sociodemographic and housing characteristics	Vehicle ownership
Geographic unit	Census tract	Census tract

The ACS provides detailed and comprehensive information on the social, economic, and housing characteristics of households or individuals in California, available for all geographies down to the block group level. It also includes information on travel patterns or vehicle use, such as the transportation mode and travel time to commute to work. The DMV data has the advantage of enriching the analysis with vehicle ownership data such as fuel type, body type, and vehicle age. The raw DMV data provides information for each vehicle registered in California.

3.2 Methods

The goal of this study is to understand the spatial heterogeneity within and between urban and rural areas of California. To achieve this, the ACS and DMV data were joined with the US Census and USDA definitions of rurality using spatial software (QGIS and ArcPro) and R. As the US Census definition is at block group level (a finer spatial delineation than census tract level), pre-processing of the data was required to redefine the block groups to census tract level (Figure 1 and Figure 2). This was done by identifying the proportion of land within the census tract delineated as rural. If the proportion was rural area within the census tract was more than 50% then the census tract was defined as rural.

As has been previously mentioned, the data was aggregated at a census tract level for ACS and DMV data. The datasets included individual, households, and vehicle characteristics in each census tract in California. The estimated descriptive statistics show population and vehicle weighted average proportions of each variable. Taking homeownership as an example, the proportion of homeowners in a single census tract was divided by the total tenure number for that same census tract (homeowners, renters or other). A population weighted average was then taken across all census tracts for urban and rural areas.

Given the continuous nature of the raw data, statistical tests were also conducted in R software to determine whether there is a statistically significant difference between urban and rural areas. Using an Anderson Darling test [18]), it was found that the data is not normally distributed and hence, non-parametric statistical tests were undertaken. To compare two groups: the urban and rural areas of the US Census definition, Mann–Whitney U tests were used [19]. To compare more than two groups: metropolitan, micropolitan, small town and rural areas of the RUCA definition, Kruskal–Wallis tests [20] were conducted.

Figure 1 and Figure 2 depict rural delineations explored in this study.

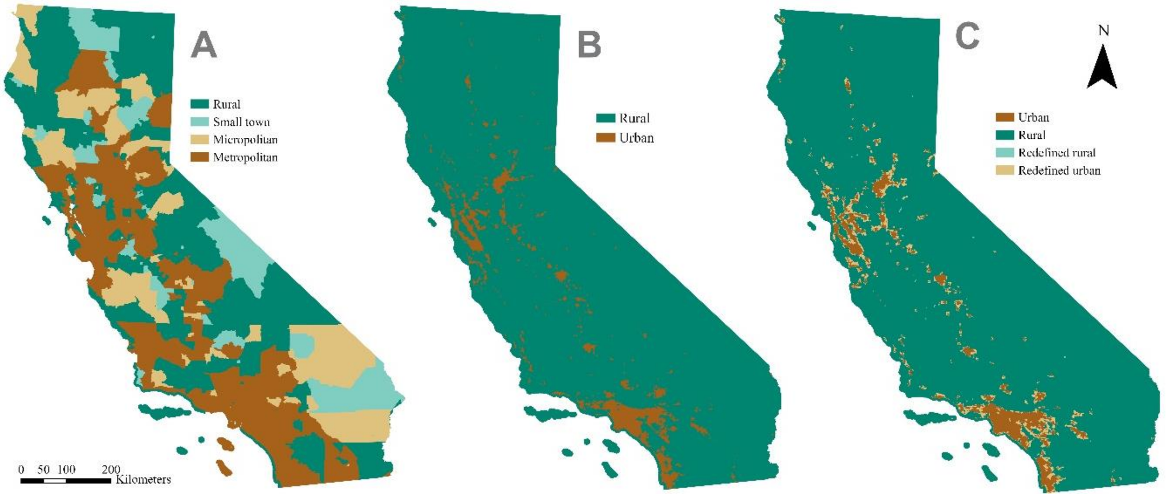

Figure 1: Rural delineation of California by A) USDA RUCA codes, B) US Census block groups, and C) redefined US Census tracts.

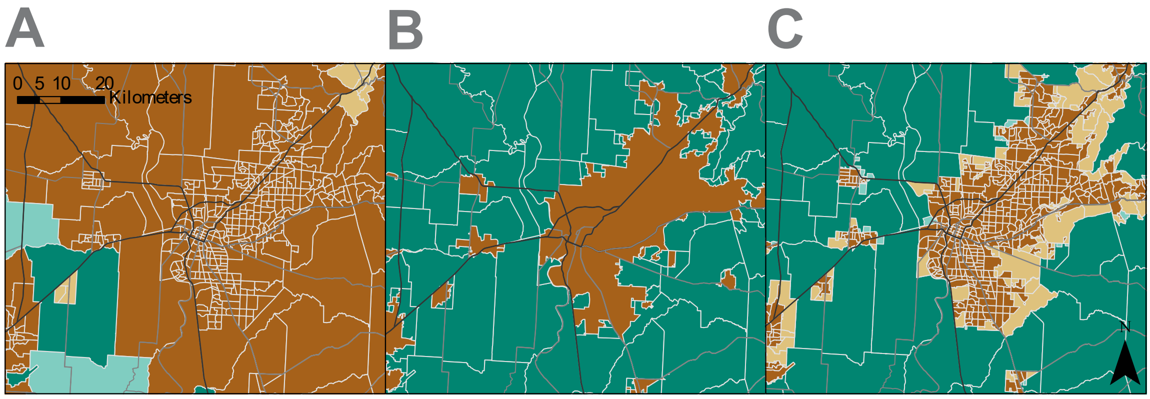

Figure 2: Rural delineation of Sacramento region by A) USDA RUCA codes, B) US Census block groups, and C) Results

3.3 Sociodemographic characteristics

According to the US Census definition of rural, 7.2% of the total population in California live in rural areas. The USDA RUCA code definition of rural defines just 2.2% of the population as rural, 0.3% as small town, and 1.1% micropolitan. In the USDA definition, metropolitan areas encompass more area and a higher proportion of the population than the Census defined urban areas. Table 2 presents sociodemographic characteristics of California residents categorized by the US Census and USDA definitions, presented as a population-weighted mean of census tracts. The proportion of people in each sociodemographic category is statistically different ($p<0.05$) across all categories except for annual household income between \$100,000-\$150,000. Rates of home ownership of detached houses was only statistically significant at the 90% confidence interval ($p<0.01$).

Home ownership is highest in rural areas across both definitions with most rural homeowners and renters living in detached houses (Table 2). In the Census definition, a higher proportion of rural residents are low income (<\$50,000 annual income) compared to urban residents. The USDA definition paints a different picture with the highest proportion of low-income residents living in small towns, followed by micropolitan areas and rural areas. Conversely, a higher proportion of urban and metropolitan residents are high income earners (>\$200,000) compared to other classifications. Formal education levels follow a similar trend with rural residents having lower rates of tertiary education for the Census definition. The lowest proportion of tertiary education was found in small town areas, followed by micropolitan and rural areas.

Table 2: Sociodemographic characteristics categorized by US Census and USDA definitions (ACS, 2017)

	Census definition		UDSA definition			
Variables	**Rural**	**Urban**	**Rural**	**Small town**	**Micropolitan**	**Metropolitan**
Population (n)	2,839,980	36,506,043	842,779	99,189	405,977	36,975,959
Household ownership						
Owner	68%**	55%**	65%**	57%**	61%**	55%**
Renter	31%**	45%**	35%**	43%**	37%**	44%**
Household type						
Detached (own)	85%*	78%*	88%**	82%**	84%**	78%**
Attached (own)	2%**	8%**	2%**	2%**	2%**	8%**
Detached (rent)	62%**	40%**	58%**	55%**	54%**	41%**
Attached (rent)	6%**	7%**	5%**	6%**	5%**	8%**
Household income						
$50,000 or less	36%**	31%**	40%**	46%**	45%**	32%**
$50,000 to $100,000	29%**	28%**	31%**	32%**	28%**	28%**
$100,000 to $150,000	16%	17%	15%**	13%**	14%**	18%**
$150,000 to $200,000	8%**	9%**	7%**	5%**	6%**	10%**
$200,000 or more	10%**	13%**	7%**	4%**	6%**	13%**
Highest level of formal education						
Year 12 diploma	21%**	18%**	21%**	23%**	21%**	18%**
Bachelor's degree	16%**	22%**	15%**	12%**	14%**	21%**
Master's degree	6%**	9%**	5%**	4%**	5%**	9%**
Doctorate degree	1%**	2%**	1%**	<1%**	1%**	2%**

** Statistically significant at the 95% confidence interval
*Statistically significant at the 90% confidence interval

3.4 Vehicle ownership

Table 3 presents the vehicle-weighted mean of vehicles attributes across California census tracts and categorized by Census and USDA rural definitions. Over 24 million vehicles are registered in California (as of 2020) with 7.7% of vehicles registered to rural addresses according to the Census definition. The USDA definition delineates 2.3% of vehicles as registered in rural areas, 0.8% registered in small towns, and 3.2% registered in micropolitan areas.

Table 3: Vehicle attributes categorized by US Census and USDA definitions (DMV, 2020)

	Census definition		USDA definition			
Variables	**Rural**	**Urban**	**Rural**	**Small town**	**Micropolitan**	**Metropolitan**
Number of vehicles	1,862,164	22,454,146	551,428	195,200	775,886	22,785,008
Fuel type						
ICEV	98.60%**	97.63%**	98.86%**	99.51%**	99.14%**	97.61%**
PHEV	0.60%**	0.97%**	0.56%**	0.29%**	0.47%**	0.98%**
BEV	0.74%**	1.37%**	0.58%**	0.20%**	0.40%**	1.38%**
FCEV	<0.01%**	0.03%**	<0.01%**	<0.00%**	<0.00%**	0.03%**
Vehicle type						
Sedan	27%**	36%**	27%**	29%**	28%**	36%**
SUV	27%**	26%**	27%**	26%**	27%**	26%**
Pickup	22%**	12%**	22%**	24%**	22%**	12%**
Vehicle age						
5 years or less	26%**	32%**	24%**	22%**	23%**	32%**
6 to 10 years	23%**	25%**	22%**	21%**	22%**	25%**
11 to 20 years	34%**	32%**	35%**	36%**	36%**	32%**
21 to 30 years	12%**	8%**	12%**	14%**	13%**	8%**
31 years or more	7%**	3%**	6%**	6%**	6%**	3%**

** Statistically significant at the 95% confidence interval

The proportion of vehicles in all categories is statistically significant ($p<0.05$). Rural residents own a higher proportion of ICEVs than urban and metropolitan residents and own less PHEVs, BEVs, and FCEVs. In the USDA definition, rates of ICEV ownership are highest in small town areas, followed by micropolitan then rural areas. Similarly, rates of BEV and PHEV ownership are lowest in small towns. Only a very small proportion of California residents own an FCEV vehicle, most of which reside in urban and metropolitan areas. Although rates of SUV ownership are similar across rural and urban areas, rural residents and non-metropolitan residents are more likely to own pickup trucks. Rural residents are less likely to own newer vehicles (10 years or less) and more likely to own older vehicles.

Despite rates of SUV ownership being similar across rural and urban areas (Table 3), Table 4 shows that a higher proportion of SUVs owned in rural areas are 11 years or older. This trend is consistent across both rural definitions.

Table 4: Rural and urban SUVs by vehicle age (DMV, 2020)

		n	5 years or less	6 to 10 years	11 to 20 years	21 to 30 years	31 years or more
Census definition	Rural	502,784	33%	23%	33%	10%	2%
	Urban	5,838,078	41%	22%	31%	6%	0%
USDA definition	Rural	148,885	30%	22%	35%	11%	2%
	Small town	50,752	28%	21%	37%	12%	2%
	Micropolitan	209,489	28%	22%	37%	12%	2%
	Metropolitan	5,924,102	41%	22%	30%	6%	0%

Of the pickup trucks in rural and urban areas, Table 5 shows a higher proportion of pickups in rural areas are 21 years or older, while the proportion of 11- to 20-year-old vehicles are similar and rates of new (5 years or less) pickup truck ownership are higher in urban areas.

Table 5: Rural and urban pickup trucks by vehicle age (DMV, 2020)

		n	5 years or less	6 to 10 years	11 to 20 years	21 to 30 years	31 years or more
Census definition	Rural	409,676	21%	16%	39%	19%	4%
	Urban	2,694,498	25%	15%	40%	16%	3%
USDA definition	Rural	121,314	20%	16%	39%	20%	5%
	Small town	46,848	18%	15%	40%	21%	5%
	Micropolitan	170,695	19%	15%	40%	21%	5%
	Metropolitan	2,734,201	25%	16%	40%	16%	3%

3.5 Travel behavior

The population-weighted mean travel behavior, measured as commute time and commute mode, for the Census and USDA definitions is presented in Table 6. All categories are statistically significant ($p<0.05$). For both definitions, a higher proportion of rural residents have a commute time of 14 minutes or less. The USDA definition shows that small town, followed by micropolitan areas have the highest proportion of residents with a short commute time. Most urban residents have a commute time of 15 to 29 minutes: a higher proportion than rural residents.

Table 6: Travel behavior categorized by the US Census and USDA definitions (ACS, 2017)

	Census definition		USDA definition			
Variables	**Rural**	**Urban**	**Rural**	**Small town**	**Micropolitan**	**Metropolitan**
Commute time						
14 minutes or less	28%**	21%**	33%**	39%**	36%**	21%**
15 to 29 minutes	31%**	35%**	29%**	26%**	27%**	35%**
30 to 44 minutes	19%**	22%**	18%**	20%**	16%**	22%**
45 to 59 minutes	8%**	9%**	8%**	5%**	7%**	9%**
60 minutes or more	13%**	13%**	12%**	10%**	9%**	13%**
Commute mode						
Drive alone	75%**	73%**	73%**	72%**	70%**	73%**
Carpool	10%**	10%**	11%**	13%**	10%**	10%**
Walk	2%	2%	3%**	6%**	2%**	2%**
Transit	2%**	5%**	2%**	<1%**	7%**	5%**
Worked from home	9%**	8%**	9%**	8%**	9%**	8%**
Taxi, motorbike, cycle and other	2%**	2%**	2%**	1%**	2%**	2%**

** Statistical significance at the 95% confidence interval

Differences in proportions of commute mode were slight but still statistically significant ($p<0.05$) with very small standard error values. The most common commute mode for rural and urban residents is driving alone. Rates of transit use were higher in urban and metropolitan areas than rural areas, however, the USDA definition shows that overall, transit rates are highest in micropolitan areas and lowest in small towns.

4 Discussion

This analysis provided comprehensive insight into sociodemographic characteristics, vehicle ownership, and travel behavior of rural residents in California. The US Census definition provided a general understanding of the differences between rural and urban residents. This analysis found that a higher proportion of rural residents are homeowners who are lower income and have lower levels of formal education than urban residents. Rural residents also own a higher proportion of ICEVs, and pickup trucks, and vehicles tend to be older in rural areas. A higher proportion of rural residents have a short commute time and a lower proportion of them take public transit to commute to work.

Capturing 7.2% of the population in the Census definition, the data shows that a higher proportion of rural residents own detached homes, earn less than $50,000, and have attained a high school diploma as their highest level of formal education. This is consistent with the findings of Wang et al. [12] who looked at rural sociodemographic characteristics to determine poverty rates. Although the authors' findings were at a county level as opposed to the Census tract level used in this study [12].

The USDA rural definition provided differences across four categories or levels of rurality: rural, small town, micropolitan, and metropolitan. Although encompassing a smaller proportion of the population (rural, small town, and micropolitan residents comprised 6.3% of the population), this definition provides nuance to the differences between non-metropolitan areas. Between rural and metropolitan areas, household ownership and type were consistent with the Census definition trends of higher ownership of detached houses in rural areas. However, the highest proportion of low-income households were found in small towns, followed by micropolitan then rural areas. This trend was consistent across education as well; The highest proportion of residents with a year 12 diploma as their highest level of formal education were small town residents.

Measures of income and education rates indicate that small town residents are more disadvantaged than other non-metropolitan residents. This finding likely explains the lower proportion of alternative fuel vehicles in these areas as literature shows early adopters of EV technology are generally people with a higher income and a higher level of formal education [10]. This finding is important as it highlights the heterogeneity of the population outside metropolitan areas. Additionally, rural areas have traditionally been touted as lagging behind urban areas in EV adoption, however, based on the USDA definition it is generally non-metropolitan areas, and more specifically small town and micropolitan areas that have the lowest rates of EV adoption.

The Census definition shows a higher proportion of rural residents own ICEVs, pickup trucks, and are more likely to own a vehicle more than 11 years old. These findings are consistent with previous research [4]. This study looked further to understand not just the prevalence of a vehicle type but also the age distribution of the vehicles. Despite rates of SUV ownership across rural and urban areas being similar, SUVs in rural areas were found to be older. In rural, small town, and micropolitan areas, not only is the proportion of pickup trucks higher but the fleet is also older. This has implications for overall fleet efficiency in rural areas as larger and older vehicles tend to be less fuel efficient and more polluting [21]. Additionally, while sociodemographic characteristics are clearly different across the USDA rural definition, rates of vehicle body types are more similar across this same definition. This may indicate that more than income and education is driving non-metropolitan residents to purchase certain vehicles.

According to the USDA definition, rates of BEV and PHEV ownership are lowest in small towns and ICEV ownership is highest. Micropolitan areas have the second lowest proportion of BEVs and PHEVs, followed by rural areas. Delineation of vehicle ownership by the USDA definition shows an overrepresentation of passenger vehicles in small town and micropolitan areas compared with the population size; Small town residents own 0.8% of the vehicles while representing 0.3% of the population, and micropolitan residents own 3.2% of the vehicles and represent 1.1% of the population. This was also found in the Census definition, but to a lesser extent; Rural residents own 7.7% of the vehicles but only represent 7.2% of the population. To elucidate this finding, further research could be done using datasets that have both household characteristics with vehicle ownership information.

Travel behavior was also different across rural and urban areas. This study found that rural residents were more likely to have a short commute time than urban residents. This is somewhat counterintuitive but may be congestion related (rural residents may be less susceptible to experiencing traffic congestion) or it may be occupation related (working on your own property or another property nearby may reduce travel time). Additionally, a lower proportion of rural residents were found to take public transit to commute to work. This is consistent with other studies that examined the use of transit in rural areas [4].

4.1 Implications for future electrification

The findings of this study have some promising implications but also drawbacks for the future of EV adoption in rural areas. EVs are a relatively new technology, and the market for large electric SUVs and pickup trucks is in its infancy. Although total cost of ownership (TCO) of EVs can be lower than ICEVs, the upfront cost of EVs is still higher than their gas equivalents [4]. Additionally, for TCO of EVs to be lower than regular gas vehicles, they need to be driven long distances and charged at home or at level 2 public charging stations (as opposed to direct current fast charging stations) [22]. As electric SUVs and pickup trucks are also new to the market, these vehicles tend to have a high price tag.

As most rural residents own detached houses, the availability of at home charging is likely higher than in urban areas where more people live in attached homes. As well, previous literature has indicated that rural vehicle owners take fewer but longer distance trips than urban vehicle owners [5] [6]. These two characteristics may imply that TCO of EVs will be lower in rural areas. On the flipside, a higher proportion of rural residents are low income and therefore may be more likely to buy used rather than new vehicles, causing the penetration of EVs into rural areas to be slower. If rural residents are looking to replace their current gas vehicles with electric equivalents, market penetration may be additionally slow as a secondhand market for these vehicles is yet to be established.

5 Conclusion

Understanding the heterogeneity of sociodemographic characteristics, vehicle characteristics, and travel behavior across the rural-urban continuum is important to be able to adequately depict non-metropolitan vehicle owners. According to the US Census rural definition, rural residents are more likely to be homeowners living in detached houses, be lower income, and have lower levels of formal education. This trend broadly stands between non-metropolitan and metropolitan areas under the USDA definition. However, differences across the non-metropolitan delineations show that small towns are more disadvantaged than micropolitan and rural areas. Vehicle owners in rural and non-metropolitan areas are more likely to own ICEVs, pickup trucks and older vehicles. Proportions of ICEVs were highest in small towns, which may be a result of these areas being more disadvantaged. Despite rates of SUVs being similar across the rural-urban continuum, these vehicles are generally older in rural areas. This research lays the foundation for future rural EV work and contributes to better understanding the current state of vehicle ownership at a local spatial scale with implications for the policies that address EV adoption in California, including infrastructure needs and energy use.

This study includes certain limitations to be considered in future work. The US Census definition provides a general overview of rural and urban areas in California and captures key differences between the two areas. The USDA definition showed that heterogeneity exists across non-metropolitan areas and that it is small town and micropolitan areas that are the most disadvantaged and have the lowest rates of EV adoption. A study by Onega et al. [23] though, highlights a larger issue with the USDA RUCA classifications as the study found a discordance between residents' self-reported categorization of rurality and the USDA designation for the area. Hence, further research investigating the limitations of this definition is needed. Furthermore, rural, and non-metropolitan areas could be further delineated with the use of land cover data to categorize vehicle owners by land use [24]. Additionally, future studies can expand the analysis to other study areas and/or consider additional datasets such as occupation related data or more detailed data related to EV owners. Lastly, this analysis is based on descriptive statistics and nonparametric tests (Mann-Whitney U and Kruskal-Wallis tests). Statistical significance does not necessarily imply practical significance or causation and thus, the results of this study should be interpreted with this caveat in mind. Further analyses are needed to understand the nature of the relationship between the proportions being compared and what is driving this relationship.

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Presenter Biography

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