Understanding Travel Demand and Built Environment Factors to Optimize Increased Zero Emission Vehicle Access in Underserved Communities: Final report

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Executive Summary

The aim of this project is to understand the mobility needs of underserved communities and understand whether and how zero-emission vehicles (ZEVs) can cost-effectively meet those needs. To achieve this aim, we conducted listening sessions (like focus groups) and an online survey, supplemented with secondary data. The sessions and survey covered mobility needs, travel behavior, perceptions of ZEVs, the impact of different interventions on increasing ZEV consideration, and barriers to ZEV adoption. The results address the following research questions (RQs) as they pertain specifically to underserved communities:

RQ1. What are the mobility needs of underserved communities, are these being met, and how are they met? (e.g. where do they travel, by what travel mode, etc.)
RQ2. What are households' awareness, knowledge, and perceptions of ZEVs?
RQ3. How do attributes of ZEVs (price, range, charging time, etc.) impact the viability of their adoption?
RQ4. How do attributes of the built environment impact ZEV viability (including house type, home charging access, public charging access, walkability, etc.)?
RQ5. What can be done to increase ZEV adoption potential in these communities?

We specifically focus on the California definition of "Priority Populations," this includes low income census tracts and low income households, as well as census tracts identified as disadvantaged census tracts as per CalEnviroScreen 4.0 (California Air Resources Board, 2021). The latter also includes tribal census tracts. In this executive summary we outline highlights from the listening sessions and survey, and then we summarize policy implications and conclusions.

Listening session findings

First, we conducted listening sessions to help achieve the aim of the project and to help develop the survey questionnaire. The sessions gave community members the opportunity to discuss various issues in their own words. We held 7 listening sessions with 86 participants in communities in the Central Valley and San Francisco Bay Area. Participants were recruited by community partners via social media, community events, and direct communication (e.g. email). Listening sessions were audio recorded and session transcripts were coded to identify themes. We conducted sentiment analysis on themes to identify whether topics were discussed in a positive, neutral, or negative way. We focus in this report on the results of this thematic and sentiment analysis.

Plug-in electric vehicles (PEVs, defined as battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) were spoken of negatively about half of the time and positively about a quarter of the time. This may indicate more negative perceptions of PEVs in this population than positive perceptions. (Participants did not discuss fuel cell electric vehicles in detail.) The most common negative perceptions of PEVs were high cost, a lack of public charging infrastructure, lack of access to charging at home (often due to living in a rented home, or an owned or rented apartment), a lack of familiarity and knowledge with PEVs, a lack of perceived benefits of PEVs over internal combustion engine vehicles (ICEVs), negative environmental impacts, safety concerns, and the need to use more time to charge a PEV (see Figure 1). Many of these findings are consistent with the literature on PEVs (of which no survey, focus group, or interview studies focus specifically on people in California priority populations). Our results indicate issues commonly reported in the literature are still a barrier to PEV adoption and are a barrier for this population. Some lesser reported barriers we detected include perceptions that PEVs do not have benefits compared to gasoline vehicles, safety concerns (which used to be common, but are less commonly reported as an issue in recent studies) and concerns that PEVs have negative environmental impacts.

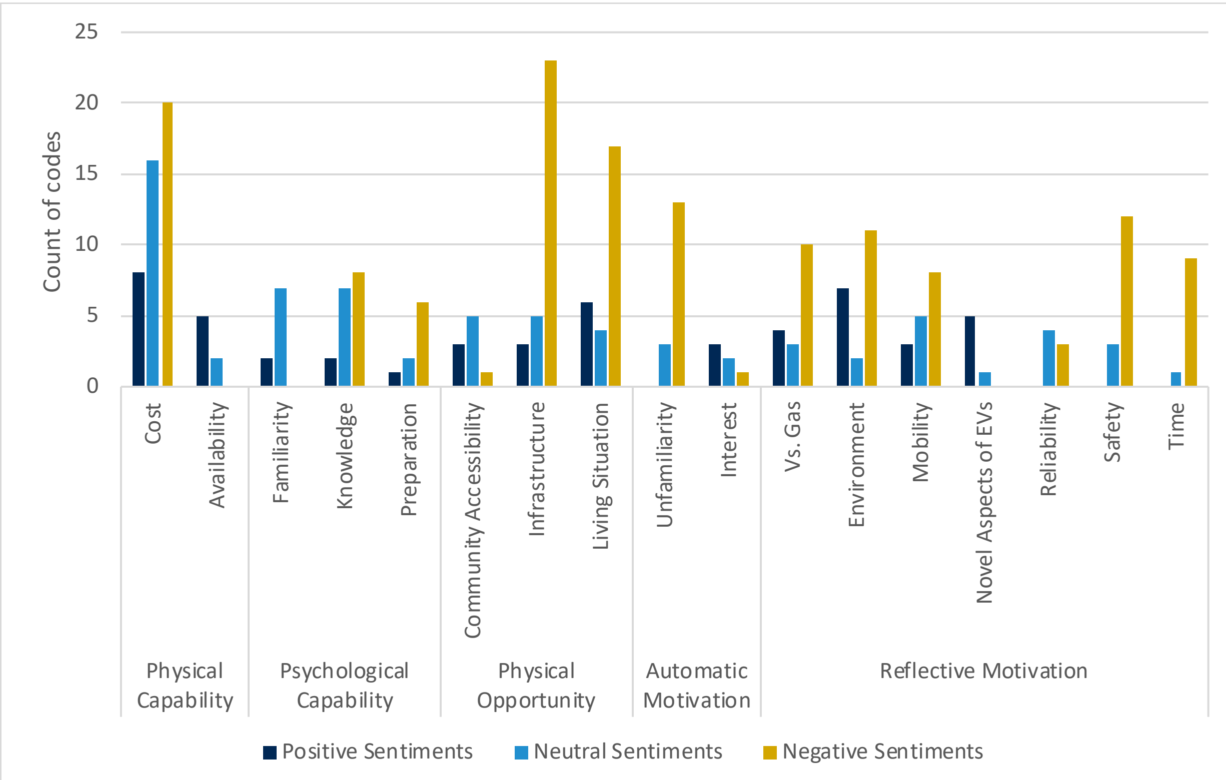


Figure 1: Count of sentiment analysis for codes (a measure of how much each topic was spoke about) by theme, organized by instrument of change area (from the COM-B (Capability, Opportunity, Motivation, Behavior) model of behavior change).

Statewide survey

The survey was designed to cover topics similar to those in the listening sessions (travel behavior and perceptions of ZEVs) but allow access to a larger statewide sample. The survey also included an experiment to test the effect of various policy interventions on BEV purchase consideration. The survey was administered between December 2023 and June 2024 to a random sample of priority population households throughout California. The sample was randomly drawn from the USPS database and was stratified by census tract and tract priority type (DAC tracts [including tribal tracts], low-income tracts, and households that are low income in non-priority tracts). The sample was stratified to ensure a sufficient sample size from all priority tract types. Included in this report is analysis of 2151 survey responses.

Travel behavior and household vehicle ownership patterns

The most to least commonly used modes among survey respondents are as follows, given as the percentage of respondents who used each mode at least once per week:

- driving (80–90%)
- walking (40–60%)
- getting a ride from a friend or family member (10–20%)
- bicycling (10%)
- transit use (10%)

It is likely that car use is high due to necessity, a lack of other mode options, and preferences for private vehicle use. The frequency of travel by each mode in our sample is similar to results in California data in the National Household Travel Survey.

Almost 40% of survey respondents reported destinations they have difficulty accessing, and a lack of car ownership correlated with having difficulty in making trips and being unemployed.

Households own 2 vehicles on average, and only 5% of the sample had no vehicles in their household. More than half of the sample purchased used vehicles, and many do not purchase vehicles from dealerships. The lowest income households purchased vehicles from private parties, and the highest income households, from dealerships. This may be important when considering incentive eligibility criteria, which currently requires vehicles to be purchased at a dealership.

Exploratory analysis of electric vehicle charging infrastructure access

We compared infrastructure access by home type, home ownership, community type, age, gender, education, number of vehicles in the household, and whether respondents live in an urban or rural tract. Charging access at home differed significantly among certain groups defined by each demographic characteristic we found the following significant differences:

- 73.7% of households living in rented homes reported no charging access, compared to 34.1% living in owned homes.
- 39.2% of female survey respondents reported no charging access, compared to 54.9% of male survey respondents.
- 52.8% of households earning <$100,000 per year reported no charging access, compared to 35.5% of households earning more than $200,000 per year.
- 48.7% of households living in urban areas reported no access to charging at home compared to 40.3% in rural areas.
- 55.3% of households with 1 vehicle in their household reported no access to charging, compared to 43% with 2 vehicles in their household.
- For census tract types we found the following percentages of households did not have access to charging at home:
    - 60.1% in DAC and low-income communities
    - 46.2% in DAC only census tracts
    - 49% in low income only tracts
    - 48.4% in none priority tracts

- 35.6% in partial tribal tracts
- 34% in fully tribal tracts

We investigated access to level 1 (L1), level 2 (L2), and direct current fast chargers (DCFC) within a 5-, 10-, or 15-minute drive of the respondent's home and places they travel to and within the census tracts survey respondents reside. Those living in partial tribal census tracts vs. other tracts had access to fewer chargers in their home census tracts for L1, L2, and DC fast chargers within a 5-, 10-, or 15-minute drive of their household. Respondents in DAC and full tribal tracts, as compared to those in other census tracts, has a similar number within a 5- or 10-minute drive, though fewer chargers within a 15-minute drive. In addition, households living in partial tribal tracts as compared to other tracts tended to have fewer chargers within 5, 10, and 15 minutes of their destinations.

Knowledge, consideration, and perceptions of PEVs

In the survey we consider whether respondents can name a PHEV or BEV as an indicator of knowledge, 43% of survey respondents can correctly name the make and model of PHEV or BEV (Figure 2). These results are similar to a statewide survey from 2021(Kurani, 2022a). We also asked respondents whether they support the California 100% ZEV sales regulation. More respondents supported a 100% ZEV sales regulation compared to those who were opposed to it, however less than half of respondents supported the regulation. We found no difference in whether respondents could name a BEV or PHEV or whether they had considered a BEV or PHEV across census tract types (DAC, low income, tribal, etc.). There were some differences in support for 100% ZEV sales regulations with more respondents in partial tribal tracts supporting 100% ZEV regulations, while more respondents in fully tribal tracts opposed 100% ZEV regulations.

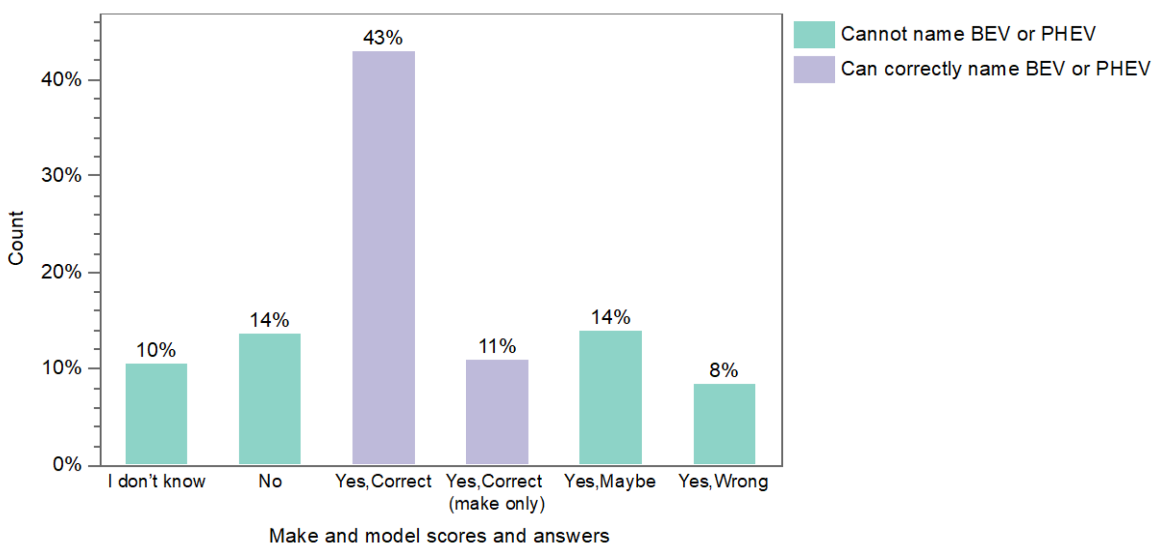


Figure 2: Whether respondents can correctly name a PHEV or BEV. Respondents who answered, "I don't know" and "No" were not asked to name a vehicle. Those who answered "Yes" were asked to name a PHEV or BEV and their answers were scored to determine whether they were correct, correct but with only the make and no model listed, maybe

correct (we could not determine whether the answer was correct or incorrect, and the answer contained make or model information of a PEV (e.g. 'Ford Mustang' was coded as maybe correct because there is an electric version of that vehicle (the Ford Mustang Mach-E)), and wrong.

Next, we asked respondents whether they had considered buying a PHEV or BEV. More than half of survey respondents had not previously given any consideration to purchasing a BEV or PHEV. Around 15% of the sample had gathered information on BEVs or PHEVs or actively shopped for one. Of those who had considered a BEV or PHEV, more than half had not made up their mind yet, whereas around 20% decided to not purchase one. The most reported reasons to not purchase a BEV or PHEV were a lack of home and public charging infrastructure, high purchase cost, short driving range, a lack of available vehicles, the high cost of home charging infrastructure installation.

The most negative of perceptions related to BEVs (i.e. with the most respondents that disagree with or fewest that agree with positive statements on BEVs or the most respondents that agree with or fewest that disagree with negative statements) regard access to charging, including public access and home charging access, and driving range. There are also slightly negative perceptions (where more respondents are neutral, and fewer are on the extreme ends of the scale from strongly agree to strongly disagree) about BEV safety, the ease of maintaining a BEV, and battery degradation. The most positive perceptions relate to being able to charge a BEV at home (41% agreed they would be able to), knowing enough about BEVs to decide about getting one (40% agreed they know enough), and being aware of electric vehicle incentives (41% agreed they know about incentives).

Classifying respondents based on knowledge, perceptions, and consideration of electric vehicles

We used latent class analysis to identify clusters of survey respondents based on their perceptions of BEVs, knowledge of BEVs and PHEVs, their level of consideration to purchase a BEV, and support for 100% ZEV sales. This method allows better identification of perceptions of BEVs by accounting for knowledge and consideration to purchase a BEV. We also investigate factors related to class membership including demographics, attitudes, and built environment variables. This identified five classes:

- Active Supporters (14% of respondents) have considered or own a BEV, have the strongest support for 100% ZEVs sales, good knowledge of PEVs, and positive perceptions on most BEV attributes. This class is concerned about public charging and slightly concerned about range.
- Passive Supporters (34%) have thought about purchasing a BEV though not seriously, have slight support for 100% ZEVs, and have mixed knowledge. These respondents have neutral perceptions on most attributes but are concerned about home and public charging and about range.
- Active Resisters (8% of respondents) have not and will not consider purchasing a BEV, they have the strongest opposition for 100% ZEVs and very negative perceptions of BEVs.
- Passive Resisters (27% of respondents) have not considered a BEV but may, they exhibit slight opposition to 100% ZEVs, mixed knowledge, and neutral perceptions on most

attributes. They are concerned about public charging and slightly concerned about range and battery degradation.
- Unengaged (18% of respondents) have not considered a BEV but may, are neutral towards 100% ZEVs, have neutral perceptions about BEVs and poor knowledge. These respondents appeared to have not thought about BEVs before the survey.

We investigated factors related to *class membership* (in each of the above five classes), including demographic, built environment, and attitudinal factors. This helps understand which household and respondent characteristics are related to perceptions, knowledge, and consideration to purchase a BEV. Class membership was related to:

- respondent demographics, including household income, race or ethnicity, age, gender, and whether respondents rent or own their home;
- attitudes related to car ownership, the environment, technology, land use, exercise, and socializing; and
- built environment variables, including whether respondents live in a rural or urban area, public charging access, and the number of PEVs in their census tract.

There was no significant relationship between class membership and whether respondents live in a DAC, low income, tribal, or none priority tract. Classes therefore are more related to individual household characteristics and attitudes, as well as some built environment attributes, but not census tract priority type.

The effect of incentives, infrastructure, and battery assurance on likelihood to consider BEV purchase

We used a factorial vignette survey experiment to test the effect of different policy interventions (incentives, infrastructure access, and battery assurance measures) on respondents' likelihood to consider purchasing a BEV. The experiment was designed to represent existing policy interventions that could address some barriers reported by participants in the listening sessions. This analysis controls for survey respondent demographics, attitudes, built environment variables, and respondent perceptions of BEVs.

This analysis found that the most effective ways to encourage BEV adoption may be via large purchase incentives and access to charging at home or work.

Figure 3 shows the results of this experiment as the marginal effects from a beta regression model. The figure shows the effect of the tested policy interventions on BEV purchase consideration.

When controlling for demographics, attitudes, perceptions, and exogenous variables, large purchase incentives significantly increase the likelihood to consider a BEV purchase. An incentive of $7,500 to $12,000 showed a significant effect, a 1/3 reduced incentive of $5,000 to $8,000 had an almost significant effect over no incentive with a smaller effect size. Access to charging at home, destination/work, home and destination/work, or home and public fast charging significantly increase likelihood to consider a BEV compared to the control of public slow only charging. Access to only public fast charging had no significant effect on BEV consideration compared to the control of public slow only charging.

When controlling for demographics, attitudes, perceptions, and exogenous variables, information on battery assurance measures (battery rebates and battery warranties) had no direct significant effect on BEV consideration. This may be because these are insufficient in directly addressing perceptions on battery reliability and battery degradation, or because many households in priority populations typically purchase vehicles more than 8 years old or with 100,000 miles on them, therefore they would benefit from warranties.

In addition to incentives and charging access, demographics, attitudes, and perceptions of BEVs are related to purchase consideration. Holding all else constant, the following characteristics were associated with a tendency to consider a BEV purchase:

- younger age;
- higher income;
- residence in census tracts with more PEVs per 1000 vehicles;
- positive perceptions of BEV charging, range, battery quality, and the likelihood of being able to charge from home;
- positive attitudes to travel, being social, and in favor of cars and mixed land use;, and a general willingness to wait.

While consideration to purchase a BEV is related to household income or household federal poverty level (FPL), we did not find any significant interaction effects between interventions and income or FPL. This means the effect of incentives and infrastructure access is not significantly different for the lowest income buyers compared to higher income buyers in this sample of priority population households. Notably, there was no difference in the effect of incentives on households below 300% FPL vs. below 400%. Households below 400% FPL were previously eligible but are no longer eligible for an incentive, despite the incentive impacting their decisions similarly to how it affects households around and below 300% FPL. Similarly the evaluation of CVAP by Chakraborty et al (2024b) found buyers with higher household FPL percentage were highly dependent on that incentive to purchase a PEV.

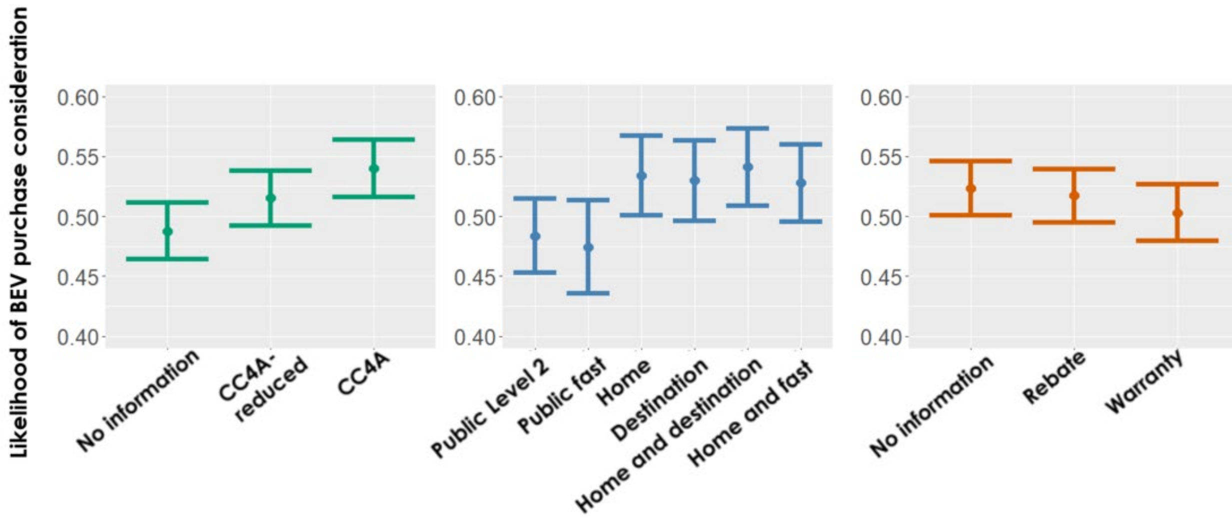


Figure 3: Marginal effects of considering buying a BEV given each of the policy intervention levels. For charging fast charging alone is not significant, for incentives the 1/3 reduced CC4A (Clean Cars 4 All) ($5,000 to $8,000 rather than $7,500 to $12,000) is only significant at the 10% level, no battery assurance measures are significant. All other interventions are significant at a 5% level or below.

Priorities for transportation improvements

Regarding potential investments in transportation improvements, survey respondents placed the highest priority on the following, in descending order: investments in transit, walking infrastructure, new roads, PEVs, biking infrastructure, and finally mobility wallets. Ebike or scooter sharing and car sharing investments were lower priorities, perhaps due to unfamiliarity with sharing services.

We explored geographic variation in priorities and found transit was given the highest priority for respondents in the Bay Area, LA region, and Inland Empire. A similar trend occurred for mobility wallets. There is little to no geographic variation across the state in prioritization for improving walkability and bikeability, with respondents in all regions giving these high priority. Prioritization for PEV incentives is highest in the Central Coast region. Finally, improvements in roads are ranked highest by respondents in the Southern San Joaquin Valley and lowest in the Bay Area and North Coast.

Policy implications

Many policies and programs in California are designed to increase ZEV access in priority populations. Many of our policy recommendations relate to continuing, expanding, or improving these existing efforts. In the policy implications section of this report, we tie research findings to policy implications and outline whether there is a need for new, expanded, or revised policy. In brief, the recommendations cover expanding access to charging at home or workplaces, reducing the cost of charging, providing incentives, revising program designs so they better align with the needs of priority households, investing in engagement with communities on PEV related topics, and increasing the supply of affordable PEVs. More broadly, we recommend, investments in other modes such as transit and walking and biking infrastructure. The recommendations also include wealth building, community engagement, and land use planning. Here we briefly summarize the policy implications.

Charging infrastructure access

- Increase access at home and work as primary locations for charging.
- Continue and expand programs that offer incentives, funding, or install charging at people's homes.
- Provide home charging incentives at point of payment for charging installation and cover all costs associated with home charging installation (including panel upgrades, charging equipment, and installation costs).
- Expand programs that allow the right to install charging by including more dwelling types, parking situations, and homes with rent control.
- Explore establishing a program that allows priority population households to request charging installation if they own a PEV or are considering one.
- Explore introducing minimum requirements for installation of PEV charging at existing buildings.
- Continue and expand programs that provide incentives (e.g., charging cards) that offset charging costs, especially for households that cannot charge at home.
- Continually fund infrastructure programs, i.e., identify sustainable and continuous sources of funding such that there are no gaps in funding for priority populations.

Incentives

- Continue to provide incentives that offset upfront cost of PEVs for priority households.
- Continually provide incentives (i.e., identify sustainable and continuous sources of funding such that there are not gaps in funding for priority populations).
- Reduce the administrative burden of incentive applications and continue to fund programs that assist consumers in navigating the application processes.
- Make program design decisions based on data, including program evaluation surveys and the data from other projects. Explore returning to prior 400% FPL rather than 300% FPL criteria for CC4A to include more low-income households whose purchase is dependent on incentives.
- Explore expanding the availability of incentives to sales than occur outside of dealerships.

Engagement

- Continue and expand funding for programs and organizations that engage with communities.
- Continue and expand funding to support education and awareness about PEVs and PEV incentive programs.
- Continue programs like advanced clean cars 2 (ACC2) that may encourage automakers to invest in engaging consumers with PEVs via marketing strategies, if the PEV market

becomes demand constrained and automakers need to sell more PEVs to comply with the regulation.

Supply side issues

- Lengthen and increase mileage limits of PEV warranties (e.g. to 10 years and 150,000 miles) to support low income PEV owners who may experience a battery failure. Though at this may not encourage more PEV purchases it may reduce the risk of a PEV being a financial burden.
- Continue and expand programs to support adoption of used PEVs (including those outlined above) and programs that support the market for used PEV.
- Consider programs that incentivize the sale of efficient and affordable PEVs (e.g., through revisions to ACC2 that encourage affordable and efficient PEVs).

Conclusions

Throughout this study a lack of home infrastructure emerged as a barrier to BEV purchase, especially for those living in apartments or rented homes. We find public infrastructure is also a barrier, though on its own may not overcome issues associated with a lack of charging, with home and/or work needed as a primary charging location. High vehicle costs are also a barrier to adoption. Range is a concern for many but may be less of a barrier than infrastructure and vehicle cost, with perceptions of range improving when knowledge of BEVs improves. In addition, we found this population is unfamiliar with PEVs, lacks knowledge of them, has low awareness of PEV incentives, does not perceive substantial benefits of PEV ownership compared to conventional vehicles, and has other priorities over PEV adoption. Other research has found some of this to also apply to the broader California population (Kurani, 2022a). In this survey, perceptions of PEVs are most negative among respondents who purchase used cars, are older, who are middle income in the sample, rent their home, do not have pro-environmental attitudes, are pro-car ownership, and live in rural areas and areas with fewer registered PEVs. The lowest income households appear to be largely unengaged with PEVs and have neutral perceptions of them. Answers to the research questions (RQs) follow.

What are the mobility needs of underserved populations and how are they met? (RQ1)

The transportation needs of priority populations vary, as with any population. Most trips are made by private car, and many respondents also walk regularly. Transit use was not frequently reported, potentially due to a lack of sufficient access. Relatedly, transit improvements were reported as a high priority. A substantial portion of respondents (37%) report that their transportation needs are not satisfactorily met. Reported trip distances may not preclude a BEV or PHEV from meeting travel needs, as almost all trips are within the driving range of new or used BEVs. However, technical compatibility of BEVs (i.e. their ability to meet travel need) is not the same as perceived compatibility (i.e. whether people think BEVs are suitable to meet their needs).

What are households' awareness, knowledge, and perceptions of ZEVs? (RQ2)

Most survey respondents have not thought about purchasing a BEV or PHEV, most report not knowing enough about BEVs to decide about getting one, and most are not aware of incentives. Perceptions of BEV attributes are mixed, the most negative are on the availability of charging infrastructure, home charging access, and driving range. More survey respondents support 100% ZEV sales than are opposed to it. The listening sessions also indicated that infrastructure, range, vehicle cost, and vehicle availability are substantial barriers to PEV purchase. Many of these trends may be due to the early stage of the PEV market, though will need to change as California progresses towards 100% ZEV sales and eventually to an all-ZEV fleet.

How do attributes of ZEVs impact their viability for adoption? (RQ3)

Perceptions of ZEV attributes that may impact their viability include vehicle cost, driving range, lack of vehicle availability, charging cost, a lack of benefits of PEV adoption, the cost to install a home charger, and less frequently cited issues such as concerns about battery degradation and vehicle reliability. Many of these barriers are from respondents with limited knowledge of PEVs. Some perceived attributes—such as limited range and a lack of benefits—may be diminished as barriers when and if people become more knowledgeable about PEVs. However, some PEV attributes, such as charging access and vehicle cost, will themselves need to be changed to become less prominent barriers.

How do attributes of the built environment impact ZEV viability? (RQ4)

Home type and ownership are significantly related to the viability PEV adoption. While the communities covered in the study differed in their actual access to public charging infrastructure, the respondents from these communities did not significantly differ in perceptions of this access. This discrepancy may be due to a lack of awareness of infrastructure and because public charging is not significantly related to likelihood to consider a BEV. Respondents in rural vs. urban areas did differ in their current perceptions, knowledge, and consideration of purchasing a BEV, but not in responses to the survey experiment which is more forward looking. This suggests that while to date fewer rural households have considered a BEV, holding all else constant, rural households are similarly likely to consider a BEV at some future point. The most substantial built environment barrier to PEV adoption may be a lack of home charging—either due to living in an apartment, condo, or a rented home—or being unable to install a home charger. Finally, when household attributes are controlled for, we find few differences in perceptions, knowledge, or consideration to purchase a ZEV by census tract type. Overall, we find individual household characteristics are more significantly related to various issues related to ZEVs, rather than the census tract a household resides in. This means programs with an equity focus may want to target interventions based on household attributes rather than census tracts.

What can be done to increase ZEV adoption potential in these communities? (RQ5)

Increasing ZEV adoption in underserved communities may require substantial incentives (e.g., the Clean Cars 4 All incentive); charging access at home and/or work (public fast charging alone does not have any significant effect on increasing consideration to purchase a BEV); and efforts to educate and engage with communities. Overall, there is a need for continued policy support, and the revision of existing programs to better align with the needs of underserved populations.

Summary

We conclude that PEVs can be a viable transportation mode in priority populations if the right support is provided. The needed support includes substantial incentives for PEV purchase, developing more access to home or workplace/destination charging infrastructure, subsidizing PEV charging costs, engaging with communities, increasing the supply of affordable PEVs, continual research to identify barriers and solutions, and strategies that build wealth in communities. However, some households may prefer to not purchase a PEV regardless of policy support, notably the class of respondents who we identify as actively resistant to ZEVs. Finally, we find consideration to purchase a PEV, vehicle ownership, infrastructure access, perceptions, knowledge, and consideration of PEVs are more related to household demographic attributes, attitudes of respondents, and other factors, rather than the census tract type households reside in. This highlights the need to consider household and population attributes, rather than only the region households live in.

Introduction

The aim of this project is to understand the mobility needs of underserved communities and understand whether and how zero-emission vehicles (ZEVs) can cost-effectively meet those needs. To achieve this aim, we conducted listening sessions (like focus groups) and an online survey, supplemented with secondary data. The sessions and survey covered mobility needs, travel behavior, perceptions of ZEVs, the impact of different interventions on increasing ZEV consideration, and barriers to ZEV adoption. The results address the following research questions (RQs) as they pertain specifically to underserved communities:

- RQ1. What are the mobility needs of underserved communities, are these being met, and how are they met? (e.g. where do they travel, by what travel mode, etc.)
- RQ2. What are households' awareness, knowledge, and perceptions of ZEVs?
- RQ3. How do attributes of ZEVs (price, range, charging time, etc.) impact the viability of their adoption?
- RQ4. How do attributes of the built environment impact ZEV viability (including house type, home charging access, public charging access, walkability, etc.)?
- RQ5. What can be done to increase ZEV adoption potential in these communities? (including incentives, infrastructure, outreach and education)

We conducted listening sessions and a statewide survey with a survey experiment to answer the research questions. The first four questions we answer using results from listening sessions and descriptive and correlational analysis of the survey. Question 5 we primarily answer with results from a survey experiment. Prior to this project we were unaware of any survey than randomly sampled a large number of households in priority populations in California to understand issues related to ZEV adoption. The contribution of this research is gathering that data and reporting answers to the above research questions for this specific population of Californian households.

We used a combination of complementary qualitative and quantitative methods. We used qualitative methods to engage with communities, because we were unable to identify social science studies on priority populations that investigate issues related to electric vehicles, and because of the value of qualitative research. Qualitative research allows for in-depth understanding of a topic, especially if there is either no basis or contested theoretical and/or empirical bases of understanding. Qualitative research is also useful for exploring complex issues; generating new hypotheses and unexpected findings; giving greater context to research findings; producing higher external validity because the research may be conducted in the real world; understanding and highlighting diverse experiences rather than emphasizing the most common or average outcomes; and empowering participants. The last item is notably important to this project to allow individuals in underserved communities to speak in their own voices. Studies using both qualitative and quantitative methods often produce better outcomes than do quantitative methods, which may leave researchers detached from the reality of lived experiences of those they study (Agius, 2013; Black, 1994; DiCicco-Bloom and Crabtree, 2006; Johnson and Waterfield, 2004; Maxwell, 2020; Opsal et al., 2016; Palmer and Bolderston, n.d.; Thyer, 2012).

We use quantitative methods to sample from a larger cross section of priority populations than is possible in qualitative research. This allows us to create statistically significant results that may represent the population we are interested in, statistically compare different populations, identify correlations in the data, and, for the survey experiment, identify causal effects of policy interventions. However, surveys have poor external validity compared to qualitative research, do not allow participants to explore topics in detail, and are often extractive methods, among other limitations. Our goal by using both methods is to produce more useful results compared to using only one method.

This report is structured as follows. We first review related literature and then outline the methods used. The results section first explores results from the listening sessions, mostly focusing on themes related to plug-in electric (PEVs). Next we explore survey results in the following order: demographic characteristics of respondents, travel behavior and unmet travel, access to charging at and near home, knowledge of PEVs, consideration of buying or leasing a PEV, perceptions of electric vehicle related attributes, results from the survey experiment that explores the effectiveness of different policy interventions, and finally survey respondents' prioritization of different sustainable mobility investments. We follow the results section by exploring policy implications and finally outline conclusions from this study.

Throughout this report we refer to the following vehicle types: battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel cell electric vehicles (FCEVs), plug-in electric vehicles (PEVs, which are BEVs and PHEVs), zero emission vehicles (BEVs, PHEVs, and FCEVs). Some results relate specifically to BEVs, PHEVs, or FCEVs; others relate to PEVs (BEVs and PHEVs) generally; while others relate to all types of ZEVs. For the most part the results focus on PEVs. Table 1 shows the acronyms and definition of each. We also occasionally refer to hybrid electric vehicles (HEVs), which are not classified as ZEVs and are only fueled by gasoline.

In the paper we also refer to level 1 (L1) charging, level 2 (L2) charging, and direct current fast charging (DCFC). L1 charging (120v, around 1kW) charging and is available at home, work, and public locations though is mostly used at locations with long dwell times (home or work). L2 charging (220-240v, 7-19kW) charging and is available at home, work, and public locations though is mostly used at locations with long dwell times (home or work). DCFC (400-1000v, 50-350kW) is the fastest charging for PEVs and is almost only located in public areas.

Table 1: Acronyms used for different types of zero emission vehicles and the definition of each.

Acronym		Description
BEV	Battery Electric Vehicle	Vehicles with a battery and electric motor for propulsion
PHEV	Plug-in Hybrid Electric Vehicle	Vehicles with an engine, battery, and electric motor for propulsion
PEV	Plug-in electric vehicle	Both BEVs and PHEVs, vehicles that are plugged in and use a battery and motor for some or all of their propulsion.
FCEV	Fuel Cell Electric Vehicles	Vehicles with a fuel cell fueled with hydrogen which powers an electric motor for propulsion. Most FCEVs also have a small battery and function as a hybrid.
ZEV	Zero Emission Vehicles	In this report BEVs, PHEVs, and FCEVs.

Literature Review

Here we review literature related to this study, starting with transportation and equity, then electrification and equity, and, finally, barriers to PEV adoption.

Principles of Transportation Equity

Transportation inequities occur when disadvantaged communities and underserved populations experience the disproportionate burdens of transportation, lack adequate benefits of transportation, or are excluded from full participation in transportation decision-making. These disproportionate impacts have their roots in historic, systemic injustices against communities of color, which have been segregated by transportation infrastructure and have continued to be neglected for investments in infrastructure and service (Barajas, 2021). The list of disparities is long. Low-income communities and communities of color are more likely to be exposed to transportation pollution and experience related health impacts due to freeway proximity (Rowangould, 2013). Places with a high number of traffic crashes are more likely to be communities of color (Barajas, 2018; Chalfin and Massenkoff, 2022; Schneider et al., 2021). Communities of color have poorer job access and are less likely to have access to grocery stores, green spaces, and other amenities (e.g. Ermagun and Tilahun, 2020; Grengs, 2015). People of color and lower-income individuals have lower car ownership, which means longer travel times and overall less access to goods and services because of urban spatial structure (Blumenberg et al., 2020a; Blumenberg and Agrawal, 2014). Low-income individuals living in rural areas face disadvantages due to long travel distances between destinations, and those who have limited car access must overcome significant barriers to meet their daily needs (Barajas and Wang, 2023). The car-centric nature of development in the United States means that full participation in society is difficult without access to a vehicle. Full penetration of plug-in electric vehicles (PEVs) in disadvantaged communities have the potential to bring significant benefits: they would provide vehicle access where needed without contributing to immediate environmental justice concerns in the way that mass distribution of internal combustion engine vehicles would.

Planning and policies that aim to address transportation inequities generally address distributional equity principles (Karner et al., 2020), defined as fairness in delivering benefits and mitigating burdens of transportation. For example, metropolitan planning organizations most commonly prioritize projects for programming inclusion that are located in historically marginalized communities or are projected to bring certain transportation benefits and mitigate burdens in those communities (Krapp et al., 2021). Many transportation justice scholars argue that the key distributional benefit of transportation is access, or the ease with which people can reach destinations (Bierbaum et al., 2021; Martens, 2017; Martens et al., 2012; Pereira and Karner, 2021).

Electrification and Equity

In California PEV buyers have a mean household income far higher than the state average, 81% own their home, 81% have a college degree, only 25% are female, and PEV owners have 2.5 vehicles on average (Lee et al., 2019). Many PEV studies do not report race or ethnicity of buyers. One study from California that did consider race or ethnicity found 55% of PEV owners were white (Muehlegger and Rapson, 2018). A study from Maryland found that 4% of PEV owners were African-American, while 30% of the state's population is African American (Andrew Farkas et al., 2018). Research on PEV buyers and disadvantaged communities found some PEV owners do reside in disadvantaged communities, however these adopters have higher incomes than average disadvantaged households (Canepa et al., 2019). While PEV buyer demographics are not similar to *all* car owners, PEV rebate recipients are similar to *new* car buyers who have higher income, are older, are more likely to have a college degree, own their home, and identify as white (Williams, 2023).

PEV adoption is also related to beliefs, attitudes, and norms (Haustein and Jensen, 2018). Positive attitudes towards the environment is related to PEV acceptance in 33 of the 38 studies reviewed by Wicki et al. (2022), while interest in technology is significant in 7 of 12 studies reviewed. Additionally, studies find that concern about foreign oil dependance (Carley et al., 2013; Hardman and Tal, 2018) and local air pollution correlate with PEV adoption.

The 2018 Low Income Barriers Report (CARB, 2018) used a literature review, meetings (with community-based organization [CBOs], environmental groups, stakeholders etc.), four community case studies, and consultation with other agencies to examine barriers to ZEV adoption. The report also found barriers to clean transportation access include convenience, safety issues, affordability, lack of and access to funding and investments, and low awareness of clean transportation.

Ku et al (Ku et al., 2021) used spatial GIS analysis to consider transportation issues and issues related to electrification and equity in Oakland. They found that residents who had low-incomes and/or were Black, Indigenous, and people of color (BIPOC) would benefit the most from equitable PEV adoption. However, most families that are benefiting from PEV rebate programs are those with incomes above $50K a year. The authors suggest there needs to be more equitability in electrification in terms of infrastructure development and policy, especially in areas such as West Oakland where disadvantaged neighborhoods are more likely to face worse air quality and would therefore benefit the most from electrification.

Residents from underserved communities and residents of multi-family housing have greater challenges accessing electric vehicle charging, including a lack of the following: at-home charging access (Axsen and Kurani, 2012; Lopez-Behar et al., 2019; Pierce et al., 2020), access to smartphones, charging network subscriptions, public charging stations in their communities (which have been characterized as "charging deserts"), or space for charger installation (Sevier et al., 2017).

Most electric vehicle charging occurs at home, however many households may not be able to charge at home due to where they park their vehicle, being unable to afford a home charger, a lack of permission to install one, or issues with electricity access. Several studies find home charging is the most influential in the decision to purchase a PEV (Axsen and Kurani, 2011; Bailey et al., 2015a; Dunckley and Tal, 2016; Skippon and Garwood, 2011) .

In investigating the distribution of charging in California, Hsu and Fingerman (Hsu and Fingerman, 2021) found Black and Hispanic neighborhoods had 0.7 times the access to public chargers as the non-minority majority group, even when income, proximity to freeways, and home type were controlled for. White-majority census block groups were 1.5 times more likely to have access to public charging stations compared to Black- and Latino-majority census block groups. A similar study in Washington State (Min et al., 2023) investigated spatial distributional equity of PEV charging and rooftop solar and found, similar to the California study, that PEV charging is not evenly distributed, with access to PEV charging being significantly related to economic variables (including income and home value). More equitable distribution of public charging, however, would not address an inequity in access to at-home charging, because public charging can be 2-4 times more expensive than home charging and can cost more per mile than driving an internal combustion engine vehicle (Hardman et al., 2021).

Provision of public chargers to enable sufficient access to charging for PEV use among disadvantaged communities is not the only equity perspective—and some scholars have argued is not the appropriate perspective for achieving transportation justice (Carlton and Sultana, 2022; Henderson, 2020). Justice-oriented scholars call for research and analysis beyond measuring the distribution of infrastructure and service in disadvantaged communities. They implore researchers to understand how transportation systems enable people to fully participate in society. This view on transportation justice, embodied in the capabilities approach, urges state actors to take a more expansive view of the kinds of investments that communities need (Hananel and Berechman, 2016; Karner et al., 2020). For example, while PEV charging access may be an eventual need in disadvantaged communities, basic investments in more immediate needs such as public transit service, infrastructure for cycling and walking, and access to healthy foods may be more immediate needs and more appropriate avenues for investment. Therefore, some barriers to adoption of PEVs may be rooted in more basic failures of planning and investment.

PEV Adoption and Barriers to Adoption

Studies show PEV incentives are positively related to PEV sales, adoption decisions, and stated intentions to purchase an electric vehicle (Hardman et al., 2017). Incentives delivered at the point PEV acquisition are more impactful and efficient (Roberson and Helveston, 2022). Two studies show that the impact of incentives increased in importance over time (even when controlling for income and other attributes of PEV buyers that are changing over time) (Jenn et al., 2020; Johnson and Williams, 2017). Considering that use of incentives correlates with certain demographics (e.g., income) and that their importance may increase over time (Jenn et al., 2020), incentive removal could have negative implications for low-and moderate income buyers . In addition, low-income buyers may have limited access to incentives that require electric vehicles to be purchased at a dealership, because 40% of low income car buyers do not purchase cars from dealerships (Pierce et al., 2020).

Many incentive programs are not well designed to benefit those that need them most. Higher-income households, which make up a larger share of the PEV market, receive a disproportionately high amount of government subsidies and PEV benefits (Sheldon, 2022). If incentive funding is limited, it may be necessary to target incentives to those whose PEV purchase is dependent on them. Incentives could better reach those who most need them by: increasing the amount for lower income buyers, having price caps or income caps for eligibility, removing requirement for purchase at dealerships, making used vehicles eligible, not tying incentive amounts to tax liability, applying incentives at the point of PEV purchase, having low administrative requirements for buyers, providing assurances on incentive availability (e.g., mitigate funding discontinuities, as have occurred in California (Center for Sustainable Energy, 2021)), and increasing awareness of available incentives.

PEV adoption may also be influenced by fuel prices, with lower electricity prices and higher gasoline prices potentially increasing PEV sales. Studies in several regions have found gasoline prices correlate with PEV demand (Kangur et al., 2017; Narassimhan and Johnson, 2018; Plötz et al., 2016; Wee et al., 2018a). According to Bushnell et al. changes in gasoline prices have a larger impact on PEV demand than changes in electricity prices (Bushnell et al., 2022).

The limited driving range of BEVs is a commonly cited barriers to PEV adoption (Wicki et al., 2022), with some research showing range as the most important barrier (Axsen et al., 2017; Franke et al., 2012; Rezvani et al., 2015; Schneidereit et al., 2015). While many of these studies were published before recent increases in PEV range, Herberz et al. (2022) show that range is still a perceived barrier. Long charging times of PEVs is also a commonly mentioned barrier to PEV adoption (Adepetu and Keshav, 2017; Franke et al., 2012; Jabbari et al., 2017; She et al., 2017; Tarei et al., 2021; Vassileva and Campillo, 2017; Wicki et al., 2022), as is a lack of access to home charging (Visaria et al., 2022). Next, purchase price is a barrier to PEV adoption (De Rubens et al., 2018; Kurani et al., 2018; O'Neill et al., 2019; Wicki et al., 2022) with some studies cost as the largest barrier to adoption (Adepetu and Keshav, 2017; Vassileva and Campillo, 2017). Lower operating costs may offset higher initial costs, but not always in instances of lower gasoline and higher electricity prices (Chakraborty et al., 2021; Rapson and Muehlegger, 2023). Dealerships and salespeople may also be a barrier to PEV adoption (Cahill et al., 2014; De Rubens et al., 2018; Krishna, 2021; Kurani et al., 2018; Matthews et al., 2017; O'Neill et al., 2019; Turrentine et al., 2018), when dealers have poor knowledge of PEVs and are unmotivated to learn about PEVs (De Rubens et al., 2018; Turrentine et al., 2018).

Among the general population, studies show a low knowledge, awareness, and familiarity with PEVs (Krause et al., 2013; Kurani, 2022b) and these measures so far have appeared to change little over time (Kurani, 2022a; Long et al., 2019). These factors relate to attitudes and willingness to adopt PEVs (Axsen et al., 2017; Hardman et al., 2017; Rezvani et al., 2015; Tarei et al., 2021; Wicki et al., 2022). While technical progress continues on developing PEV charging and improving PEV range, several cross sectional studies in North America and Canada (Kurani, 2022a, 2022b, 2019; Long et al., 2019) show little change in knowledge and perceptions over time.

The literature review summarized here was used to inform the methods used in this study, including the decision to conduct listening sessions (due to a lack of studies specifically on this population), and the topics included in the survey.

Methods

Listening sessions

To understand knowledge and perceptions of PEVs in underserved communities and to inform the development of the survey, we hosted seven community listening sessions in English and Spanish in regions of California that were considered historically underserved, including Oakland and Visalia. The sessions followed a semi-structured protocol and about halfway through each meeting, a 10 to 15-minute presentation on ZEVs was held to help inform participants about ZEVs. The focus groups explored travel experiences, barriers, needs of participants, knowledge and perceptions of electric vehicles, and participants' priorities for transportation improvements. In this interim report we primarily focus on knowledge, preferences, and perceptions of PEVs (FCEVs were discussed less in the sessions). Participants were recruited by community partners via social media, at community events, and through direct communication (e.g., email). Participants received a $25 gift card for participating as an incentive. Appendix 1 includes the protocol used in the listening sessions and the content of the informational presentation.

Results are framed using the COM-B behavior change model (Figure 4) (Michie et al., 2011). The model breaks down an individual's ability to change their behavior into 3 categories: capability, opportunity, and motivation. We used this model because the adoption of a PEV represents a behavior change. In our use of the model, the behavior change is the decision to adopt a PEV or ZEV. The model helps identify different issues related to PEV adoption and provides recommendations of how to address the issues related to capability, opportunity, and motivation. The COM-B model includes physical capability, psychological capability, physical opportunity, social opportunity, automatic motivation, and reflective motivation. The definitions in the model are as follows.

- Capability is an individual's psychological and physical capacity to engage in the behavior concerned, including the knowledge and skills to perform the behavior. Interventions related to addressing capability include education, training, increasing knowledge, and skills needed to make change.
- Motivation consists of processes that energize and direct behavior, not just goals and conscious decision-making. These include habitual processes, emotional responses, and analytical decision-making. Motivation includes both automatic motivation and reflective motivation. Interventions to address motivation include increasing knowledge, eliciting positive feelings toward behavior, associative learning, and imitative learning.
- Opportunity includes factors that lie outside the individual that make the behavior possible or prompt it. Opportunity includes both physical opportunity and social opportunity. Interventions to address opportunity include changes to the environment.

Capability, opportunity, and motivation all impact the ability of an individual to change behavior, and capability and opportunity also impact motivation.

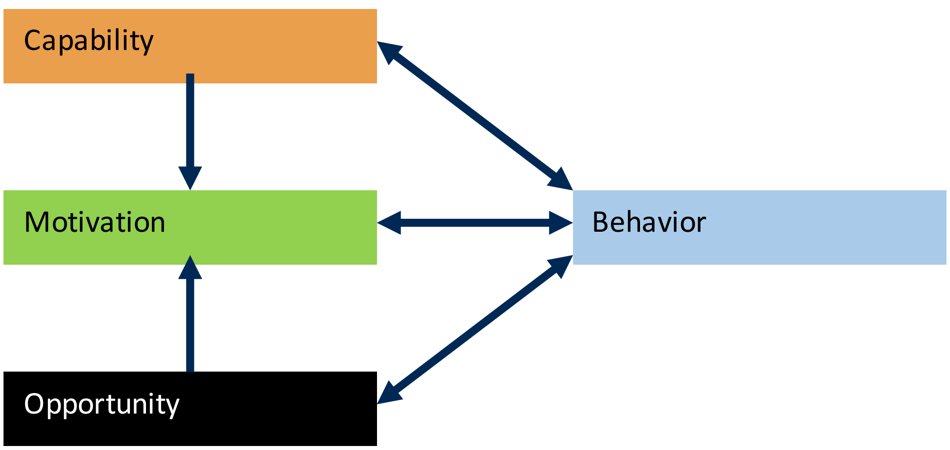


Figure 4: COM-B Behavior Change Model Theoretical Framework. Directional arrows indicate the direction in which aspects typically influence one another.

Listening Session Analysis

All seven listening sessions were audio recorded and then transcribed by a team of English- and Spanish-speaking individuals. Spanish sessions were translated to English so that all analysis could be done in the same language. These transcripts were coded in a three-step process using a grounded theory and thematic analysis approach, first line by line, followed by axial coding (or categorizing), and finally selective coding (Gibbs, 2012). After this we organized our codes in line with the COM-B model. Codes were created inductively, meaning they were derived from the data. This inductive three step process is used to minimize researcher-induced bias and identify new findings that may be overlooked in a selective or deductive approach. Another benefit of line-by-line coding is the analysis can capture how much a topic is spoken about. As an example, if a participant stated, "I think PEVs are too expensive," this would be coded as the barrier of "Cost." NVivo 12 Plus was used to analyze the transcript and perform coding. For the purposes of this report, we selected only codes related to decision-making and related actions and themes regarding the individuals' perceptions of adopting PEVs or ZEVs. Micromobility modes of transit such as e-bikes and e-scooters were not included at this time.

Codes are organized into their respective area of behavioral change using the COM-B model. Codes were distributed, according to the coder's expertise, into one of these areas based on how participants' words aligned with the areas.

For the purpose of the analysis, physical capability includes all the physical barriers to purchasing (including respondent's ability to afford a PEV); psychological capability includes the mental wherewithal and preparation necessary to purchase and own an electric vehicle; physical opportunity includes all barriers external to one's personal situation (including built environment aspects such as access to charging infrastructure); social opportunity includes having an adequate social network and role models that could support the decision to own an electric vehicle; automatic motivation includes the inherent desire for an electric vehicle; and reflective motivation includes priorities that may provide competition for the desire to own an electric vehicle.

After thematic analysis was completed, the codes of all listening sessions transcripts were assigned either "before informational presentation" or "after informational presentation." These served to differentiate what individuals spoke about during the listening sessions both before and after the presentation on ZEVs (the presentation covered BEVs, PHEVs, and FCEVs, most of the discussion focused on PEVs though). We took this step to see whether the information increased the detail of the conversation on ZEVs, which was the purpose of the presentation. We also did this to see whether the presentation changed the sentiment in how ZEVs were discussed, which was not the purpose of the presentation. For the purposes of this analysis, results were limited to only codes that had five or more references.

Finally, a separate coding procedure was used to perform a sentiment analysis on the dataset. The seven transcripts were once again coded line by line, this time looking for any statement related to PEVs, ZEVs, and activities related to them, such as charging. These statements were assigned "positive," if the statement seemed favorable about PEVs and their related infrastructure, "negative," if the statement seemed unfavorable, and "neutral," if the statement seemed neither favorable or unfavorable or it was clarifying or looking for more information about PEVs. Additionally, if there was negative sentiment towards vehicles but not specifically PEVs, this was also categorized as "neutral." The same coder performed the thematic analysis and sentiment analysis to reduce bias. The sentiment analysis results were cross tabulated against the previous thematic analysis. The resulting matches were then limited to those that had at least 4 responses total in "positive," "neutral," and "negative" to minimize mismatches and overlaps due to the different coding styles. These were then re-organized into the COM-B model to compare participants' sentiments about the barriers to and instruments of change. Additionally, the sentiment analysis was cross-tabulated with the temporal analysis to determine whether the informational presentation influenced individuals' attitudes towards ZEVs.

Appendix 1 includes some descriptive statistics of listening session participants, the sessions included a diverse population that mostly had low incomes and included households who owned at least 1 car.

Questionnaire Survey

Sample & Recruitment

The target sample for the survey was California *priority populations*, which includes households in disadvantaged communities (DAC) (which includes tribal census tracts and disadvantaged census tracts as defined by CalEnviroScreen 4.0), low-income tracts, and low-income households in non-priority census tracts. Participants were randomly selected from each of these census tract categories. Our sample is a stratified random sample, where the strata is each priority population category (households in disadvantaged tracts, low income tracts, tribal tracts, disadvantaged and low income tracts, and low-income households in non-disadvantaged tracts). The sample was stratified to get larger sample sizes in some priority population categories that have relatively small populations in the state (e.g., tribal census tracts). The random sampling drew from an address-based sample. We randomly selected a sample of 77,421 addresses. Table 2 shows sample counts for each priority population and the number of survey responses from each tract type.

Table 2: Priority population tract categories and counts of the number of households we will invite to take the survey.

Priority population tract category	Email sample	Mail Sample	Total sample	Completed and cleaned responses
DAC and Low Income	10,154	9110	19,264	388
DAC only	5146	5042	10,188	229
Low Income only	10,155	9003	19,158	588
None	9036	7512	16,548	485
Tribal (full tract)	2024	2041	4065	195
Tribal (partial tract)	4136	4062	8198	266

Survey recruitment was multimodal (email, mail, and a paper survey). A total of 40,651 participants were invited to take the survey by email and 36,770 participants invited to take the online survey by mail. Four email reminders were sent to those who did not respond in the email group and one mail reminder was sent to those who did not respond in the mail group. We subsequently sent paper surveys, which included an option to take the online survey, to a random selection of 20,000 recipients of mail or email who had not responded. An incentive of an $8 Amazon gift card was given to the first 2,500 responses. This value was determined based on reviewing literature on the effect of survey incentives on response rates (James and Bolstein, 1992; Singer, E., & Ye, C., 2013; U.S. Census Bureau., 2017). As of May 9, 2024, the survey had a response rate of 3%.

In October 2023 we piloted the survey with a convenience sample of households in the Sacramento region and PEV owning households in California. Both groups were recruited from respondents from prior PEV Center Surveys. The pilot survey identified few problems in the survey and a good completion rate, though had a longer than desired completion time. Based on this, we simplified some of the wording of questions and removed some questions. The survey was launched on November 30, 2023.

Survey Outline

The outline of the print survey is shown in Appendix 5. The survey contained sections on:

- Travel mode use and frequency of mode use
- Trip origins and destinations, the mode for each trip, trip purpose, trip duration, and time spent at the destination
- Household vehicle ownership and vehicle purchasing behavior
- Knowledge, perceptions, and prior consideration to buy an electric vehicle
- A survey experiment testing the effect of different policy interventions
- Respondent priorities for transportation improvements
- Household and respondent demographics
- Attitudinal questions

Survey Experiment Design

We used a survey experiment to investigate the effect of various policy interventions on BEV purchase consideration (the experiment only focused on BEVs, not FCEVs or PHEVs). This allows us to identify which interventions do and do not significantly impact consideration to purchase a BEV.

We designed the experiment partially based on the results from the listening sessions. The listening sessions identified several barriers to BEV adoption, including high vehicle price, a lack of charging infrastructure, and concerns about vehicle reliability and battery degradation, in addition to low knowledge. Based on this, we designed a survey experiment to test the effect of providing information on three categories of existing policy interventions intended to address these barriers, including financial incentives, infrastructure, and battery assurance measures. The vignette-style survey experiment design is shown in the OSF (Center for Open Science) preregistration (Hardman et al., 2023). Incentives and battery assurance measures each consist of three levels, while charging infrastructure has six levels.

We used a full-factorial between-subjects design. Respondents were randomly shown one of 54 possible scenarios (see Table 3), consisting of a possible combination of various levels of policy interventions, after which they were asked their likelihood to consider buying a BEV on a continuous 700-point scale (from very unlikely to very likely). We use such a design as it allows us to manipulate one or more attributes of the scenario while holding others constant, isolating the effect of each policy intervention level. The slide bar was designed with two end points and numbers (1-7) as a guide for respondents. We chose this scale based on a review of the literature on slider bar design (Buskirk, 2015; Chyung et al., 2018; Guin et al., 2012; Liu, 2017; Toepoel and Funke, 2018)

Survey experiments are less prone to social-desirability bias compared to direct questioning. Although they can be a poor predictor of real behavior and may be less good at measuring behavioral intention compared to measuring general attitudes, both discrete choice experiments and conjoint analysis suffer from this limitation. The benefits of a survey experiment include a comparatively simpler design, needing to show fewer experiments to each respondent, less risk of fatigue effects, and informational burden impacting response.

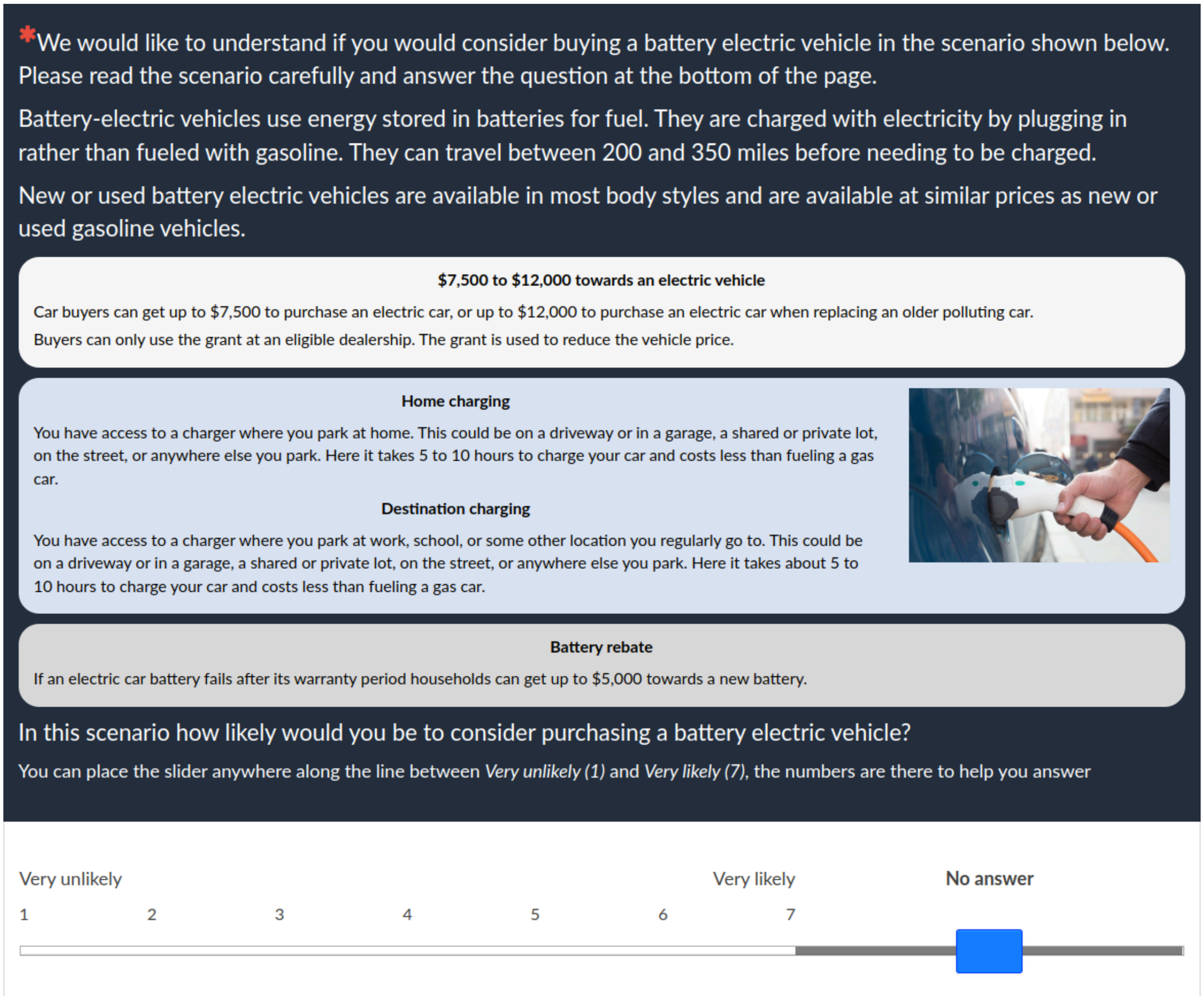
To ensure all theoretically relevant dimensions are included, the information respondents need to consider a BEV (what BEVs are, cost, range, model availability) are held as a constant in all experiments to help address bias from omitted variables. In particular, due to respondents' lack of understanding of BEVs and the survey experiment only having three dimensions, we included an informational introduction to the survey experiment, giving respondents the information they need to consider an electric vehicle. The experiment does not specify vehicle body style, whether the vehicle is new or used, or whether respondents should purchase or lease a vehicle. We leave these as abstract because electric vehicles are abstract to most vehicle buyers, and to give respondents freedom to consider a vehicle type and ownership type that they imagine and is relevant to them. The survey experiment included the following question text intended to provide any information respondents need to respond to the question:

> *We would like to understand if you would consider buying a battery electric vehicle in the scenario shown below. Please read the scenario carefully and answer the question at the bottom of the page.*
>
> *Battery-electric vehicles use energy stored in batteries for fuel. They are charged with electricity by plugging in rather than fueled with gasoline. They can travel between 200 and 350 miles before needing to be charged.*
>
> *New or used battery electric vehicles are available in most body styles and are available at similar prices as new or used gasoline vehicles.*
>
> *In this scenario how likely would you be to consider purchasing a battery electric vehicle?*

Table 3: Vignette dimensions (policy interventions), vignette levels, and the text show to survey respondents for each vignette level (*indicates reference or control level).

Intervention	Levels	Text shown to survey respondents
Financial incentives	None*	
	Clean Cars for All- reduced	$7,500 to $12,000 towards an electric vehicle Car buyers can get up to $7,500 to purchase an electric car, or up to $12,000 to purchase an electric car when replacing an older polluting car. Buyers can only use the grant at an eligible dealership. The grant is used to reduce the vehicle price.
	Clean Cars for All	$5,000 to $8,000 towards an electric vehicle Car buyers can get up to $5,000 to purchase an electric car, or up to $8,000 to purchase an electric car when replacing an older polluting car. Buyers can only use the grant at an eligible dealership. The grant is used to reduce the vehicle price.
Charging infrastructure	Public level 2*	Public charging You have access to chargers in your community. Here it takes about 5 to 10 hours to charge your car and costs less than fueling a gas car.
	Public fast	Public charging You have access to chargers in your community. Here it takes about 15-40 minutes to charge your car and costs the same as fueling a gas car.
	Home	Home charging You have access to a charger where you park at home. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes 5 to 10 hours to charge your car and costs less than fueling a gas car.
	Destination	Destination charging You have access to a charger where you park at work, school, or some other location you regularly go to. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes about 5 to 10 hours to charge your car and costs less than fueling a gas car.
	Home and destination	Home charging You have access to a charger where you park at home. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes 5 to 10 hours to charge your car and costs less than fueling a gas car. Destination charging You have access to a charger where you park at work, school, or some other location you regularly go to. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes about 5 to 10 hours to charge your car and costs less than fueling a gas car.

Intervention	Levels	Text shown to survey respondents
	Home and public fast	Public charging You have access to chargers in your community. Here it takes about 15-40 minutes to charge your car and costs the same as fueling a gas car. Home charging You have access to a charger where you park at home. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes 5 to 10 hours to charge your car and costs less than fueling a gas car.
Batteries	None*	
	Rebate	Battery rebate If an electric car battery fails after its warranty period households can get up to $5,000 towards a new battery.
	Warranty	Battery warranty Automakers will replace electric car batteries that have less than 75% of their original range before 8 years or 100,000 miles at no cost to owners.



*We would like to understand if you would consider buying a battery electric vehicle in the scenario shown below. Please read the scenario carefully and answer the question at the bottom of the page.

Battery-electric vehicles use energy stored in batteries for fuel. They are charged with electricity by plugging in rather than fueled with gasoline. They can travel between 200 and 350 miles before needing to be charged.

New or used battery electric vehicles are available in most body styles and are available at similar prices as new or used gasoline vehicles.

$7,500 to $12,000 towards an electric vehicle

Car buyers can get up to $7,500 to purchase an electric car, or up to $12,000 to purchase an electric car when replacing an older polluting car.

Buyers can only use the grant at an eligible dealership. The grant is used to reduce the vehicle price.

Home charging

You have access to a charger where you park at home. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes 5 to 10 hours to charge your car and costs less than fueling a gas car.

Destination charging

You have access to a charger where you park at work, school, or some other location you regularly go to. This could be on a driveway or in a garage, a shared or private lot, on the street, or anywhere else you park. Here it takes about 5 to 10 hours to charge your car and costs less than fueling a gas car.

Battery rebate

If an electric car battery fails after its warranty period households can get up to $5,000 towards a new battery.

In this scenario how likely would you be to consider purchasing a battery electric vehicle?

You can place the slider anywhere along the line between *Very unlikely (1)* and *Very likely (7)*, the numbers are there to help you answer

Very unlikely Very likely **No answer**

1 2 3 4 5 6 7

Figure 5: Example survey experiment as seen by survey participants. In this example vignette respondents see a full CC4A incentive, home and destination charging, and the battery rebate. The slider bar could be moved anywhere between "Very unlikely" and "Very likely". The slide bar was designed with two end points and numbers (1-7) as a guide for respondents. We chose this scale based on a review of the literature on slider bar design (Buskirk, 2015; Chyung et al., 2018; Guin et al., 2012; Liu, 2017; Toepoel and Funke, 2018)

Survey analysis

Below we describe the methods used to analyze the survey, focusing on the use of regression and clustering methods. We also used t-tests, ANOVA, and chi-square tests to for some bivariate analysis. Appendix 2 outlines some additional details for analysis.

Analysis of vehicle ownership

We used a Poisson regression model to analyzed factors related to the number of vehicles owned by a household. This count-based regression technique is well-suited for the non-negative integer nature of the dependent variable: the number of vehicles owned by a household. The Poisson regression model assumes that the vehicle count follows a Poisson distribution, where the mean and variance of the distribution are equal. The results can be interpreted as the expected change in the log of the vehicle count for a unit change in the corresponding independent variable, holding all other factors constant. Table 1 in Appendix 2 presents the descriptive statistics of the parameters used in the vehicle ownership model. The vehicle ownership model used 2151 completed survey responses. The household (HH) parameters used in the model include HH size, HH income, ratio of purchase price of vehicles (as reported by the respondents) to HH income, whether respondents have access to additional vehicles for the HH, number of children and number of drivers in the household. Appendix 5 provides the survey statistical analysis with a summary table of these variables and the reference category used for these indicator variables. The indicator variables include race/ethnicity, gender, education level, employment status, and type of dwelling type (rent/owned, single family/apartment/condo, etc.). We also capture the type of vehicle owned (ICEV & HEV or BEV & HEV), and whether respondents purchased or leased their primary vehicle. We also integrate into the model built environment parameters from the US EPA SMART location database, including residential density, land use diversity, design of the built environment, accessibility, and distance to transit (US EPA, 2021).

Survey Experiment Analysis

Using results from the survey experiment, we specify linear regression models to test whether there is a statistically significant relationship between various policy interventions and respondents' likelihood to consider buying a BEV on a continuous scale from 0 (Very Unlikely) to 7 (Very Likely). We consider in the analysis households that own vehicles and those that are at least considering buying a vehicle. Prior to conducting the analysis, we confirmed that the vignette levels seen by survey participants are balanced, i.e., within the various interventions, each level was presented to a similar number of respondents, and there is minimal correlation between the levels, meaning the presence of one level within a particular category is not correlated with the presence of any other level from another category. Based on this we determined the experimental design was executed as intended and the randomization of the survey vignettes worked as intended.

In the models, we control for socio-demographics, attitudes, and built environment variables, in addition to the interventions (Table 6). We use exploratory factor analysis to identify the underlying relationships between the nine indicator variables of BEV perceptions.

We specify beta regression models to test whether there is a statistically significant relationship between various levels of policy interventions and respondents' likelihood to consider buying a BEV. Beta regression models are designed for modeling continuous dependent variables which represent a proportion or percentage, and constrained between 0 and 1. Our assumption is that the data is continuous and that respondents interpreted the scale similarly as one another meaning a one unit increase in the dependent variable is equivalent access observations, something we hope was achieved through the design of the slider scale. The model is assumed to follow a beta distribution, which is flexible to many different shapes, including asymmetrical or U-shaped, since its density depends on the two parameters indexing the distribution: 1) the mean parameter μ, the expected value of the response variable, and 2) a precision parameter phi, which controls the dispersion or variance around the mean (Ferrari and Cribari-Neto, 2004). The precision parameter and variance in the beta distribution are inversely related, thus higher values of the precision parameter indicate lower variance in the mean of the response variable. The model uses a logit-link function to relate the linear predictors to the predicted value of the response variable. The basic form of the model is written as:

$$g(\mu)=X\beta$$

Where:

- μ is the mean of the response variable, bounded between 0 and 1.
- $g(\,)$ is the logit link function
- X represents the vector of independent variables.
- β is the vector of coefficients for the covariates.

Since the response variable is constrained between 0 and 1, we convert the continuous 100-to-700-point scale to a 0- to 1- scale. We then constrain values equal to exactly 0 and 1 to 0.001 and 0.999, respectively. The distribution of the response variable, shown in Figure 6, follows roughly a U-shape distribution. In addition to being flexible to such a distribution type, another benefit of the beta regression model is that unlike linear regression, it does not make predictions outside the range of the response variable, thus, the beta model would not predict a respondent to be more than very likely, or less than very unlikely to consider purchasing a BEV.

Finally, we also estimated an ordinal regression model (not included in the report) and the results were similar with not different conclusions drawn from that model. We retain the beta regression model since we believe it is easier to interpret.

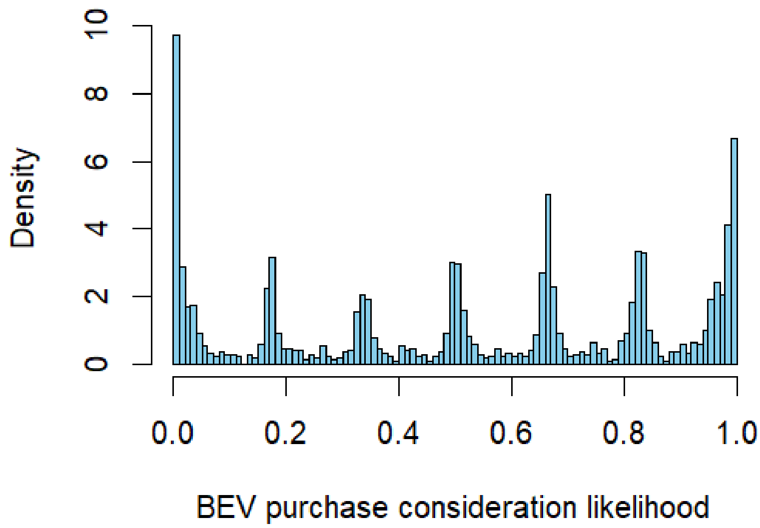


Figure 6: Distribution of response variable.

Variables in analysis

In addition to the interventions, we also control for socio-demographics and contextual variables, in addition to attitudinal variables, described in Table 6 and Table 4. The 15 attitudinal variables (see Appendix 2, table 4) categorized by life style, travel, land use, and personality, are based on the results of Shaw (Shaw, 2021) , with each variable representing a unique construct in and of themselves. We confirmed that none of the attitudinal variables have a correlation with each other greater than 0.3. Lastly, we control for BEV perceptions through exploratory factor analysis, described in the following section. We specify five separate models; the first four of which control individually for policy interventions, socio-demographics, BEV perceptions, and attitudes respectively, and a final model which controls for all of the variables, in addition to the contextual variables.

We do not control for census tract type (DAC, low-income, tribal, etc.) due to its high correlation with measures of EVs per capita in a census tract. We tested models which controlled for census tract and EVs per capita individually. Results of likelihood ratio test indicated the model controlling for census tract type was not statistically significantly different from the model which did not control for census tract type. However, we did find there to be significant differences between the model controlling solely for EVs per capita, versus a model not controlling for this variable. In addition, we do not control for absolute measures of home charge access (or proxies such as home ownership or home type), or public charging, as the survey experiment is intended to control for public and home charging availability through hypothetical scenarios. We do however include subjective measures of charging accessibility, including perceptions of home charge access and whether there are enough public charging locations.

Exploratory factor analysis

We use exploratory factor analysis (EFA) to identify the underlying relationships between nine indicator variables of BEV perceptions, which are treated as continuous and measured on a 5-point Likert-type scale from “Strongly Disagree” to “Strongly Agree”. For statements which “Strongly Agree” aligns with a negative perception, we use the inverse value so that a higher value for each statement aligns with positive BEV perceptions. **Table** 4 provides a description of the perception-related variables, in addition to their factor loadings. A factor loading of 0.50 or above, indicated in bold, was used as a threshold to determine whether a variable is strongly related to a factor. Both the Tucker-Lewis index and root mean square error of approximation exceed their recommended thresholds for acceptable model fit.

We find that respondents' perception of home charge access (“*My household would be able charge a battery electric vehicle at home*”) represents its own unique construct, thus is removed from the factor analysis but maintained in the regression as a control variable. We find that a three-factor solution optimizes EFA model fit for the remaining eight perception indicators. The factors are related to battery quality concerns, whether there are enough BEV chargers and whether BEVs have enough range, and awareness of BEV incentives and whether respondents have enough knowledge of BEVs to decide about getting one. We then predict for each respondent their factor scores, which are also treated as control variables in the regression analysis.

Table 4: Exploratory factor analysis of BEV-related perceptions, the table shows factor loadings for each BEV related statement for the three identified factors.

Survey question	Charging and range	Awareness and knowledge	Battery quality
"Battery electric vehicles travel far enough before needing to be charged"	**0.72**	0.02	0.28
"There are enough places to charge battery electric vehicles"	**0.5**	0.05	0.1
"I am aware of the different electric vehicle incentives available to me"	0.06	**0.6**	0
"I know enough about battery electric vehicles to decide about getting one"	0.02	**0.74**	0.05
"Electric vehicle batteries degrade too fast"	0.19	-0.01	**0.52**
"Battery electric vehicles are easier to maintain than gasoline vehicles"	0.24	0.25	**0.59**
"Battery electric vehicles are more damaging to the environment than gasoline vehicles"	0.08	-0.04	**0.74**
"Gasoline vehicles are safer than battery electric vehicles"	0.14	0.03	**0.64**

Latent class analysis

We used latent class analysis to identify classes of survey respondents based on their perspectives on PEVs. This helps reveal perceptions, knowledge, consideration, and support for PEV regulations with more nuance. Here we describe the methods and data used to identify classes of survey respondents based on their knowledge, perception, BEV purchase consideration, and ZEV policy support. Step-3 latent class analysis (LCA) is used to identify these unique classes and build a multinomial logistic regression model. Appendix 2 Exploratory Analysis of Latent Classes provides more detail of the LCA and multinomial logistic regression (MNL) models.

Step-3 latent class analysis (LCA) was implemented using the “poLCA” in R. LCA refers to a model in which observed categorical variables are a result of unobserved or latent distributions (Sinha et al., 2021). Step 1 of Step-3 LCA involves identifying the latent classes. These classes are estimated using the expectation-maximization (EM) algorithm and maximum likelihood estimation (MLE). To begin, the probability of survey respondent belonging to one class is randomly chosen. Subsequently, MLE is used to determine and assign “posterior probabilities.” This is an iterative process to maximize the log-likelihood of the model. Different numbers of classes are tested, with the optimal number being selected as per the Bayesian information criterion (BIC), Akaike information criterion (AIC), entropy, and smallest latent class size. Step 2 of Step-3 LCA refers to class assignments. Survey respondents are categorized based on modal class assignment where a respondent is assigned to the class that they have the highest probability of belonging to. Twelve variables, described briefly in Table 6, are used to develop a latent class model, related to respondents' knowledge, perceptions, consideration to purchase a BEV, and support for ZEV policy.

Table 5: Variables used in the latent class cluster analysis for the classification.

Variable name	Type	Description
Knowledge	Dummy	Yes, Correct (2) *Reference:* No, Incorrect, Don't know, Partially correct (1)
Home charge	Categorical	Strongly Disagree(1) – Strongly Agree(5)
Range		Strongly Disagree(1) – Strongly Agree(5)
Safety		*(inverse)* Strongly Disagree(1) – Strongly Agree(5)
Environmental impact		*(inverse)* Strongly Disagree(1) – Strongly Agree(5)
Maintenance		Strongly Disagree(1) – Strongly Agree(5)
Knowledge		Strongly Disagree(1) – Strongly Agree(5)
Enough chargers		Strongly Disagree(1) – Strongly Agree(5)
Battery degradation		*(inverse)* Strongly Disagree(1) – Strongly Agree(5)
Incentive awareness		Strongly Disagree(1) – Strongly Agree(5)
BEV consideration	Categorical	"Haven't, won't" (1) – "Already own" (6)
ZEV policy support	Categorical	Strongly Oppose(1) – Strongly Support(5)

In the third step, we use a multinomial logistic regression model to explore how demographics, attitudes, and built environment may relate to survey respondent classification into one of the latent classes while holding all else constant. We also explore descriptive statistics (see Appendix 2). A description of the control variables is presented in Appendix 2, in the section *Exploratory Analysis of Latent Classes*. This model was created using the "multinom" function of the "nnet" package in R. The nominal dependent variable consists of more than two categories, where we select a base category to compare with other categories. The outcome is the natural logarithm of the ratio between the probability of belonging to a base category and the probability of belonging to another specified category, called the relative log odds.

Five assumptions are made in implementing this model: observations are independent, independent variables are not collinear, independent variables and the log odds of the dependent variables are linear, there are no outliers in the data, and there is an independence of irrelevant alternatives (IIA). Collinearity is tested using the variance inflation factor (VIF) and we found that no VIF scores exceeded 5, indicating acceptable levels of correlation among independent variables. Linear relationships between continuous variables and the log odds of dependent variables were checked using scatter plots, and there were no curved relationships in our data. The IIA assumption refers to the unchanged likelihood of an observation belonging to a category when new categories are added and is particularly important for MNL models. Because we were not using this model to predict outcomes, we believe this assumption will not impact our analysis. To measure the goodness-of-fit in logistic regression models, we used McFadden's pseudo-R^2. This statistic evaluates how well the independent variables explain the variation in the dependent variable. Specifically, it assesses the degree to which the independent variables improve the prediction of class membership compared to a model with no predictors.

Table 6: Variables used in latent class regression MNL model and survey experiment beta regression model (used in *MNL only).

Category	Variable	Type	Description
Demographics	Age	Continuous (14-80 years)	Midpoint of age category
	Gender	Dummy	Male Female or other (Reference)
	Race*	Categorical	White (Reference) Asian Hispanic/Latinx Other
	Education	Dummy	College educated or above High school or less (Reference)
	Income	Categorical	Less than $50,000 $50,000 to $99,999 $100,000 to $149,999 $150,000 or more (Reference)
	Home Ownership*	Dummy	Own Rent/other (Reference)
	New car buyer	Dummy	Typically buys new cars Typically buys used cars (Reference)
	Vehicles per driver	Continuous (0-5)	Vehicles/Drivers in household
Attitudes	Pro-car	Continuous (1-5)	Strongly Disagree(1) – Strongly Agree(5)
	Pro-too busy		
	Pro-social		
	Anti-tech		
	Pro-mixed land use		
	Anti-waiting		
	Anti-exercise		
	Anti-environment		
	Pro-no frills		
	Pro-travel		
	Pro-one thing at a time		
	Pro-family		
	Pro-sprawl		
	Pro-commute		
	Pro-walking		

Built Environment	**2010 People per Square km***	**Continuous**	
	Urban vs. rural	Dummy	Urban Rural (Reference)
	DCFC within 5 mins of residence*	Continuous	
	2010 PEVs per 1000 Households	Continuous	
	Highest Home Charging Accessibility*	Discrete	Level 1 Level 2 EVSE (Reference) No Charging

Results

In the results section we first discuss the results of the listening sessions. We then present results from the survey beginning with sample demographic characteristics, then travel behavior and household vehicle ownership, followed by access to PEV charging. Next, we explore consideration to purchase a PEV, perceptions of BEVs, knowledge of PEVs, and respondent support for ZEV sales regulations. This section includes the latent class model. Then, we explore the results of the survey experiment. Finally, we present descriptive statistics of respondent priorities for transportation improvements.

Findings from listening sessions

We detected themes related to all areas of the COM-B model. The most themes were associated with motivation (whether there is sufficient motivation to carry out the behavior), followed by capability (whether the behavior could be accomplished), and finally opportunity (whether there are sufficient opportunities for the behavior to occur; see Figure 7). These themes include issues related to vehicle and infrastructure costs, the availability of infrastructure, having competing priorities, knowledge and familiarity with PEVs. Below we describe perceptions related to each category and include quotes related to each barrier in Table 7. Finally, we identify and explore the specific themes related to each category in Figure 9, including the ZEV specific themes and whether ZEVs are perceived positively or negatively.

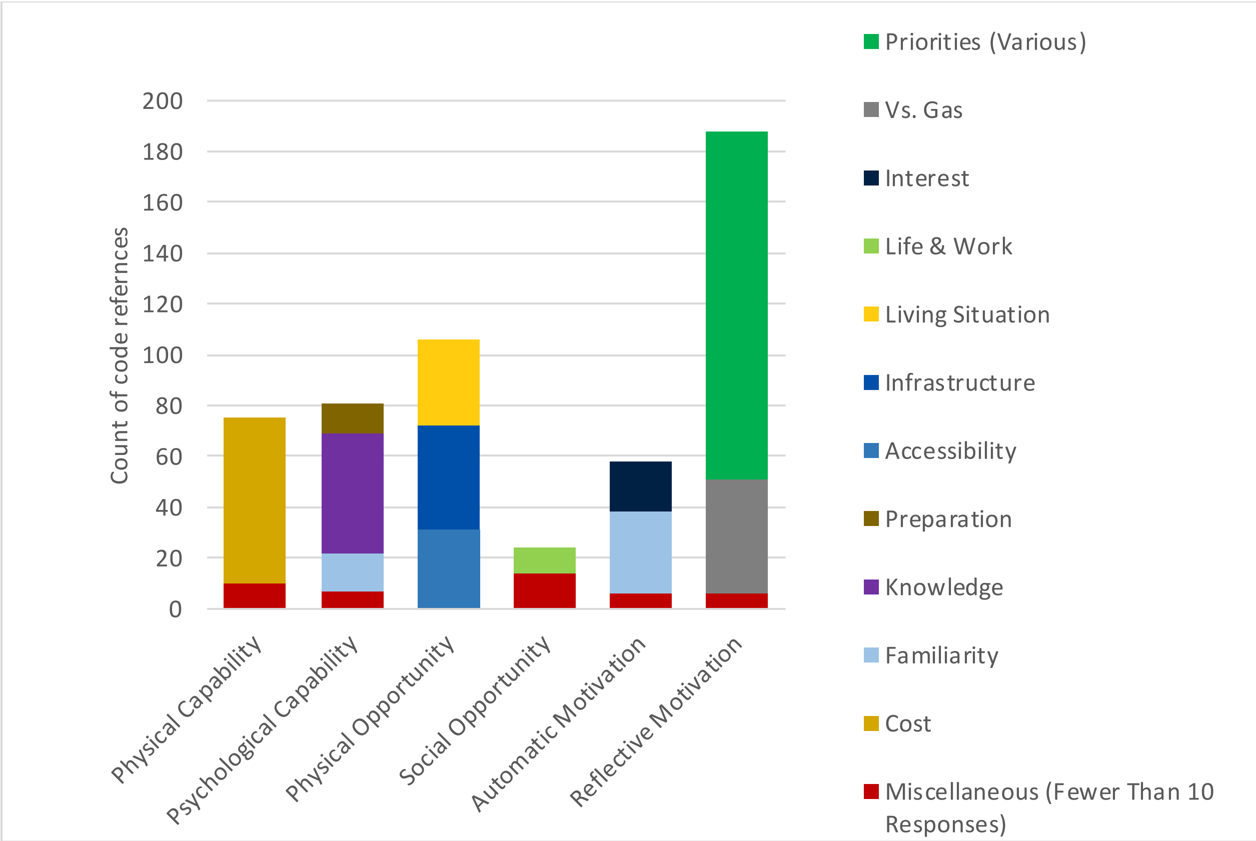


Figure 7: Number of responses by area of behavior change, separated out into categories with 10 or more references (out of 535 total references). *Capability* refers to an individual's psychological and physical capacity to engage in the behavior concerned, including the knowledge and skills to perform the behavior. *Motivation* refers to processes that energize and direct behavior, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making. *Opportunity* includes factors that lie outside the individual that make the behavior possible or prompt it. See methods or (Michie et al., 2011) for more detail.

Physical Capability

Beginning with physical (and in our case financial) capability for someone to own an electric vehicle, there were a total of 10 codes (or subcategories) that fell into this category that were composed of 75 references (the number of times the code is mentioned) across the seven meetings. These were organized into 3 themes: cost of PEVs was the largest with 65 references, followed by accessibility concerns for people with disabilities, and perceptions that PEVs were not readily available. For people with disabilities, the most common code was "concern over disabilities," which was seen once each in 2 different meetings. This theme primarily involved people inquiring whether PEVs were accessible to people with disabilities, and as one individual put it, *"I'm assuming their vehicle will likely need modification if a person requires certain modifications on the vehicle."* Other nodes pointed to making charging stations more accessible and consideration for the fact that PEVs are historically much quieter than most vehicles, which can pose a concern for individuals with visual impairments.

For cost, participants perceived PEVs as too expensive to purchase. This theme also includes other issues with cost, including the cost of maintenance, charging, and the availability of and access to incentives. There was also mention of a perceived lack of incentives for used vehicles: *"If you're the second owner or the third, you don't get anything [incentives], so you miss out."*

Psychological Capability

Within psychological capability there were 84 references. The most common theme was the need for more knowledge to decide about getting an EV. As one person stated, *"I think the culture and education is another big part into the challenge of adopting electric vehicles."* Additional issues within this category centered around knowledge or lack thereof of electric vehicles, charging stations, and similar topics, such as where to get PEV maintenance. Overall, there was a lack of knowledge of PEVs among all sessions, however there were two references showing two participants did have "knowledge about PEVs." However, "I don't know anything," was a more common sentiment toward electric vehicles. In conjunction with the lack of knowledge, many sentiments were of people benefitting from electric vehicles only when they know enough about them. For example, some perceived PEVs require additional planning, while others indicated the need to be more aware of the needs of your vehicle too.

Connected to the issues with knowledge were issues of familiarity with PEVs. Tesla was the most frequently mentioned vehicle that participants were familiar with. One respondent reported, *"Tesla's been on the news for the last three weeks."* Within this theme, there is also unfamiliarity with electric vehicles and a desire to learn more about them. To assist with making them more relatable, there were also 2 instances of comparing electric vehicles to cell phones, such as *"It's like cell phones: it's better to let it fully charge fewer times."*

Finally, within psychological capability are the connected ideas that PEVs are inevitable, and whether individuals are willing to change or are fearful of the future. The idea that PEVs are a necessity in the state of California was brought up twice: "*Yeah if I still live in California, I'm going to have to own an electric car."* Meanwhile, many are afraid of what the future will hold. While there are a handful willing to make the change to PEVs, there were only two references related to this.

Physical Opportunity

Physical opportunity had 106 references. The most common involved questions regarding whether our current infrastructure can support the transition to PEVs. Within this instrument of change, the most common issues related to infrastructure access, which was spoken about in 6 of the 7 meetings and came up a total of 41 times. This idea mainly centered around the availability of electric charging stations but could also included the ability for PEVs to be repaired. *"[Policymakers] need to put repair shops [for electric cars] and more charging stations because there are places without them, [one would have to go] to the far end [of the city to charge], I don't know how [policymakers] haven't thought of this yet."* Other sentiments expressed anxiety over the vast quantity of cars that would need to swap over to zero-emission vehicles, and how this may overload our current infrastructure and the power grid. However, some individuals also recognized improvements: *"There's more charging stations becoming available in more areas."*

Accessibility was also a big factor, at 31 references. This is unlike the previously mentioned point of accessibility that surrounds disability; rather, this concerns the barriers that the average individual would experience in buying an electric car. Many individuals feel are concerned about buying electric vehicles because of their limited range or inability to perform jobs that participants need their vehicles to do. An individual talking about making a road trip, for example, asked, *"You charge up in Vegas and then how far can you go?"* However, these individuals also recognize that infrastructure access is improving. While there are concerns over where to get PEV maintenance, an individual spoke about their son who was a mechanic, stating *"My son went to UTI, and that's, you know, a trade school, and part of their curriculum is electricity and electric cars."*

The final part of physical opportunity regards the feeling that people are limited to whether they can purchase a vehicle because they live in an apartment or don't have home charging access. There were 15 references to PEVs not being accessible for people in apartments, and 13 references to the need to be a homeowner before you can own an electric vehicle. Common sentiments expressed were: "*If you live in an apartment I'm not sure if that [owning an electric vehicle] might work,"* and *"If you own an electric car I think you must have a house to have access to a charging station."* While there were two references stating that some apartments do have charging infrastructure, there were also references stating that parking is so difficult to find in these apartments that having access to charging stations may not even matter.

Social Opportunity

Social opportunity included 24 references. While this was a less referenced category compared to others, the main focal point was on a lack of role models for switching over to PEVs. Friends and family were referenced four times, compared to twice for colleagues, and twice for government officials. The idea that PEVs are politically motivated was referenced 3 times. To quote an anecdote on the family side*, "She* [a family member] *was first in the family to get a Prius and so yeah it's kind of just been something that she's been advocating the whole family for."* Government is placed here due to the sentiment that individuals are looking to their leaders to set an example. *"What milestones have they reached and [what have they done for] turnover of their city vehicles?"* was asked in conjunction with the idea that the government is trying to push electric vehicles on people without changing their own vehicles.

The other less referenced facets of social opportunity involve community solutions and cultural change. For example, two references cited community-led initiatives for electric charging stations: *"I've seen some community opportunities where they put like a little charging station in the community."* However, a large roadblock to this change is cultural. As one individual stated, "*I think the other issue that with electric cars, people focus a lot on the deficiencies."* To achieve further success in the social opportunity realm, there may need to be more positive electric vehicle experiences.

Automatic Motivation

Automatic motivation had 58 references. The primary sentiment regarding motivation was one of worry, unease, and unfamiliarity. Chief among these complaints was that PEVs are too new. *"People are unfamiliar to the new technology,"* as one individual put it. There's a multitude of sentiments connected with this idea, including that PEVs look strange, the mechanics are unfamiliar, they appear low quality, and they are fragile. Overall, motivation to purchase an PEV is low because of this general unease.

Despite this, there was some interest in PEVs, especially after further information was provided to individuals. For example, multiple people replied in the affirmative when asked, "So now that you know a few more details about electric vehicles, do you think that they would help you meet your transportation needs?" While there are mixed sentiments, interest in PEVs was referenced nine times across three meetings, while disinterest was only referenced twice. This leads into the final section of automatic motivation regarding a willingness of individuals to try electric vehicles. PEV test drives, for example, were referenced three times. As one individual stated, *"If it is something that we're gonna have to do, then at least we're the Guinea pigs right now."* There are individuals willing to put in the time to try these new solutions, despite an overwhelming feeling that these vehicles are "too new."

Reflective Motivation

Finally, reflective motivation was the most commonly referenced instrument of change. Competing priorities make up the bulk of references, with 137 references. This code reflects that many participants have priorities that are more important to them than purchasing an electric vehicle and the perceived misalignment of electric vehicles with these priorities. The priorities observed were comfort, convenience, the environment, image, mobility, money, reliability, safety, and time. The three referenced the most were the environment, mobility, and safety.

The environment mainly involved people questioning whether PEVs are beneficial for the planet because of the materials that go into PEVs and mining related to PEV production. For mobility, a concern is the range of electric vehicles which may impact drivers overall mobility, which participants wanted to maintain, including for long trips. As for safety, participants were concerned about the risk of battery fires. All three of these competing priorities center around respondents prioritizing their concerns over mobility, safety, the environment, and reliability.

The other portion of reflective motivation regarded competing modes of transportation. While there were two references to trains being preferred over PEVs, and one each for biking and taking the bus, the main competitor is the gas vehicle. Participants perceived gas vehicles as a more competitive mode of transportation and did not see benefits of PEVs sufficient to motivate them to purchase one. This included perceptions that PEVs did not have environmental benefits, gas cars refueling faster, and no difference between PEVs and gas cars because "a car is a car." However, many of these sentiments were expressed prior to the information section of the meeting. With further education, these perceptions may change.

Table 7: Summary of results related to COM-B instrument of change, the number of references per instrument, and example quotes for each.

Perception/ Instrument of Change	Number of references	Example Quotes	
Physical Capability	**75**		
Accessibility	4	"I think there is a question here about whether programs are available for folks with disabilities. I'm assuming their vehicle will likely need modification if a person requires certain modifications on the vehicle."	"Especially for the blind it is dangerous, also the deaf or hard of hearing"
Cost	65	"It'd probably be best to buy a new one if you could afford one. They're just they're so pricey."	"But if you're of the second owner or the third, you don't get anything so you miss out. So I definitely think that there is an economic factor to that.
Availability	6	"And there's just there's more car companies gradually creating more of them."	"What I'm observing is they're becoming more widespread: electric cars."
Psychological Capability	**84**		
Familiarity	15	"For me, just I heard the most famous is Tesla right now, I think."	"It's like cell phones: it's better to let it fully charge fewer times than to keep topping it off or to get have lots of short charges. "
Knowledge	47	"So I think the culture and education is another big part in the change of adopting electric vehicles."	"We'd have to go to electrician or do you go to a mechanic?"
Preparation	12	"So you need to be more aware of the needs of your vehicle too."	"We knew two places. And it's like ok well that's good locally but back then we had to drive to San Francisco lots. You really can't charge it"

Perception/ Instrument of Change	Number of references	Example Quotes	
Inevitability	3	"Yeah if I still live in California, I'm going to have to own an electric car."	"There's a lot of questions I think, in the near future, … like you guys probably know that we have to be careful. We're all going to have to use them. "
Mentally Prepared	4	"The way you're telling me sounds a little bit better but the way I'm looking at it in my head I think 'Oh, my gosh."	"And she is replacing her Mustang that she loves, her gas guzzler, for this new Tesla"
Physical Opportunity	**106**		
Community Accessibility	31	"I'm sure that a lot of our mechanics are gearing up and getting educated, you know, to be able to take on the new challenge of this new vehicle"	"Some of these little towns are woooooo, they don't even have gas stations. Where do you charge up, you know. You charge up in Vegas and then how far can you go?"
Infrastructure	41	"Regardless of all of that, even if it's available to anyone the infrastructure's not here yet. "	"And there's more charging stations becoming available in more areas."
Living Situation	34	"If you live in an apartment I'm not sure if that might work. You might need get an extension [cable] in your apartment."	"Talking about charging the car… not everyone can access a garage, how will those with no garage access charge their cars?"
Social Opportunity	**24**		
Culture Change	2	"Can't go wrong with them. But as I said, I'm a power user so I'm an exception."	"I think the other issue that with electric cars, people focus a lot on the deficiencies and I think it's kind of the model kind of turned upside down."
Community Solutions	8	"I know I've seen some community opportunities where they put like a little charging station in the community option these two vehicles or something like that."	"I would like to share it cause it's not affordable to me but we've talked about the sharing of the cars coming in. "

Perception/ Instrument of Change	Number of references	Example Quotes	
Friends & Family	4	“And so she was first in the family to get a Prius and so yeah it's kind of just been something that she's been advocating the whole family for. “	“I guess I should say that I'm afraid to try something new because I’ve been hearing a lot from my friends.”
Life & Work	10	“What's really driving this. Is it political or is it environmental?”	“We have a maintenance yard where I live, it's a co-op and people were talking about putting a charging station inside the fenced area or outside by the administration building.”
Automatic Motivation	**58**		
Unfamiliarity	32	“I know that technology has been around for a while I think in the span of vehicles and just automobiles in general, right. It's still a new technology.”	“The way they look and how they’re built, it just looks weird.”
Interest	20	“I do see myself driving an electric car”	“But for my part, I feel like electric cars are a great way to go.”
Willing to Try	6	“To electric vehicles, driving around the community and look at and access and learn about these things in real time like if you were to test drive a car. “	“I still have the same thing as you, anything can really happen but if it is something that we’re gonna have to do then at least we’re the Guinea pigs right now. “
Reflective Motivation	**188**		
Vs. Gas	45	“The maintenance. We don’t [know] how or if it’s more expensive than gas. “	“Personally, I don’t care if the car is electric or if its gas powered, a car is a car.”
Vs. Bike/Public Transit	6	“I think we have to focus on [trains] rather than electric vehicles because [trains] will last a lot longer”	“But there's really no transit where he is, so he's got a car. It only goes about 40 miles on a charge, but that’s really all he needs.”

Perception/ Instrument of Change	Number of references	Example Quotes	
Competing Priorities:	**137**		
Comfort	2	"I would like a little bit of space you know. I don't want the PEV like on me."	"So I would want a little bit of space- a little bit of space"
Convenience	4	"I don't want the inconvenience of having to recharge it and just the hassle of driving it's much more stressful."	"They'll sit there for two to three hours charging it and I'm like maybe I'll just go charge it and go to the store and look around and wait until it's ready. "
Environment	34	"If it's going to help the environment, you know go for it. "	"With changing the batteries, all those batteries end up going to a special dump, they take a long time to decompose and are bad for the environment."
Priority Lack	1	"They would be able to but maybe they will not. We're talking about the Central Valley. I know that they're focusing a lot on it because of the storms we've had lately you know for the homeless- there's some people that are getting snowed in. "	
Image	5	"I think that I've been I guess hooked on it because my sister is like one of those woke environmentalists "	"I wonder how much profit is there to the companies that run these charging stations?"
Mobility	26	"I was gonna say to find the chargers and that's what I'm thinking of like if you take a trip you know. Like say you take a trip like from here to New York. "	"Well she can't go very far, so no Vegas trips on this thing but they're perfect for around town and super cheap."
Money	9	"I personally, I believe that electric vehicles aren't super up to date yet or very modern as far as like pricing goes for charging."	"I will say that I have contemplated like moving over to full electric but even to just with the cost of electricity like to charge at home or to charge somewhere else like that's also crazy."
Novel Aspects	9	"It is part of the future, along with autonomous vehicles and all the other."	"And you can tap into that and more vehicles that they're making have the ability to power a house, which is pretty cool. "

Perception/ Instrument of Change	Number of references	Example Quotes	
Reliability	12	“I think knowing that you know when you buy a used one, there's no guarantee it's not going to have a lot of flaws in it and also the mileage is a lot less.“	“But the cars are fine: the body, chassis, electronics, they’re all perfectly fine but it's basically a dying car.”
Safety	20	“All the batteries go up and once the battery’s on fire, they cant do nothing. So I wanna know: how safe?”	“If we had the money right now, no I still would not go get it because of safety.”
Time	15	“Yeah, I mean if you’re in a hurry to get somewhere or you’re on a trip or it’s an emergency to get somewhere, it’s just not gonna happen yet.”	“Neither do I have time to go outside to charge and wait for 3 hours… if I did own one it would take a lot of time [out of my day].”

Chronological analysis

Here we explore changes in topics discussed and sentiment before and after the presentation. Overall, participants spoke about electric vehicles more after than before the presentation (362 codes after vs. 189 before), indicating the informational presentation achieved its goal. Table 8 shows the number of responses before and after the presentation for all codes for PEVs, PEV charging, interest in PEVs, and knowledge. Table 9 shows change in sentiment before and after the presentation. Based on this, no substantial change occurred in the percent of codes that were positive or negative.

Discussion of more specific PEV topics also increased following the informational presentation, including mentions of and questions about PEV charging. Questions posed to the research team became more nuanced and specifically related to PEVs after the presentation. For example, questions such as *"Where do I have to charge [an electric car]?"* were asked before, while questions such as *"Is it possible to have a longer lasting battery?"* were asked after. The number of individuals expressing interest in purchasing PEVs also increased, while the number of people reporting that they did not have enough knowledge about PEVs in order to make an informed decision about them dropped to zero. Finally, more individuals requested additional information about PEVs after the presentation was completed. Because the presentation was a brief overview of multiple PEV topics, many people requested more information about certain topics, such as one quote: *"If the public knew there were three versions…of like where to charge…[that] would be really cool."*.

Table 8: Count of codes before and after the informational presentation and whether there was an increase or decrease in the number of codes.

Topic	Change	Responses Before Presentation	Responses After Presentation
Discussion of PEVs (Total)	↑	189	362
Discussion of PEV Charging	↑	9	59
Interest in PEVs	↑	2	7
Not Enough Knowledge About PEVs	↓	6	0
Request for Additional Information	↑	2	14

Table 9: Count of positive, neutral, and negative codes before and after the informational presentation.

	Before Presentation	Percentage of Total Before	After Presentation	Percentage of Total After
Positive	46	29.87%	78	23.35%
Neutral	40	25.97%	106	31.74%
Negative	68	44.16%	150	44.91%
Total	154	100.00%	334	100.00%

Sentiment analysis

For the sentiment analysis crossed with the thematic analysis, we focus on themes with 4 or more total results. The results of this are shown in Figure 8 and Figure 9. The COM-B areas with the most positive sentiments are Physical Capability, driven largely by PEV manufacturer availability and charging incentives; Reflective Motivation, due to the sentiments that PEVs are important for the environment and that they can do novel things such as power a house; and Physical Opportunity, due to certain positive aspects of charging while being a homeowner. The areas with the most neutral sentiments are Physical Capability, including themes related to charging costs; Psychological Capability, which saw very neutral sentiments towards Tesla as well as multiple requests for more information about PEVs; and Reflective Motivation, mostly due to neutral sentiments about PEV mobility and the battery lifespan. Finally, the areas with the most negative sentiments are Physical Capability, including complaints about the cost of PEVs and about power companies not helping with the cost of charging them; Physical Opportunity, which had a multitude of complaints about charging infrastructure as well as the inability of some apartment dwellers to charge an EV; and Reflective Motivation, which included concerns about safety, dangerous metals being used in the batteries, and charging taking too much time. Automatic Motivation was also represented, especially in the negative column, but not to the extent of other areas. Meanwhile, Social Opportunity returned no results for this analysis. While these areas did not have as many results in the COM-B model to begin with, the explanation for these two areas being much more underrepresented could be that many sentiments in these areas were mentioned 4 or fewer times, so some of these unique or niche areas were not captured under the parameters of this analysis.

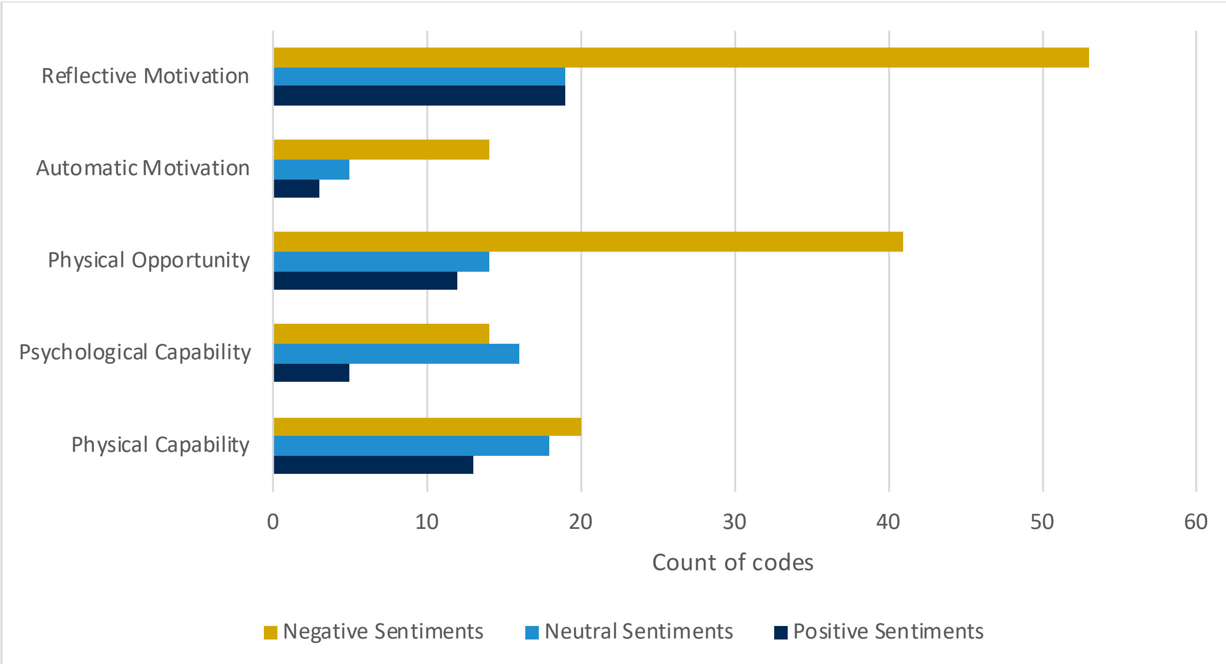


Figure 8: Count of sentiment analysis for codes by instrument of change area. (We did not identify sentiment related to social opportunity.)

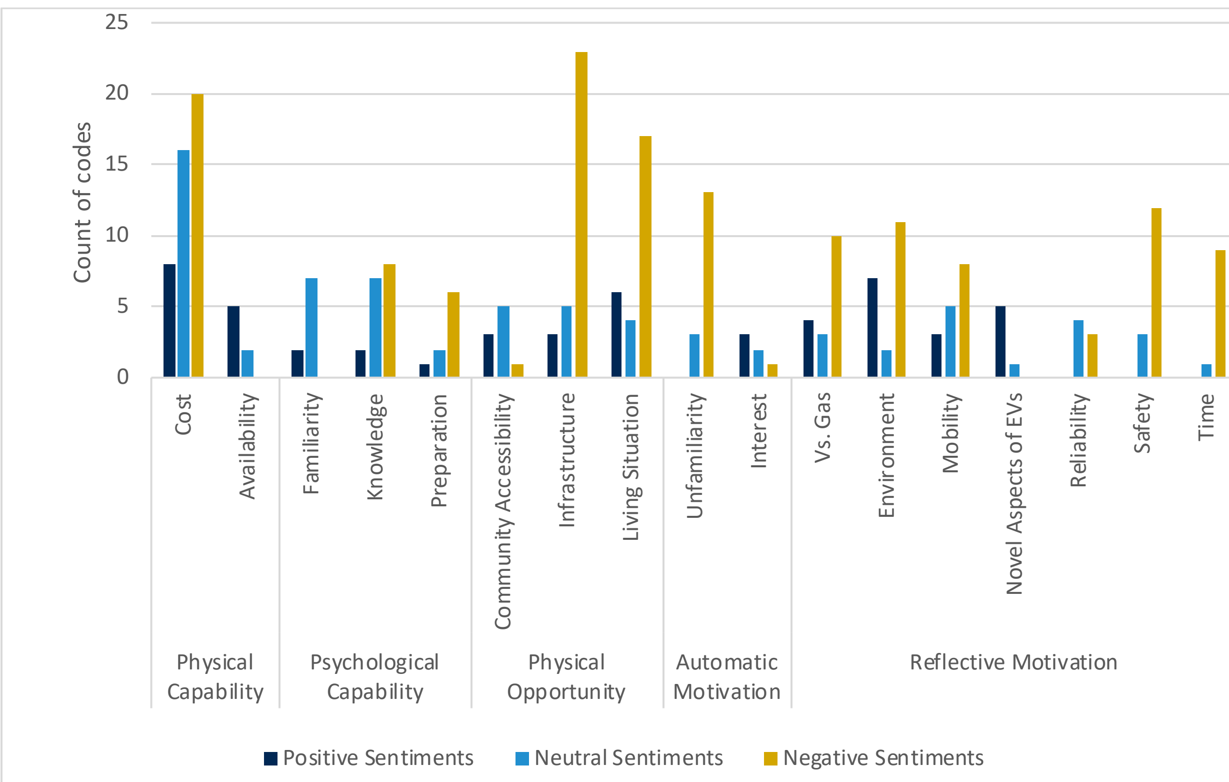


Figure 9: Count of sentiment analysis for codes by instrument of change area and individual code. (We did not identify sentiment related to social opportunity.)

Summary of listening session findings

The most prominent barriers to PEV adoption based on this analysis may be vehicle cost, a lack of public and home charging (the latter coded as “living situation”), low knowledge and familiarity with PEVs, a lack of perceived benefits of PEVs vs. gas cars, concerns about the environmental performance and safety of PEVs, and PEVs requiring more time to use due to longer charging times. These issues have some of the most negative sentiments observed from participants.

The COM-B model is useful in framing our analysis and in identifying solutions to identified barriers since the model ties solutions to behavioral components. Since the model has a foundation in behavioral health, not all interventions may be appropriate for encouraging a change in vehicle ownership, especially interventions related to coercion and restriction. However, interventions related to education, incentivization, training, environmental change, and enablement may be appropriate. Education and training could relate to providing more information on PEVs, how to access PEV incentives, and other issues. Incentivization could include continuing and expanding existing programs that incentivize PEV purchase. Environmental change (i.e., changing the environment in which people live) may need to focus primary on increasing access to PEV charging infrastructure. Finally, enablement could relate to ensuring communities have access to everything they need to carry out the described behavior.

Survey Results

Demographics

Table 10 shows a comparison of the survey sample to 2020 census data for tracts that are priority tracts and for the entirety of California. There are some differences in our sample and priority populations, though our survey was mostly done in 2024 and the census, in 2020. Despite some differences, the sample is heterogenous, and the survey provides data from a diverse population of households. In comparison to priority populations and the state population, the sample has the following differences:

- Age - a higher percent of respondents over the age of 60.
- Employment status - a lower number of respondents in full time employment, potentially due to having a higher number of retired respondents (which the census does not ask about).
- Education - fewer respondents who did not graduate from high school, and more respondents who graduated from college.
- Household income - lower income than the state population, and higher in some categories than the average for priority population census tracts. Notably there are fewer respondents earning less than $50,000 compared to in the census.
- Home ownership - more respondents own their home.

Table 10: Survey respondent and household demographics and census demographics. [1]Census only asks about sex, our survey asks about gender, [2]Census asks about race, and has a follow up question about Hispanic identity.

Respondent characteristics	Survey		Census (Priority)		Census (State)	
	% of Total	N	% of Total	N	% of Total	N
Survey taker age						
14 or younger	0.38%	8	19.06%	4,406,189	18.39%	7,239,502
15 to 18	1.10%	23	6.92%	1,600,325	6.60%	2,599,130
19 to 29	9.27%	193	15.81%	3,655,113	14.22%	5,598,160
30 to 39	16.04%	334	15.01%	3,470,471	14.56%	5,731,477
40 to 49	15.27%	318	12.44%	2,877,604	12.88%	5,067,295
50 to 59	15.37%	320	11.81%	2,730,087	12.57%	4,948,799
60 to 69	21.76%	453	9.96%	2,303,891	10.72%	4,219,339
70 to 79	15.23%	317	5.69%	1,316,494	6.42%	2,527,755
80 or older	4.08%	85	3.30%	762,895	3.62%	1,424,647
Decline to state	1.49%	31				
Survey taker gender						
Decline to state	2.74%	57	49.95%	11,550,184	49.92%	19,647,157
Female	48.00%	998				
Genderqueer/non-binary	0.82%	17	50.05%	11,572,885	50.08%	19,708,947
Male	48.24%	1003				
Other	0.10%	2				
TransMale/Transman	0.10%	2				
Race or ethnicity of survey taker						
Asian	13.06%	278	12.70%	2,937,542	15.12%	5,949,136
American Indian or Alaska Native	1.64%	35	1.30%	300,636	1.00%	394,188
Black/African American	4.51%	96	6.60%	1,527,276	5.60%	2,202,587
Hispanic or Latino/Latina/Latinx	19.31%	411	51.53%	11,915,178	39.68%	15,617,930
Middle Eastern/North African	1.13%	24				
Native Hawaiian/Other Pacific Islander	1.13%	24	0.44%	101,137	0.38%	150,531
White/Caucasian	56.16%	1195	41.82%	9,669,635	48.13%	18,943,660
Two or more races	0.00%		37.14%	8,586,842	29.77%	11,716,002
Other	2.49%	53				

Respondent characteristics	Survey		Census (Priority)		Census (State)	
	% of Total	N	% of Total	N	% of Total	N
Prefer not to say	8.27%	176				
Employment status of survey taker						
Employed full-time (35 hours or more per week)	41.42%	809	55.86%	8,543,600	57.64%	14,835,224
Employed part-time (less than 35 hours per week)	10.24%	200	17.83%	2,726,840	17.69%	4,552,439
Retired	31.75%	620				
Full-time student	3.94%	77				
Part-time student	1.48%	29				
Self-employed	7.94%	155				
Seasonal work	1.33%	26				
Do no work for pay	3.02%	59	26.31%	4,023,340	24.67%	6,348,899
Prefer not to say	6.20%	121				
Education						
Grade 8 or less	1.65%	35	20.50%	3,649,002	14.88%	4,549,795
High School Graduate or GED	21.08%	448	25.76%	4,584,800	21.99%	6,724,467
Some College or Associate's			30.67%	5,460,399	30.16%	9,224,175
College Graduate	43.11%	916	23.07%	4,106,748	32.97%	10,083,097
Masters, Doctorate, or Professional Degree	30.59%	650				
Prefer not to say	3.58%	76				
Household income						
Less than $10,000	3.39%	72	5.38%	404,646	4.43%	589,266
$10,000 - $24,999	7.15%	152	11.60%	872,030	8.78%	1,169,145
$25,000 - $49,999	11.72%	249	18.51%	1,392,254	14.67%	1,952,967
$50,000 - $74,999	13.08%	278	16.14%	1,213,421	13.74%	1,829,990
$75,000 - $99,999	11.81%	251	13.08%	983,501	11.98%	1,595,223
$100,000 - $149,999	16.56%	352	16.86%	1,267,631	17.80%	2,369,964
$150,000 - $199,999	9.55%	203	8.54%	642,453	10.73%	1,429,065
$200,000 or more	11.53%	245	9.90%	744,125	17.87%	2,380,346
Prefer not to say	15.20%	323				
Number of people in the household						
1	23.57%	498	24.86%	1,869,564	23.86%	3,176,768

Respondent characteristics	Survey		Census (Priority)		Census (State)	
	% of Total	N	% of Total	N	% of Total	N
2	39.56%	836	27.80%	2,090,583	30.47%	4,056,892
3	15.14%	320	16.21%	1,219,045	16.71%	2,225,468
4	21.71%	459	31.13%	2,340,693	28.96%	3,856,694
Home ownership						
Own	61.08%	1298	46.59%	3,503,811	55.63%	7,407,336
Rent	30.35%	645	53.41%	4,016,087	44.37%	5,908,500
Other/Prefer not to say	8.56%	182				
Home type						
Detached house/single family home	57.46%	1221	50.61%	3,805,809	57.96%	7,717,602
Attached house	8.47%	180	7.27%	546,725	7.32%	974,967
Apartment or condo	25.60%	544	37.42%	2,813,758	31.21%	4,155,726
Mobile home	3.67%	78	4.70%	353,594	3.51%	467,527
Other/Prefer not to say	4.80%	102				
Survey taker driving status						
No	6.35%	132				
Yes	93.65%	1946				

Household vehicle purchasing and ownership

Here we explore trends in household vehicle ownership and purchasing and then present results of the model investigating factors related to vehicle ownership. First, we explore descriptive statistics in household vehicle purchasing and ownership. Descriptive analysis of the survey shows the following trends:

- Figure 10 shows the number of vehicles in a household for the sample, more than 67% of households reported 1 to 2 vehicles, with the average vehicle ownership per household being 2.03. Almost 5% of the sample reported having zero vehicles in their households, which is close to the approximately 7% reported for the United States (Blumenberg et al., 2020b).
- We estimate the ratio of the number of vehicles to the number of drivers in each household. Households with a ratio of less than one vehicle per driver were considered "car-deficient" households, 16% of the surveyed households are car-deficient households. This finding aligns with the national average, where approximately 15% of U.S. households are considered car-deficient, which is more than double the proportion of households with zero vehicles (FHA, 2009).
  - More than 80% of households purchase their vehicles in comparison to leasing them. Most new car buyers (88%) purchase their vehicles from a dealer, with some buying them online (Figure 11). 50% of used car buyers purchase their vehicles from a dealer, with 32% buying from a private party. 52% of respondents reported the vehicle they drive is a used vehicle, and 48% reported this was a new vehicle.
  - We also asked respondents if they typically buy new or used vehicles: 49% reported they typically buy new vehicles and 44% reported they normally buy new vehicles. Of those that reported their primary vehicle was a new vehicle, 80% also reported they normally buy new vehicles, and of those who reported their primary vehicle was a used vehicle 86% reported they normally buy used vehicles (Figure 12).
  - For used car buyers the highest income buyers (mean of $92,928 household income) purchase from automaker dealerships, whereas the lowest income buyers (mean of $63,242 household income) purchase from private parties.
  - The mean price of a newly purchased vehicle in the sample is $38,606 (median is $32,777) whereas the mean of a used vehicle is $20,264 (median is $16,000). For used car buyers, 25% purchase vehicles costing less than $8,000, and 10% purchase vehicles costing less than $3,600 (Figure 14).
  - Of the vehicles reported as the primary vehicle used by survey takers, 80% were ICEVs, 9% HEVs, 6% BEVs, 2% PHEVs, and for 2% the fuel type could not be determined.
  - Households report that their annual vehicle use is around 12,500–13,500 miles for their primary vehicle (see Figure 16).
  - Figure 15 shows an estimate of how many years of warranty a used vehicle buyer would have assuming a 100,000-mile and 8-year warranty. We include this since ACC2 has this warranty requirement. Assuming used buyers in priority populations purchase PEVs of a similar age and mileage to ICEVs when they adopt PEVs, more than 40% would purchase a PEV with no warranty remaining.

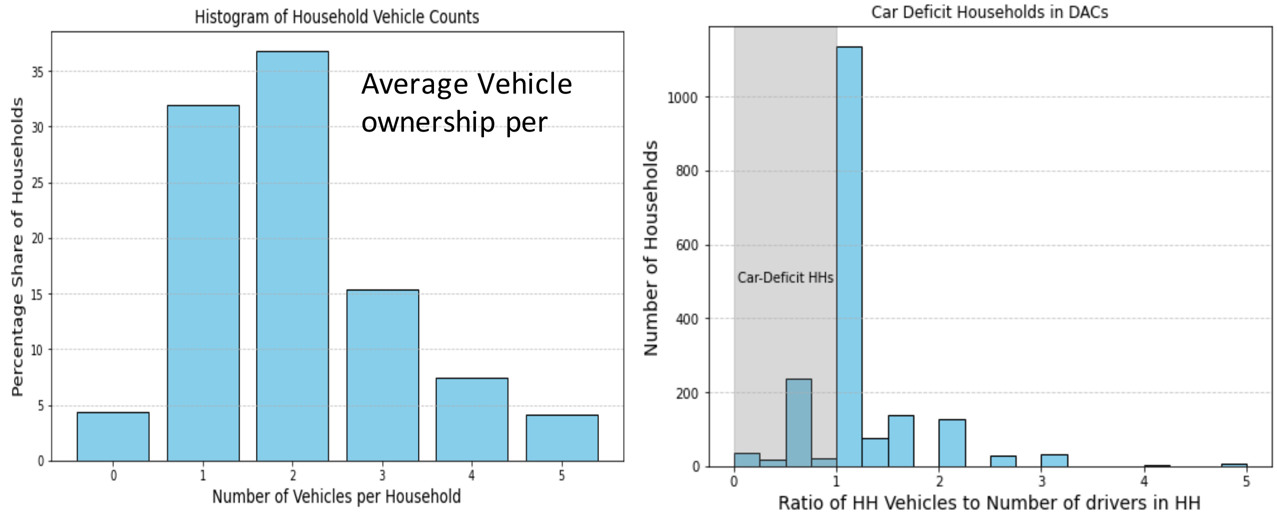


Figure 10: Distribution of number of vehicles per household (left) and the ratio of household vehicles to household drivers, and identification of car deficient households (right).

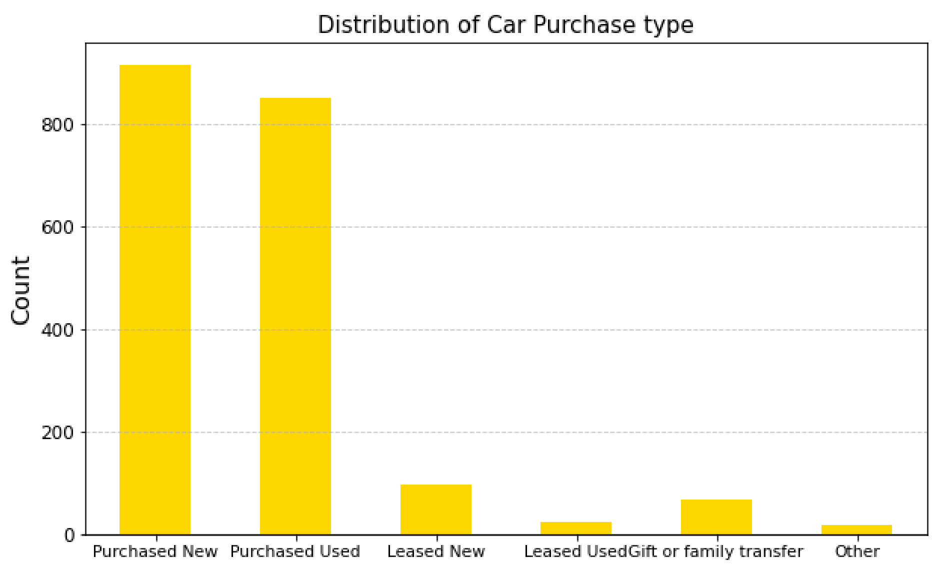


Figure 11: Distribution of vehicle purchase method (lease or purchase) and whether the car was new or used.

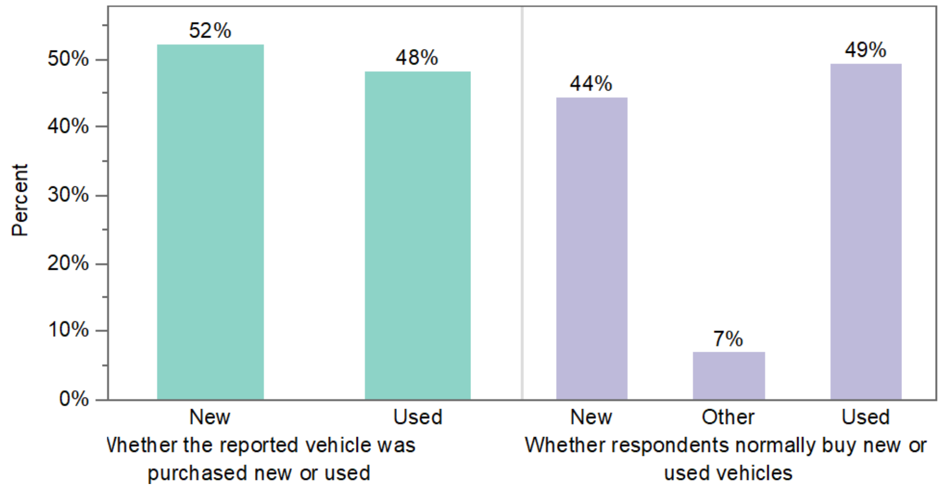


Figure 12: Whether respondents most frequently used vehicles were purchased new or used, and whether respondents typically purchase new or used vehicles.

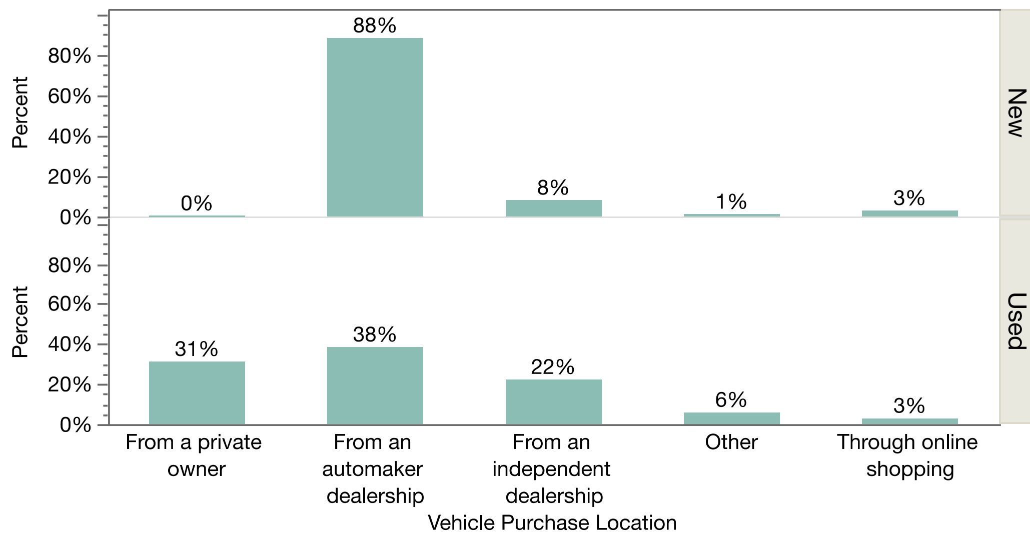


Figure 13: The location respondents' vehicle was purchased from and whether it was a new or used vehicle.

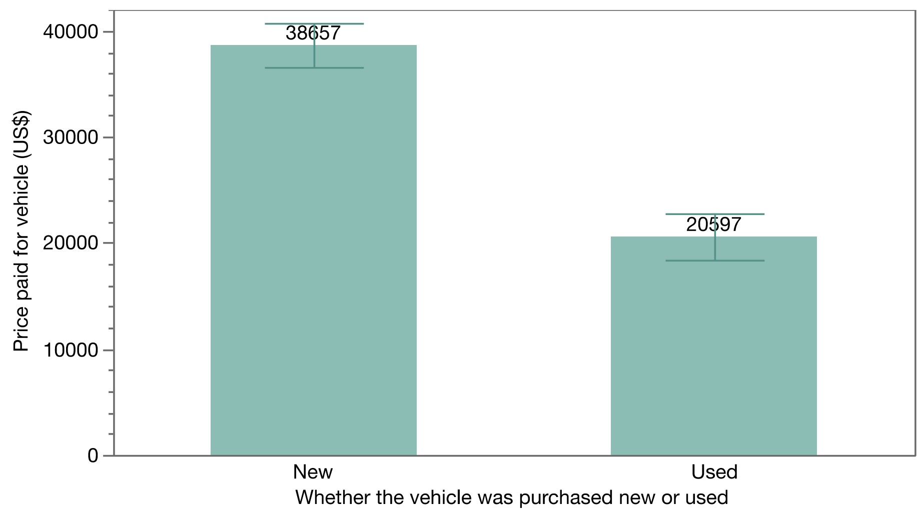


Figure 14: Mean vehicle purchase price (excluding incentives or trade in value) and whether the vehicle was new or used. Error bars show 95% confidence interval.

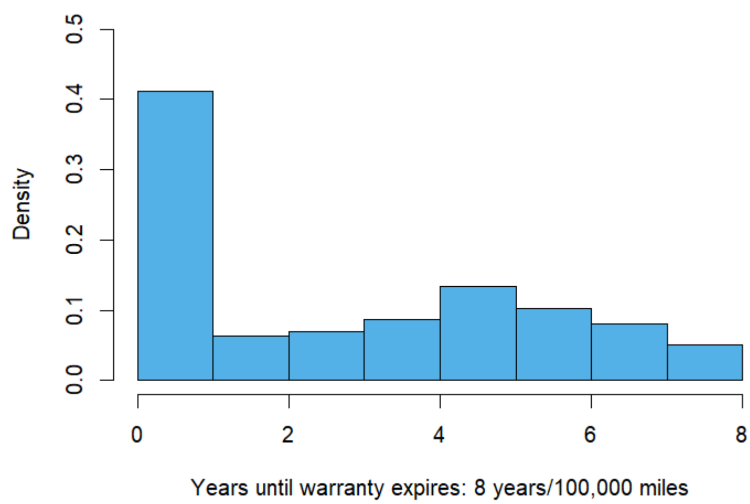


Figure 15: Years until a 8-year/100,000-mile warranty would expire for buyers of used vehicles based on the odometer reading, annual mileage, and age of the vehicle at the date of purchase.

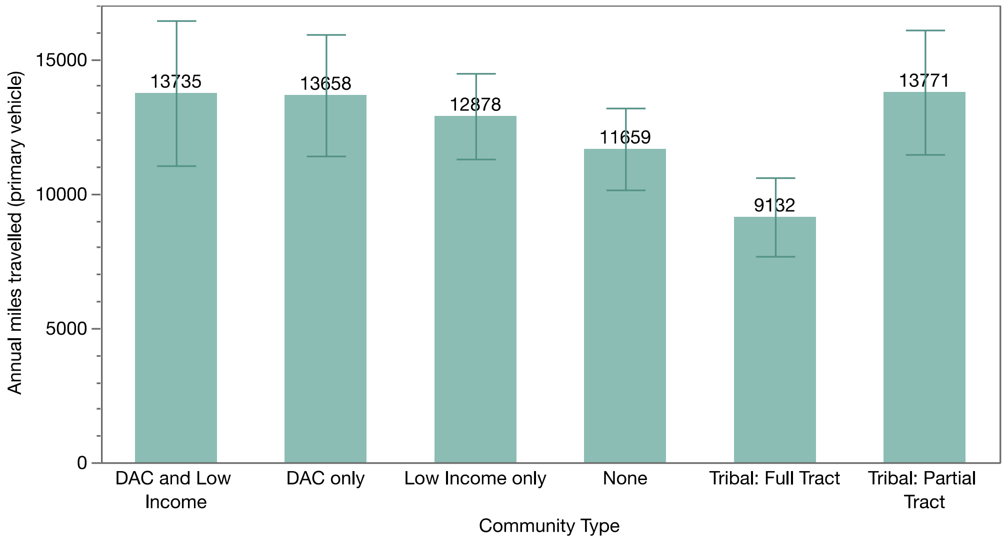


Figure 16: Annual vehicle miles travelled in the primary household vehicle, classified by community type. Error bars show 95% confidence interval.

Factors related to household vehicle ownership

This section explores results from a vehicle ownership model that helps identify factors related to owning more or fewer vehicles in a household. This includes household (HH) characteristics, socio-demographics, and built environment parameters. Table 11 summarizes the results of our analysis. The model explains 49% (R^2 of 0.49) of the variation in vehicle ownership among households. The numbers in the table show how much number of vehicles in a household to change with changes in different independent variables, holding all else constant. We focus on the magnitude of the changes, whether they increase or decrease by vehicle count, and whether these changes are statistically significant, given the measurement units for each factor. The analysis shows several factors influencing the number of vehicles in a household:

- **Household size and number of drivers:** As household size increases by one person, the number of vehicles in the household goes up by about 0.1 vehicles. Similarly, adding one more driver to the household increases the number of vehicles by about 0.48 on average. The number of children in a household doesn't significantly relate to vehicle count.
- **Access to non-household vehicles**: For each additional non-household vehicle a household has access to, they tend to own about 0.2 more vehicles. This suggests that households with more vehicles in their household also have access to more vehicles outside the household, while those with fewer vehicles also have fewer opportunities to access any vehicles at all.
- **Household income and vehicle purchase price**: The analysis shows that as household income increases, so does the number of vehicles in a household. We also find that when the cost of a vehicle takes up a larger portion of a household's income, the household tends to own fewer vehicles. Specifically, for a one unit increase in vehicle cost-to-income ratio, the number of vehicles owned goes down by 0.048. This indicates

that when the purchase of a vehicle is a larger commitment related to household income, buyers are less likely to have additional vehicles.

- **Home ownership, housing and neighborhood type**: Renters have 0.23 fewer vehicles than homeowners in the study. Further, households living in apartments or condos and those in attached houses have fewer vehicles than do those in detached or single-family homes. Households in areas designated as both "Disadvantaged Communities (DAC) and Low Income" have fewer vehicles than do those in "Low Income only" areas. Other tract types did not show a significant difference compared to low income tracts, suggesting households in Disadvantaged (DAC) and Low Income tracts have the lowest access to vehicles.
- **Education level and employment status**: With "College Graduate" as the reference category, respondents with a "Masters/Doctorate/Professional Degree" have about 0.18 fewer vehicles. Nearly half of these individuals are retirees who typically own fewer vehicles. With "Employed full-time" as the reference category, households where someone is "Retired", in “Seasonal work”, “Self-employed” and “Unemployed” have fewer vehicles. Having only seasonal work or being unemployed has a larger effect on household vehicle counts compared to being retired.
- **Race and gender**: The model also includes race and gender of the survey taker, with "White/Caucasian" and "Male" as the reference categories. We didn't find any significant relationships between gender or race and the number of vehicles owned in a household holding all else constant.
- **Vehicle purchase type**: We included whether respondents purchased or leased their primary vehicle and found that households buying used vehicles have 0.13 more vehicles in the household than those buying new vehicles do.
- **Vehicle powertrain type**: The model also considers vehicle powertrain, with "PEV" (plug-in electric vehicle) as the reference category. Households with internal combustion engine vehicles (ICEVs) have about 0.25 more vehicles compared to those with PEVs in this sample. This suggests that, holding all else constant, households with ICEVs tend to own more vehicles on average than those with PEVs in this sample. This is counter to the broader vehicle owning population where PEV owning households tend to have more vehicles. This could be a result of this population having more financial constraints than typical PEV owners.
- **Residential density**: Our analysis shows that households in urban areas tend to own fewer vehicles compared to those in rural households. Specifically, for every additional housing unit per acre, the number of vehicles in a household decreases by 0.0164 on average.
- **Transit access**: We also found that the closer a household is to a transit stop, the fewer vehicles it tends to own. For every meter decrease in distance to the nearest transit stop, the number of vehicles in a household decrease by 0.000012 on average (or for every 1km decrease in distance to transit a 0.012 decrease).

Table 11: Vehicle ownership Poisson regression model (see Methods and Appendix 2 for more information on model specification).

Model parameters	Coeff.	P-value	Marginal Effect coefficient	P-value
Household Parameters				
Number of people in the HH	0.049	0.018	0.099	0.018
Household Income ($)	2.96E-07	0.047	5.96E-07	0.047
Purchase Price/household income (interaction)	-0.023	0.025	-0.047	0.025
Access to additional vehicles	0.0938	0	0.190	0
Number of children in the household	0.018	0.632	0.0364	0.632
Number of drivers in the HH	0.24	0	0.4813	0
Household Indicator Variables				
Own home (ref. category)				
Rent home	-0.115	0.021	-0.232	0.021
Education (College graduate) (ref. category)				
Education_Grade 8 or less	0.059	0.059	0.119	0.059
Education_High School Graduate or GED	0.0043	0.804	0.008	0.804
Education_Masters, Doctorate, or Professional Degree	-0.038	0.049	-0.079	0.049
Tract_Type_LI only (ref. category)				
Tract_Type_DAC and Low Income	-0.031	0.049	-0.062	0.049
Tract_Type_DAC only	0.0237	0.923	0.047	0.923
Tract_Type_Tribal: Full Tract	-0.086	0.328	-0.1782	0.328
Tract_Type_Tribal: Partial Tract	0.068	0.262	0.131	0.262
Tract_Type_None	-0.0416	0.38	-0.0836	0.38
Gender_Male (ref. category)				
Gender_Decline to state	-0.16	0.206	-0.337	0.206
Gender_Female	-0.024	0.637	-0.048	0.637
Gender_Genderqueer/non-binary	-0.233	0.374	-0.456	0.374
Gender_Other	-0.612	0.23	-1.228	0.23
Gender_TransMale/Transman	-1.287	0.205	-2.6033	0.205
Purchase_purchase_new (ref. category)				
Purchase_Leased New	-0.055	0.429	-0.113	0.429
Purchase_Leased Used	0.156	0.42	0.314	0.42
Purchase_Purchased Used	0.069	0.05	0.138	0.065
House_Type_Detached house (ref. category)				
House_Type_Apartment or condo	-0.184	0.001	-0.371	0.003

Model parameters	**Coeff.**	**P-value**	**Marginal Effect coefficient**	**P-value**
House_Type_Attached house (townhouse, duplex, triplex)	-0.116	0.098	-0.227	0.123
House_Type_Mobile home	-0.074	0.466	-0.155	0.466
House_Type_Other	-0.188	0.288	-0.3941	0.288
House_Type_Prefer not to say	-0.079	0.69	-0.1586	0.69
Race_White Caucasian (ref. category)				
Race_AmericanIndian/AlaskaNative	-0.163	0.212	-0.3296	0.212
Race_Asian	-0.0006	0.75	-0.0012	0.75
Race_Black/AfricanAmerican	0.067	0.411	0.1567	0.411
Race_Hispanic/Latino/Latina/Latinx	0.034	0.289	0.0703	0.289
Race_MiddleEastern/NorthAfrican	-0.0218	0.987	-0.043	0.987
Race_NativeHawaiian/ OtherPacificIslander	-0.0899	0.718	-0.1713	0.718
Employment_type_Employed ful-time (ref. category)				
Employment_type_Employed part-time	0.055	0.293	0.1156	0.293
Employment_type_Full-time student	0.091	0.324	0.185	0.324
Employment_type_Part-time student	0.021	0.891	0.042	0.891
Employment_type_Retired	-0.035	0.042	-0.063	0.042
Employment_type_Seasonal work	-0.192	0.381	-0.3942	0.381
Employment_type_Self-employed	-0.006	0.955	-0.0136	0.955
Employment_type_Unemployed	-0.08	0.053	-0.1617	0.053
Powertrain_PEV (ref. category)				
Powertrain_ICEV	0.1416	0.001	0.2462	0.001
Built Environment Parameters				
Gross residential density (HU/acre) (D1A)	-0.0075	0.046	-0.0164	0.046
Jobs per household (D2A_JPHH)	-0.0021	0.4	-0.004	0.4
Total road network density (D3A) (mile/sq.mile)	-0.001	0.573	-0.003	0.573
Distance from the population-weighted centroid to nearest transit stop (meters) D4A	-1.92E-06	0.037	-1.20E-05	0.037
Observations	1798			
Pseudo R-squared	0.4909			
Log-Likelihood	-2501.0			

Travel behavior

Survey respondents across all community types most commonly reported driving daily (Figure 17). In aggregate, 64% of respondents drove every day and an additional 25% drove at least a few times per week. The amount of driving varied by community type. Residents of disadvantaged communities (DAC) reported driving most often, with 92% reporting they drove at least a few times a week. On the other hand, residents of combined DAC and low-income communities drove less often, with 81% reporting driving at least a few times a week and 10% reporting they never drove. In all other community types, 13% of respondents drove less than a few days per week. Differences in driving frequency across community types were statistically significant[1] ($\chi^2 = 83.3$, $p < 0.001$).

The next most common mode of travel was walking. In aggregate, half of the survey respondents walked at least a few times a week to reach a destination. As with driving, the frequency of walking varied across community types. Residents of fully tribal census tracts reported walking most frequently, with over 37% walking daily, 27% walking a few times a week, and only 11% reporting never walking. At the other end of the spectrum, residents of DACs and partially tribal tract reported the least amount of walking, with less than a 25% of both community types walking every day and nearly a 33% never walking. Differences in walking frequency across community types were statistically significant ($\chi^2 = 84.1$, $p < 0.001$).

Other modes were used far less frequently but still showed some important differences across the community types. Around 1/3 of respondents in aggregate reporting getting a ride at least a few times a month. However, 42% of respondents living in combined DAC and low-income communities got rides with the same frequency. Fully tribal tract residents got rides least often. DAC and low-income residents were also most likely to use transit at least a few times a month, with 45% reporting doing so. Taxi or ridehailing use was also more common among DAC and low-income combined residents, while these services were rarely used among partially tribal tract residents.

The only travel mode where differences in travel frequency were not statistically significant across community types was bicycling ($\chi^2 = 22.3$, $p = 0.323$). Roughly one-third of respondents reporting cycling for trips at least a few times a year, and 9% reported cycling at least a few times a week.

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[1] Statistical significance for frequency of mode use determined via Pearson's chi-squared test with simulated p-values (based on 10,000 replicates) to account for small cell values, adjusted for multiple comparisons using the Holm method.

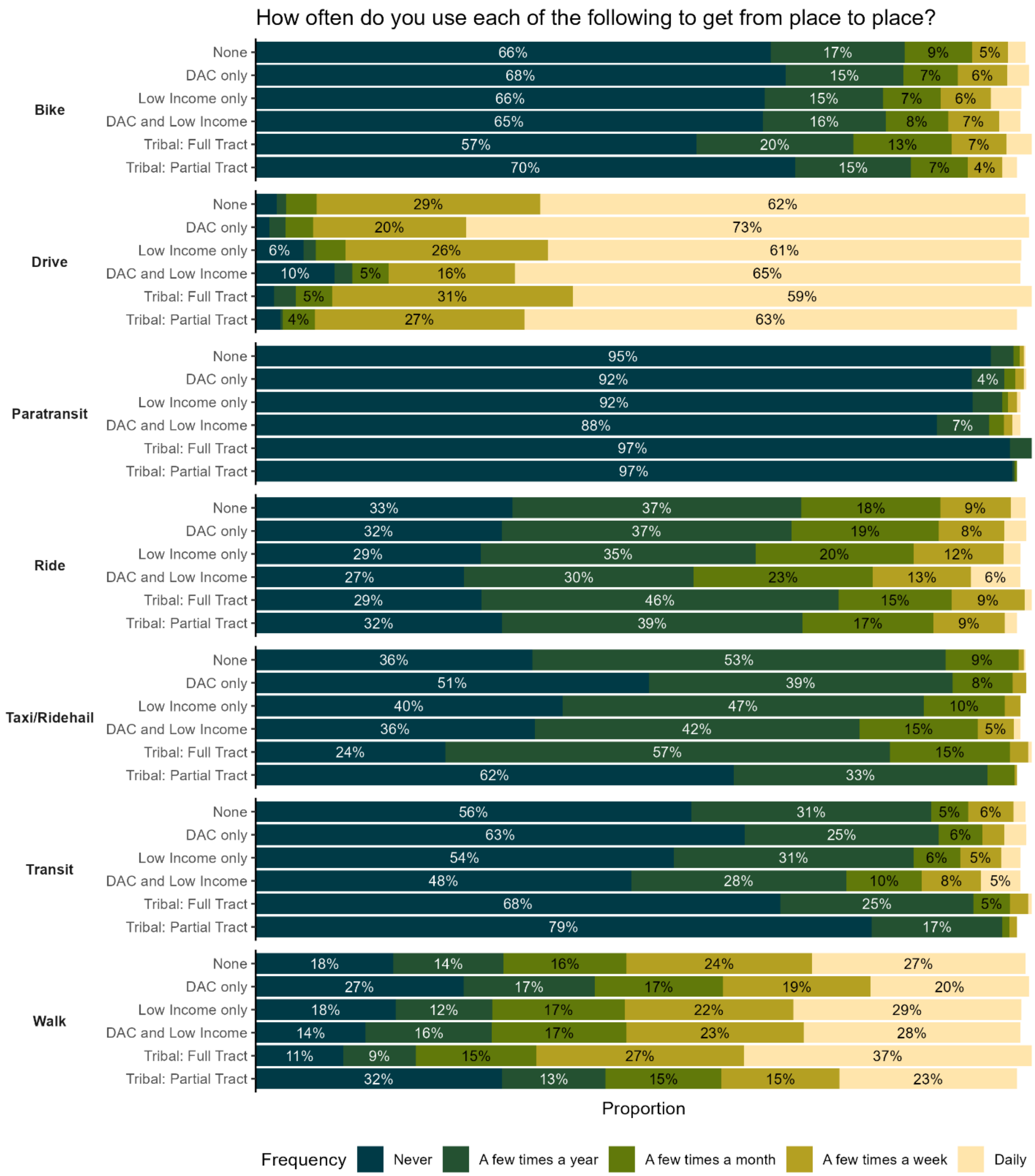

Figure 17 : Travel mode frequency

Trip characteristics

The remainder of the travel behavior questions focused on the trips made during the previous day. Survey respondents ($n = 2{,}356$, note this is higher than in other analysis since we analyze incomplete survey responses) reported the number of trips taken on a categorical scale of 0 trips to 5 or more trips (Figure 18). The median response across all community types was two trips. Residents of combined DAC and low-income census tracts were more likely to report having taken no trips in the previous day, at a similar proportion to partially tribal tracts. Combined DAC and low-income tracts were also more likely to report having taken five or more trips compared to residents of other community types, suggesting more heterogeneity in travel behavior in such neighborhoods. Residents of fully tribal tracts had the most similar trip-taking frequency within the group, with about 41% taking two trips and only 10% taking no trips. The differences were statistically significant ($\chi^2 = 53.9$, $df = 25$, $p < 0.001$).

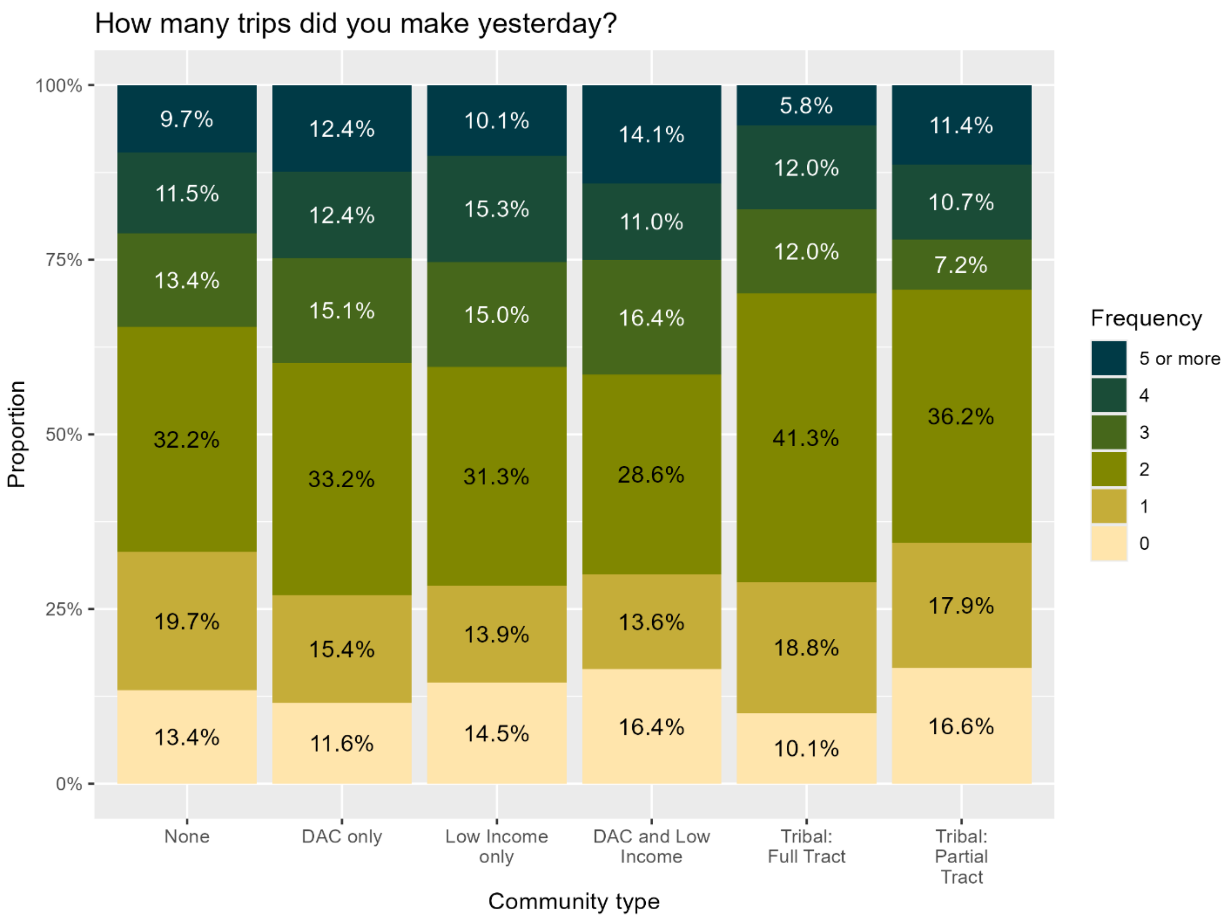

Figure 18: Number of trips taken on the previous day

The survey asked respondents to report the details of up to two trips among the trips taken in the previous day. In aggregate, the majority of these trips ($n = 2{,}994$) were driving trips: 84% of trips were made by car either alone or in combination with other modes. Mode choice varied by a small but statistically significant[2] degree across the community types ($\chi^2 = 32.0$, $df = 5$,

[2] Because so few trips were made by modes other than driving, we conducted a chi-squared test comparing driving to all other modes across the community types.

$p < 0.001$) (Figure 19). Residents of combined DAC and low-income communities completed the fewest number of their trips by driving (79%), while residents of partial tribal census tracts drove the most (90%). Residents of combined DAC and low-income communities were also the most multimodal: 20% of their trips included a mode other than driving. Residents of low-income and non-disadvantaged tracts were similarly multimodal, in that 18% each of their trips included a non-driving mode.

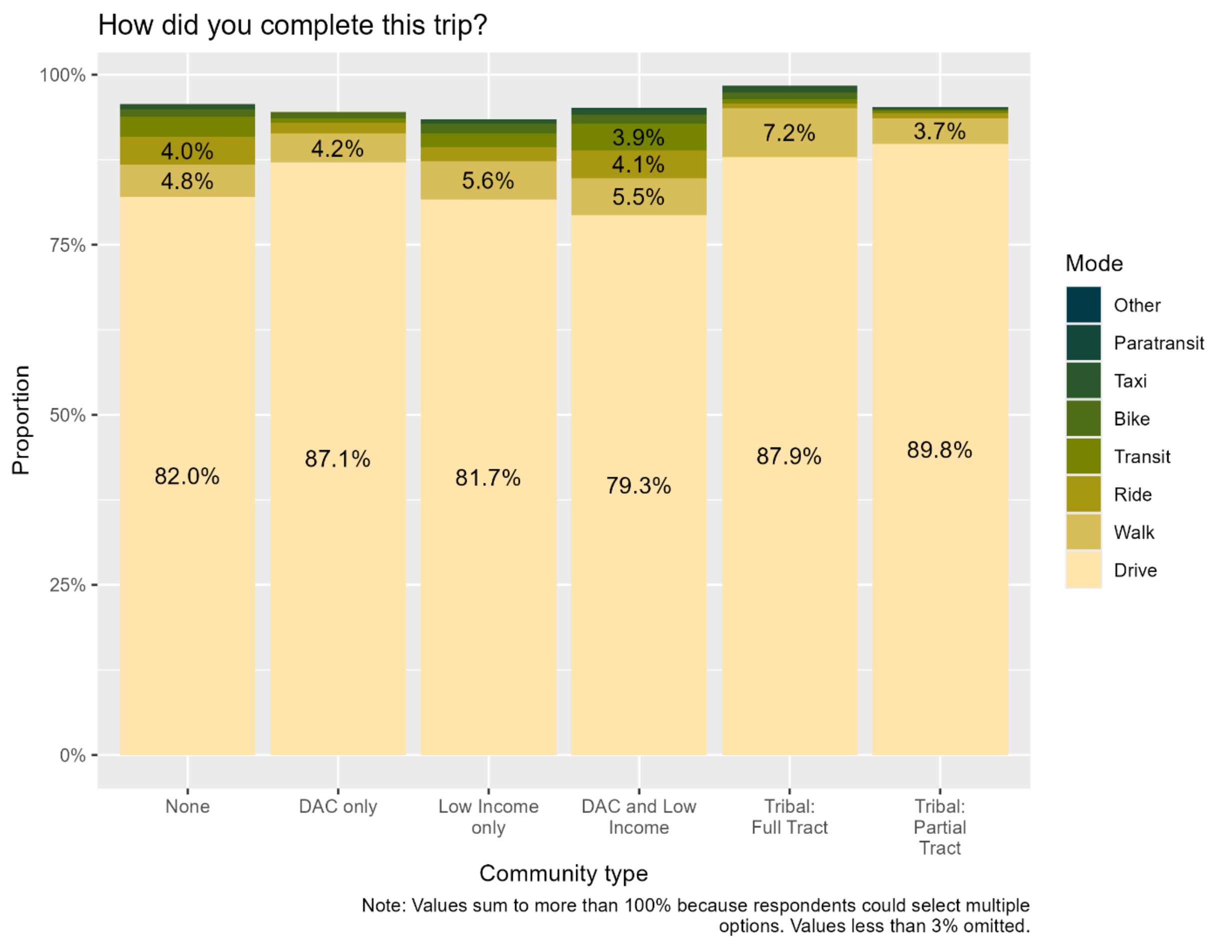

Figure 19: Mode choice by community type

Trip distance

Respondents reported a total of 2,505 trips, excluding those of 0 miles.[3] The median trip distance across the sample was 5.2 miles. The distribution was right skewed, dominated by a few outliers of long trips, giving an average trip distance of 17.3 miles. The distribution varied significantly across community types (Table 12), visualized in Figure 20. Travel distances were on average shorter for residents of fully tribal census tracts and longer for residents of partially

[3] Trips are defined as travel from an origin to a destination. A round-trip to and from a location is counted as two trips.

tribal tracts. Residents of the other community types had similar travel distances to each other. Also, 99% of reported vehicle trips were less than 300 miles, and 97.5%, less than 100 miles.

Table 12: Summary statistics of trip distances by tract

Community Type	Mean	Std. Dev	25%	Median	75%
None	19.38	101.9	2.50	5.89	14.84
DAC only	18.72	85.69	2.53	5.36	14.36
Low Income only	15.02	39.75	1.96	5.05	14.07
DAC and Low Income	20.10	142.16	2.38	4.90	11.22
Tribal: Full Tract	8.56	21.57	1.45	3.33	6.54
Tribal: Partial Tract	21.06	47.33	3.03	7.81	17.70
Full sample	17.32	85.13	2.16	5.22	12.91

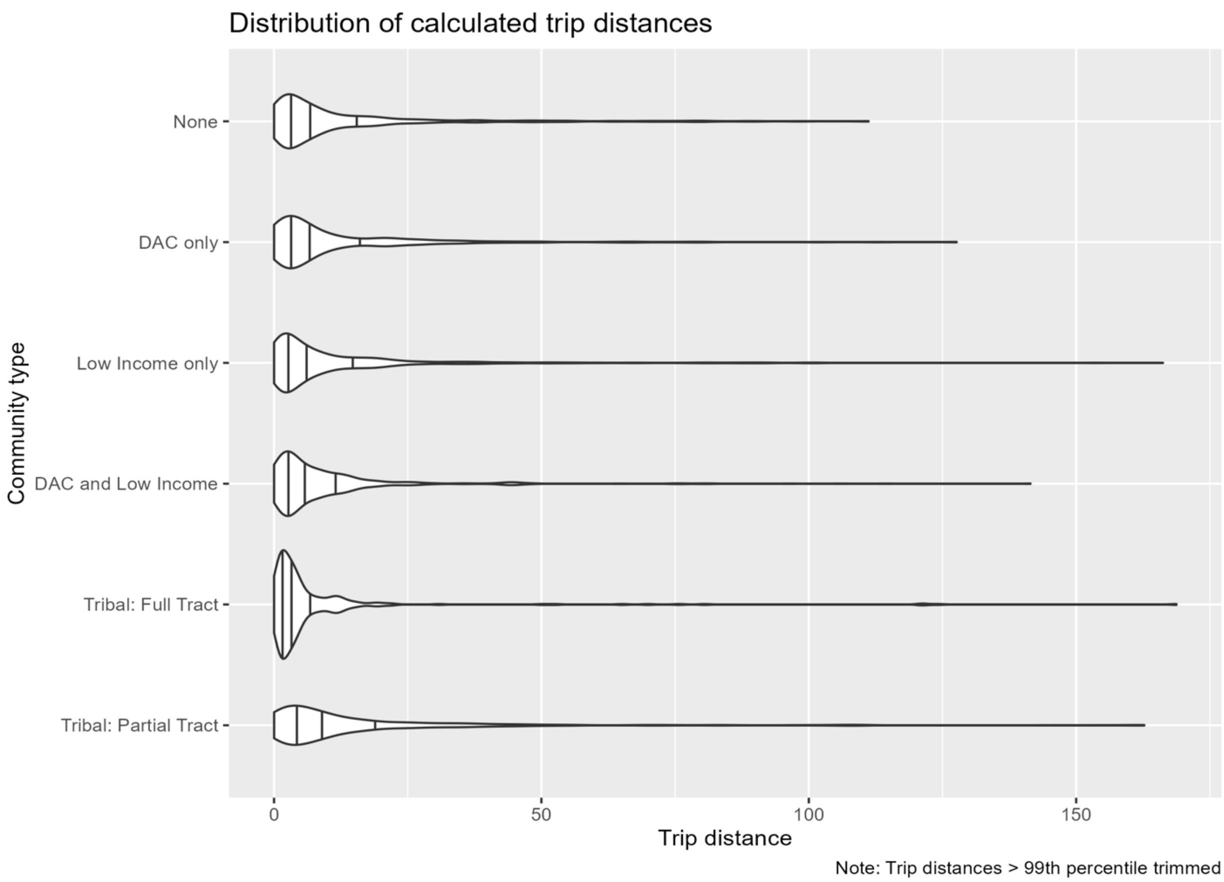

Figure 20: Travel distance distribution

Results of statistical significance testing are shown in Table 13. The table shows marginal contrasts of a linear regression model that estimates trip distance as a function of community type, Holm corrected for multiple comparisons. This summary shows a pairwise comparison of which community types have travel distances different from one another. To adjust for outliers and the right skew in the data, we log transformed the dependent variable. The model demonstrates that respondents fully tribal tracts have a significantly shorter average travel distance compared to respondents in all other community types. Residents of partially tribal tracts have a statistically significantly longer average travel distance than residents of all other community types except those not living in a disadvantaged community. No other contrast is statistically significant.

Table 13 : Comparison of trip distance by group.

Group 1	Group 2	Difference	95% CI	SE	t(2499)	*p*
DAC and Low Income	Tribal: Full Tract	0.40	[0.07, 0.73]	0.11	3.59	0.003
DAC and Low Income	Tribal: Partial Tract	-0.46	[-0.76, -0.15]	0.11	-4.33	< .001
DAC only	DAC and Low Income	0.14	[-0.19, 0.47]	0.11	1.22	0.884
DAC only	Low Income only	0.10	[-0.21, 0.40]	0.10	0.92	> .999
DAC only	Tribal: Full Tract	0.54	[0.17, 0.91]	0.13	4.30	< .001
DAC only	Tribal: Partial Tract	-0.32	[-0.67, 0.03]	0.12	-2.65	0.065
Low Income only	DAC and Low Income	0.04	[-0.22, 0.30]	0.09	0.48	> .999
Low Income only	Tribal: Full Tract	0.44	[0.14, 0.74]	0.10	4.29	< .001
Low Income only	Tribal: Partial Tract	-0.41	[-0.70, -0.13]	0.01	-4.30	< .001
None	DAC and Low Income	0.20	[-0.07, 0.47]	0.09	2.18	0.176
None	DAC only	0.06	[-0.26, 0.38]	0.11	0.57	> .999
None	Low Income only	0.16	[-0.08, 0.40]	0.08	1.94	0.26
None	Tribal: Full Tract	0.60	[0.29, 0.91]	0.11	5.65	< .001
None	Tribal: Partial Tract	-0.26	[-0.55, 0.04]	0.10	-2.56	0.073
Tribal: Full Tract	Tribal: Partial Tract	-0.86	[-1.20, -0.51]	0.12	-7.25	< .001

Trip purpose

The four most common trip purposes among survey respondents were shopping or errands, work, social or recreational, and returning home (Figure 21), the most common of which was shopping. Frequency of trip purposes across the community types were significantly different ($\chi^2 = 64.3, df = 20, p < 0.001$). Residents of fully tribal tracts were the most likely of the six community types to make a trip for shopping or errands, and least likely to make a work trip. Across the community types, fully tribal tracts were the only ones where work was *not* the second-most common trip type; it was instead social or recreational trips. Trip purposes were similar across the other community types, with similar percentages of trips being made for the four most common purposes.

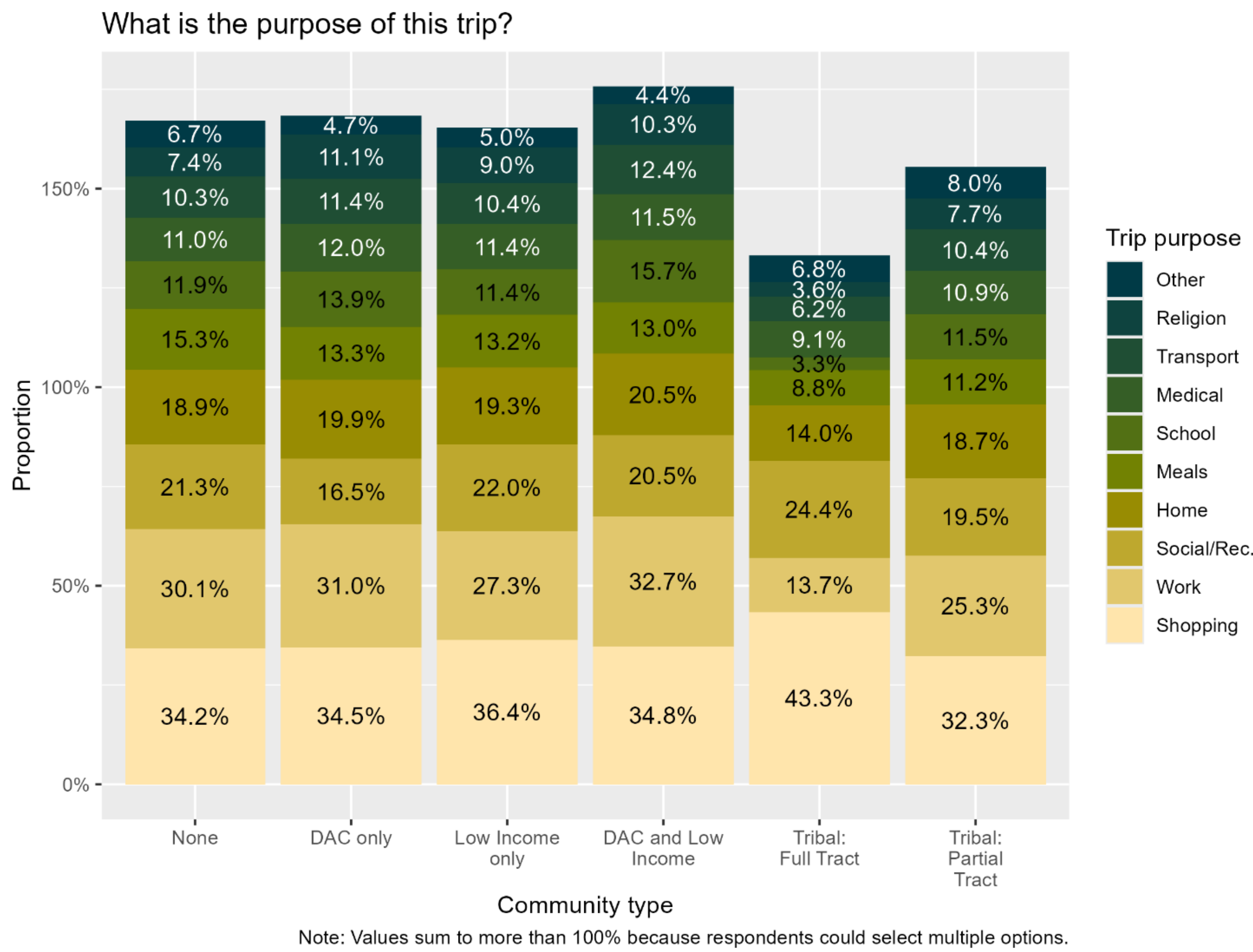

Figure 21: Trip purpose

Unmet travel needs

To assess unmet travel needs, the survey included a question asking whether the respondent experienced difficulty or inconvenience in travelling to any places. Of the respondents who answered the question ($n = 2{,}253$), 37% affirmed that they had some travel difficulty. Percentages of positive responses varied by community type (Figure 22) and differences were statistically significant ($\chi^2 = 18.5$, $df = 5$, $p = 0.002$). Residents of low-income census tracts were most likely to report having travel difficulties, while residents of fully tribal tracts and those of non-disadvantaged communities had less than average difficulty getting places.

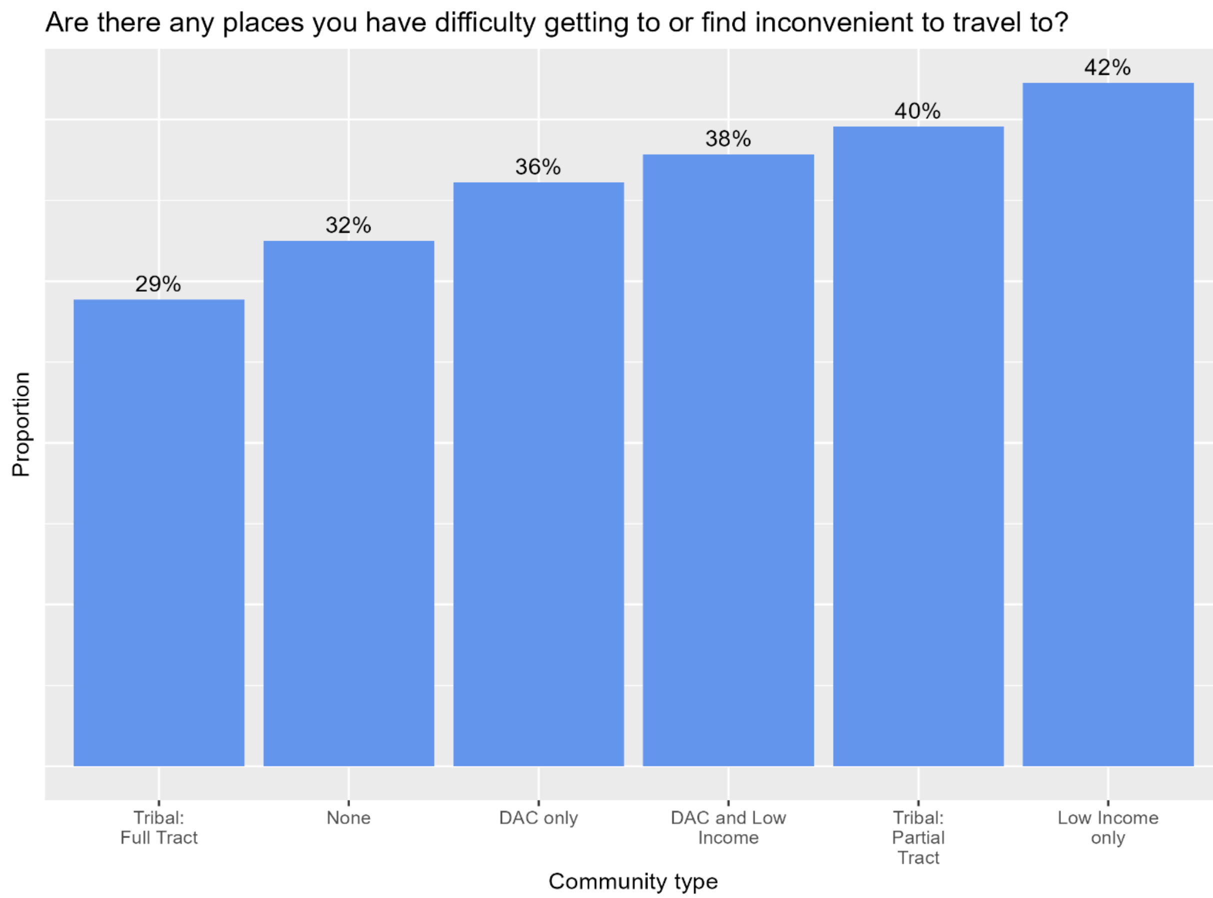

Figure 22: Travel difficulty

While there were apparent differences by community type as to whether individuals made the trip at all if they found it difficult, the differences were not statistically significant ($\chi^2 = 5.60$, $df = 5, p = 0.347$). Nevertheless, the numeric differences across the groups were large, suggestive of a difference if the sample size were larger. Residents of combined DAC and low-income communities were most likely to respond that they would not make the difficult trip, while residents of DAC communities were least likely to do so (Figure 23).

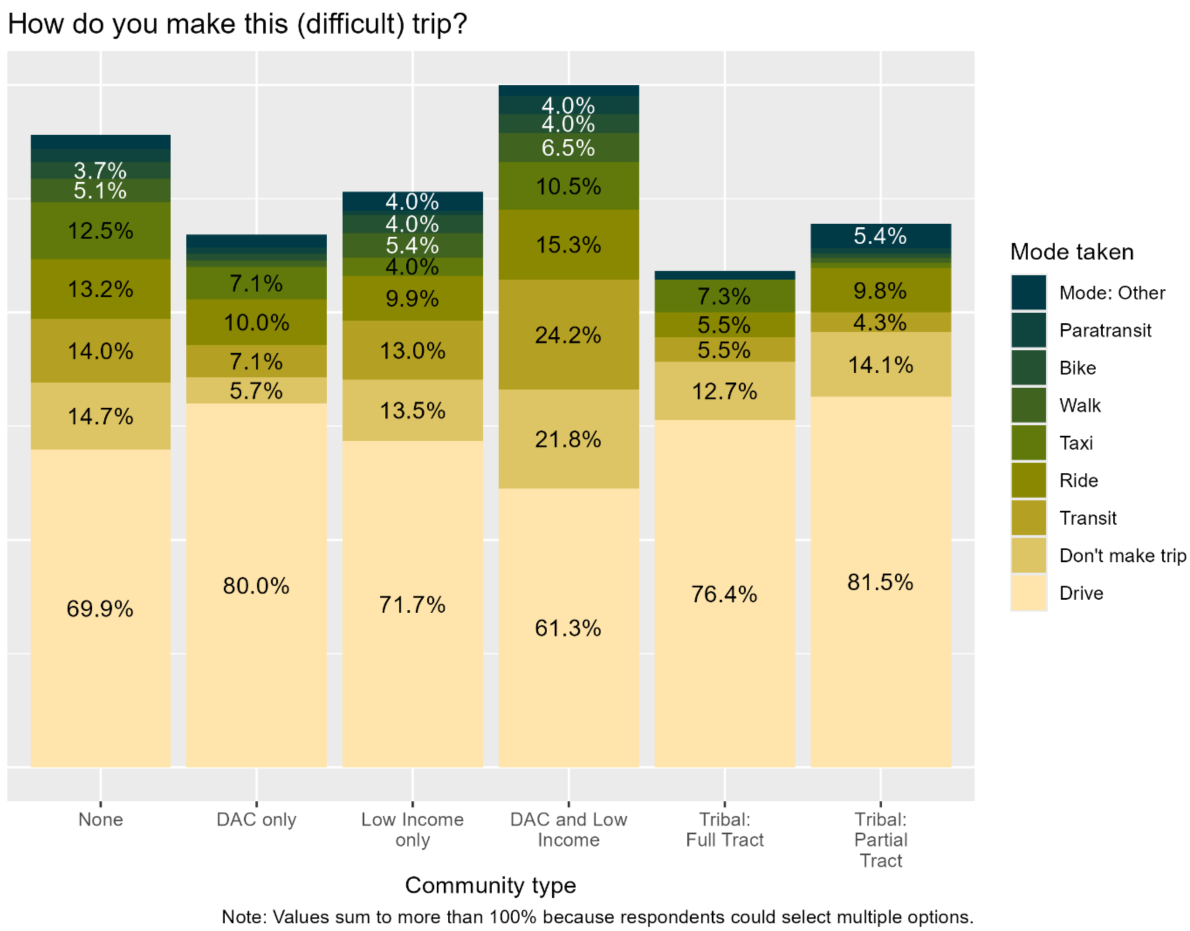

Figure 23: Mode of transport for difficult-to-make trips

Across all communities, the median distance for the difficult-to-get-to destinations was 24.6 miles, substantially farther than the trips respondents reported they made on the previous travel day. As with the actual trips made, the average distance for difficult trips varied by community type, being significantly longer for fully tribal tracts than for all other groups (Table 14). There was no discernible pattern in distance to the hard-to-reach locations for trips not made at all. In some cases, the median distance of difficult trips not made was longer (e.g., non-disadvantaged communities had a median of 63 miles), while in others, it was shorter (e.g., DAC tracts had a median of 19 miles).

Table 14 : Summary statistics of distances to difficult travel locations

Community Type	Mean	Std. Dev	25%	Median	75%
None	60.65	106.09	11.04	24.62	56.76
DAC only	68.00	171.06	7.23	20.89	74.62
Low Income only	56.34	196.22	9.12	21.26	45.83
DAC and Low Income	62.03	219.51	7.65	20.98	33.22
Tribal: Full Tract	84.70	81.13	13.38	99.64	120.05
Tribal: Partial Tract	105.34	209.67	19.99	45.22	117.45
Full sample	68.21	179.55	9.89	24.64	65.24

The most common reason respondents cited for having difficulty in making a trip was because parking was difficult to find at their destinations (Figure 24). The reasons varied somewhat among the community types. For example, parking was cited most commonly in low-income, DAC and low-income and non-disadvantaged community types, traffic was the most common concern for respondents living in DACs and partially tribal tracts, and transit reliability or service was most common reason for respondents living in fully tribal tracts. Other common reasons for travel difficulty were related to the cost of transportation and travel distance.

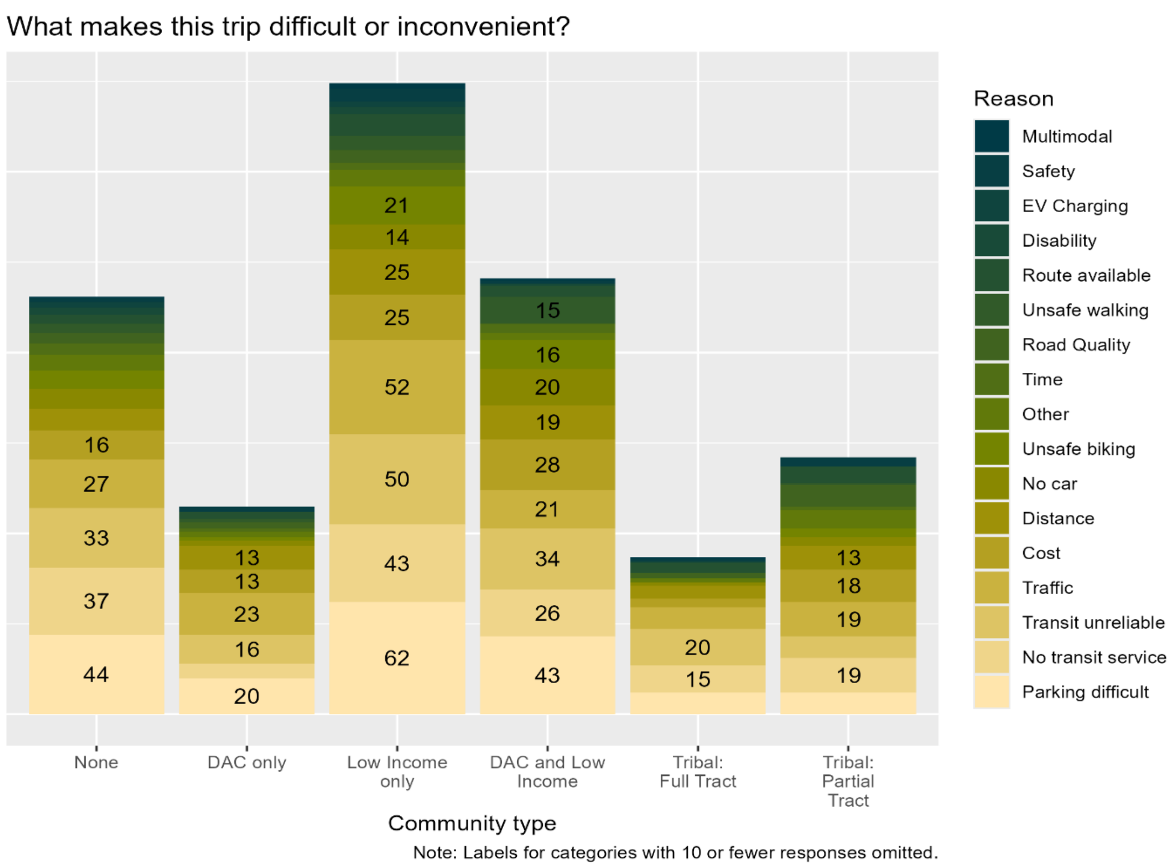

Figure 24: Reasons why a trip was selected as difficult to make.

Access to charging

Reported access to charging at home

Table 15 shows home type, vehicle parking location, and access to power where survey participants park their vehicles at home. More than half of survey takers (57.5%) reside in a detached house/single family home, less than 1/20 live in a townhouse, duplex, or triplex, and one quarter reside in an apartment or condo. Half of survey takers report parking their vehicle in a driveway/carport while one quarter park in a garage. Less than one fifth park on the street or in a parking garage. Close to half reported having level 1 (110/120 V) charging at home, one fifth have access to a 220/240 V (level 2) power outlet, and 7% have access to an electric vehicle charger. Almost half of the sample report no charging or do not know whether they have charging at home.

Table 15: Home type, vehicle parking location, and access to power at parking location. Note parking location and charging access are multiple choice questions, total respondents represents the total number of respondents who answered the question.

How would you describe your home?	Percent	n
Apartment or condo	25.6%	544
Attached house (townhouse, duplex, triplex)	8.5%	180
Detached house/single family home	57.5%	1221
Mobile home	3.7%	78
Other	1.2%	26
Prefer not to say	3.6%	76
Total		2125
Where do you usually park your car at home?		
Driveway/carport	49.1%	976
On-street (free)	16.8%	333
On-street (metered)	1.0%	20
Parking garage (private)	17.5%	348
Parking garage (public)	1.2%	23
Parking lot (no reserved space)	3.3%	65
Parking lot (reserved space)	5.1%	102
Personal garage	24.0%	476
RV park/yard/field	0.3%	6
Total respondents		1986
Where you park at home, do you have reliable access to any of the following?		
A regular electrical outlet (110-volt).	46.3%	909
A high-power electrical outlet (220 to 240-volt)	20.2%	397
A device designed specifically for charging an electric vehicle	6.7%	132
None of the above	42.4%	832
I don’t know	5.0%	99
Total respondents		1964

Figure 25 and Table 16 show the highest level of charging access by dwelling type. Respondents in detached houses, mobile homes, and attached houses report the highest charging access, with more than half of respondents in these dwellings having at least level 1 (110v) or level 2 (220v) accessible where they park at home. Apartment and condo dwellers report the lowest level of charging access, with only 1/5 of respondents reporting access to level 1 or level 2 charging where they park their vehicle at home. Figure 26 and Table 17 show access to charging at home by community type. DAC and low-income communities have the lowest charging access of all community types.

Using Chi-square goodness of fit tests, we compared infrastructure access by home type, home ownership, community type, age, gender, education, number of vehicles in the household, and whether respondents live in an urban or rural tract (see Appendix 2: Survey statistical analysis for test tables). These tests show significant differences in charging access at home for each demographic attribute tested. Access to charging at home was:

- less common among renters than home owners ($\chi^2 = 248.34$, $df = 4$, $p < 0.001$);
- less common among respondents in apartment or condos than those in all other home types ($\chi^2 = 230.85$, $df = 8$, $p < 0.001$);
- less common among respondents aged 19 to 49 years than those over the age of 50 ($\chi^2 = 127.4$, $df = 14$, $p < 0.001$);
- less common among respondents in DAC and low income tracts than those all other tracts, and more common among respondents in tribal tracts than those in all other tracts ($\chi^2 = 55.84$, $df = 10$, $p < 0.001$);
- more common among male respondents than among female respondents ($\chi^2 = 46.11$, $df = 4$, $p < 0.001$);
- less common among households with a an income of less than $100,000 per year than among households earning more than $100,000 per year ($\chi^2 = 49.79$, $df = 6$, $p < 0.001$).
- less common among respondents with only a high school degree than among those who have graduated college ($\chi^2 = 23.63$, $df = 6$, p 0.002).
- less common among respondents with 1 household vehicles than among those with 2 or more household vehicles ($\chi^2 = 248.34$, $df = 8$, $p < 0.001$) ; and
- less common among respondents in urban areas than among those in rural areas ($\chi^2 = 8.6$, $df = 2$, p 0.014).

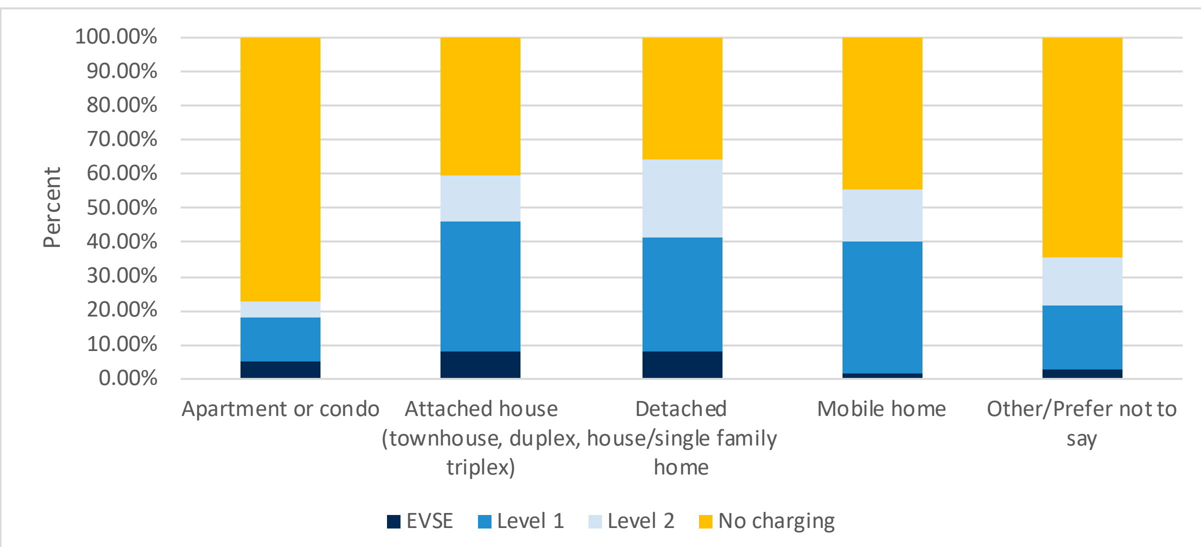

Figure 25: Highest level of charging access at home parking location and home type (n=1964).

Table 16: Highest level of charging access at home parking location and home type (n=1964).

	Highest level of home charging access			
How would you describe your home?	**EVSE**	**Level 1**	**Level 2**	**No charging**
Apartment or condo	5.16%	12.69%	4.73%	77.42%
Attached house (townhouse, duplex, triplex)	7.78%	38.32%	13.77%	40.12%
Detached house/single family home	7.80%	33.76%	22.82%	35.62%
Mobile home	1.35%	39.19%	14.86%	44.59%
Other/Prefer not to say	2.53%	18.99%	13.92%	64.56%

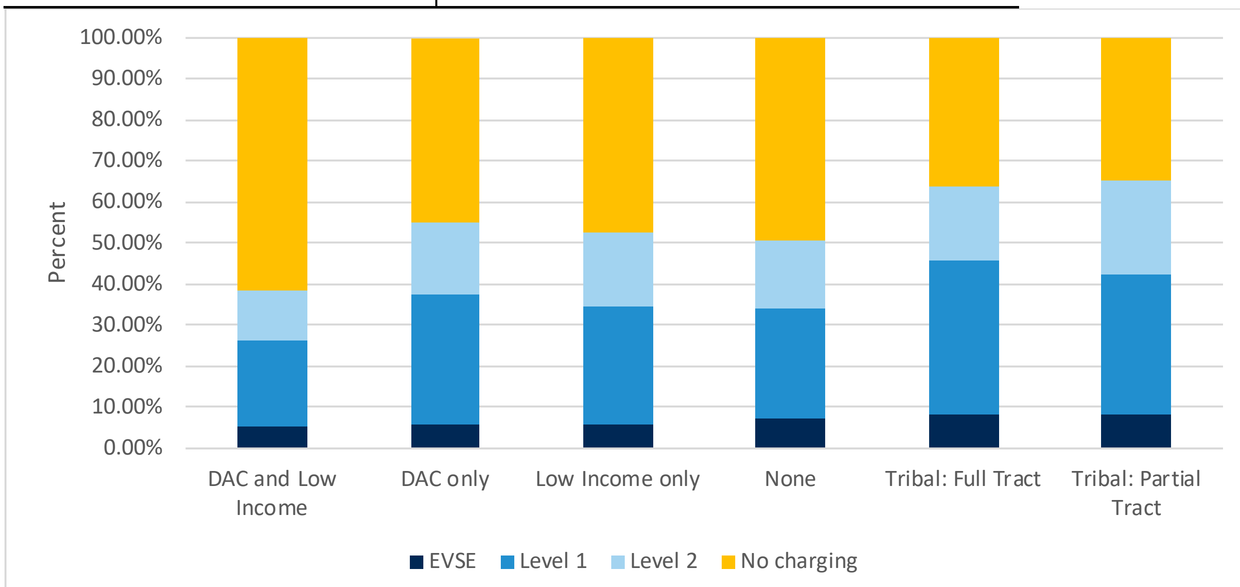

Figure 26:Percent of households with Level 1, Level 2, or No charging access where they park their vehicle at home, by community type (n=1964).

Table 17: Percent of households with Level 1, Level 2, or No charging access where they park their vehicle at home, by community type (n=1964)

	Highest level of home charging access			
Census tract type	**EVSE**	**Level 1**	**Level 2**	**No charging**
DAC and Low Income	5.45%	20.91%	12.12%	61.52%
DAC only	5.66%	31.60%	17.92%	44.81%
Low Income only	6.00%	28.71%	17.82%	47.47%
None	7.42%	26.86%	16.16%	49.56%
Tribal: Full Tract	8.38%	37.43%	17.88%	36.31%
Tribal: Partial Tract	8.33%	34.13%	22.62%	34.92%

Availability of charging near home and trip locations

Figure 27 shows a count of the number of level 1 (L1) and level 2 (L2) chargers within a 5-, 10-, or 15-minute drive of respondents' home locations by census tract type. Figure 28 shows a count of the number DCFC chargers within a 5-, 10-, or 15-minute drive of respondents' home locations by census tract type. Figure 29 shows a count of the number DCFC chargers within a 5-, 10-, or 15-minute drive of respondents' reported trip locations by census tract type. Figure 30 shows a count of level 1 (L1) and level 2 (L2) chargers within a 5-, 10-, or 15-minute drive of respondents' reported trip locations by census tract type. Respondents in partial tribal tracts have access to fewer chargers than those in other tracts. Compared to respondents in other tracts, those in DAC only tracts and fully tribal tracts have fewer chargers within a 15-minute drive but a similar number of chargers within a 5- or 10-minute drive.

Note this analysis is for survey respondents charging access and does not capture access to charging in all census tract types. See Appendix 3 for descriptive statistics of charging access at a census tract level.

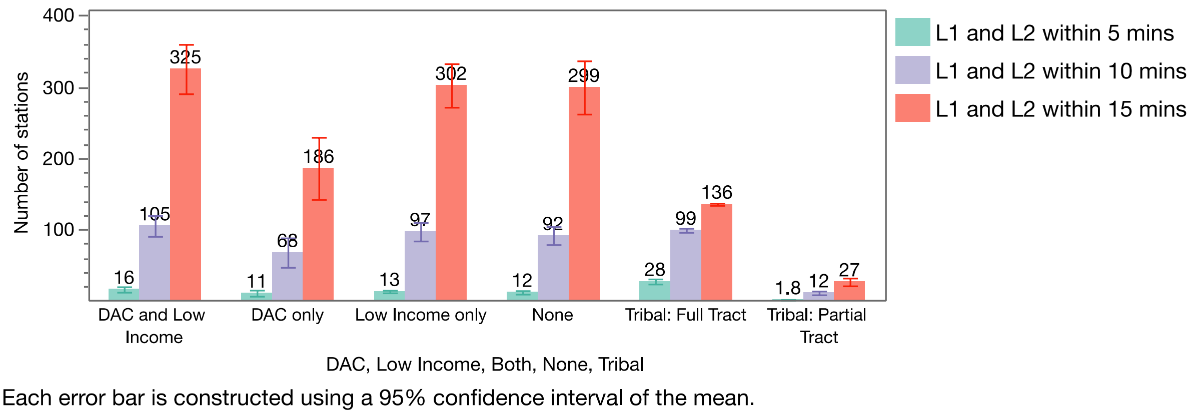

Figure 27: Mean number of level 1 (L1) and level 2 (L2) charging stations (locations) within a 5-, 10-, and 15-minute drive from respondents home location for different census tract types.

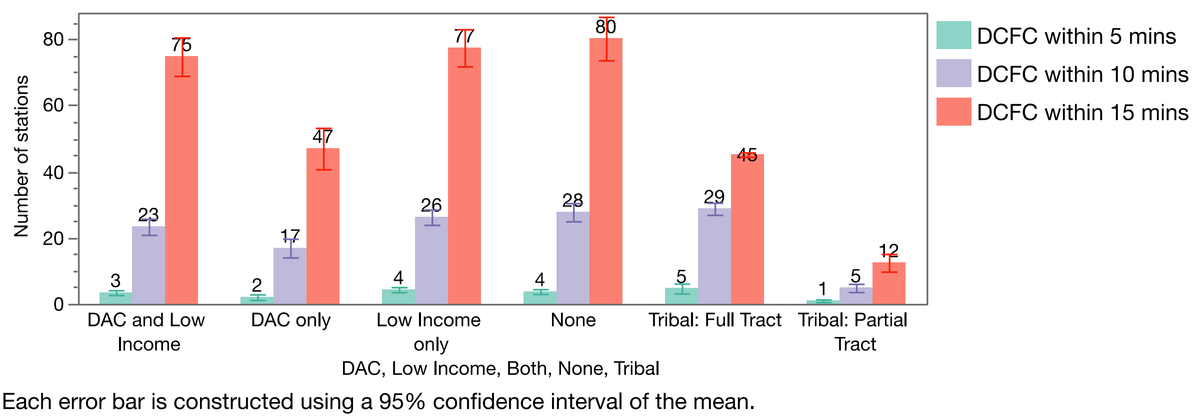

Figure 28: Mean number of DCFC charging stations (locations) within a 5-, 10-, and 15-minute drive from respondents home location for different census tract types.

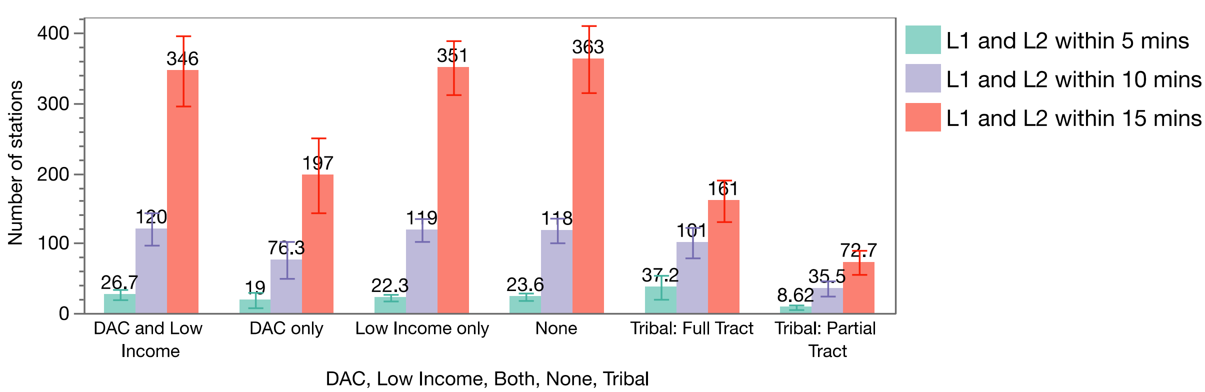

Figure 29: Mean number of level 1 (L1) and level 2 (L2) charging stations (locations) within a 5-, 10-, and 15-minute drive from respondents trip location (e.g. work, school) by census tract type.

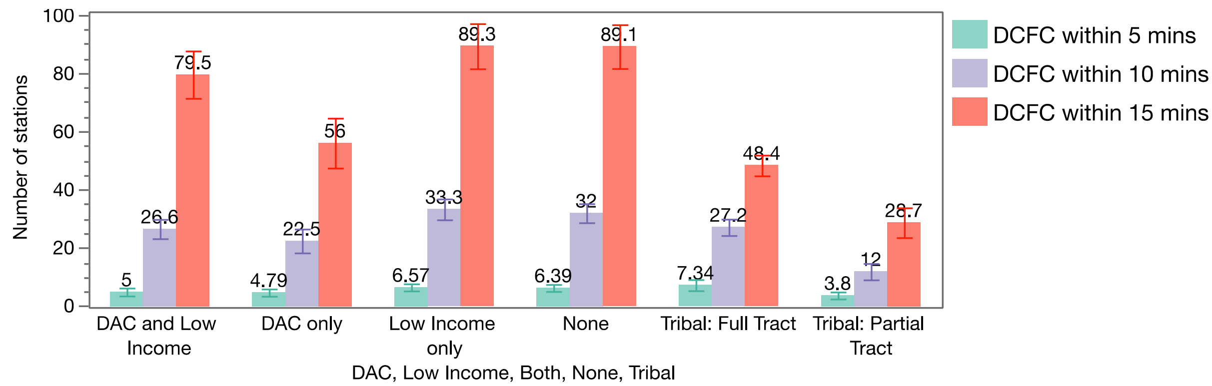

Figure 30: Mean number of level 1 (L1) and level 2 (L2) charging stations (locations) within a 5-, 10-, and 15-minute drive from respondents trip location (e.g. work, school) by census tract type.

Knowledge, Consideration, and Perceptions of Electric Vehicles

Here we explore descriptive statistics related to knowledge consideration, and perceptions of PEVs. We explore how these relate to demographics, attitudes, and built environment variables in the next section (Classifying respondents based on knowledge, perceptions, and consideration of electric vehicles).

PEV naming

Here we consider whether survey respondents can name a PHEV or BEV as a measure of survey respondents' knowledge of PEVs. If respondents can name a PHEV or BEV we consider this to represent a higher level of knowledge of PEVs compared to respondents who cannot name any PHEV or BEV. When asked if they could name a BEV or PHEV, 76% of respondents indicated they could. Many of these responses were incorrect or maybe correct. Maybe correct (Yes, Maybe in the figure) refers to responses that we could not definitively identify as being a PEV. For example, 'Ford Mustang' and 'Toyota Prius' are gasoline cars or HEVs whereas 'Ford Mustang Mach-E' and 'Toyota Prius Prime' are PEVs. If respondents only put 'Ford Mustang' or 'Toyota Prius' we scored that as "Yes, Maybe". Overall 54% of respondents were able to correctly name a BEV or PHEV. Of those that were correct more than 2/3 entered a Tesla, the next most common correct make was Chevrolet at 9% of those who were correct, followed by Nissan at 5%, then by Ford at 4%.

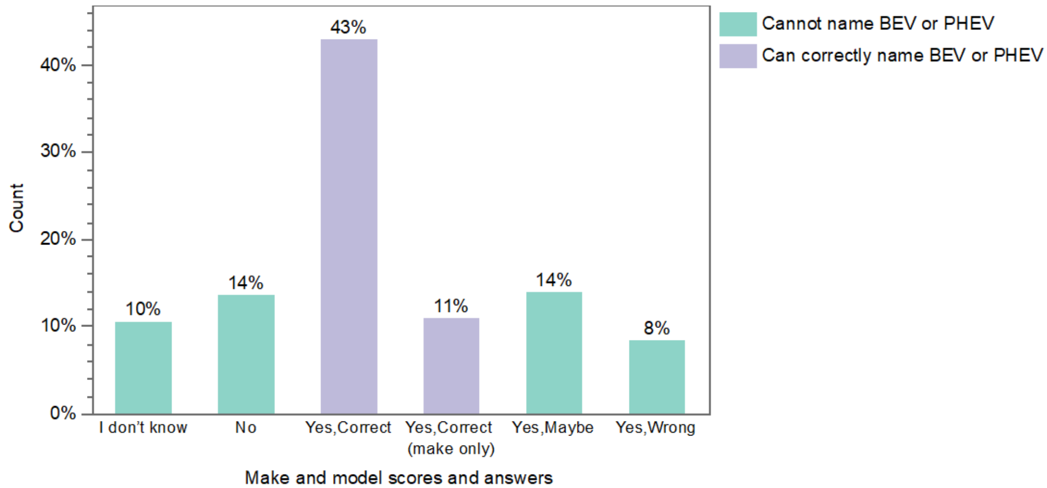

Figure 31: Whether respondents can name a BEV or PHEV (Yes, No, I don't know) and whether those who responded with "Yes" gave a name that was correct, could only name a BEV make, were maybe correct, or wrong.

Perceptions of BEVs and support for 100% ZEV sales

Figure 32 shows responses to a question that asked survey respondents whether they support or oppose the California 100% ZEV sales regulation. Overall, more respondents reported they support this than oppose it, however 37% of respondents indicated opposition. A further 16% are neutral.

Figure 33 shows respondents responses to various statements about electric vehicles. The majority of participants neither agreed nor disagreed with the statements on BEV safety, ease of maintenance, and battery degradation. This may mean many respondents have not yet formed perceptions on these issues or do not perceive these attributes to differ substantially for BEVs and conventional vehicles. The most negative perceptions were on access to charging and BEV driving range. Only 41% perceived they would be able to charge a BEV from home, and only 16% perceived there are enough places to charge a BEV. Of the respondents, 23% agreed that BEVs have enough driving range, 27% agreed that BEVs are safer than ICEV, 41% agreed that BEVs are better for the environment than ICEVs, 29% agreed that BEVs are easier to maintain than ICEVs, 25% perceived BEV batteries degrade too fast, and only 41% reported being aware of BEV incentives. Note we did not ask about vehicle cost, because respondents were told BEVs cost a similar amount as gas cars in a previous question (the survey experiment).

We checked the correlation between perceptions that there are enough places to charge a PEV and the presence of DCFC and level 1 & 2 charging in 5-, 10-, and 15-minute driving distances from respondents' home location and their reported trip locations. In testing 12 relationships between measures of infrastructure access and perceptions of whether there is enough infrastructure, there was no significant difference in all 12 cases (using ANOVA tests), suggesting the presence of infrastructure does not relate to perceptions of it.

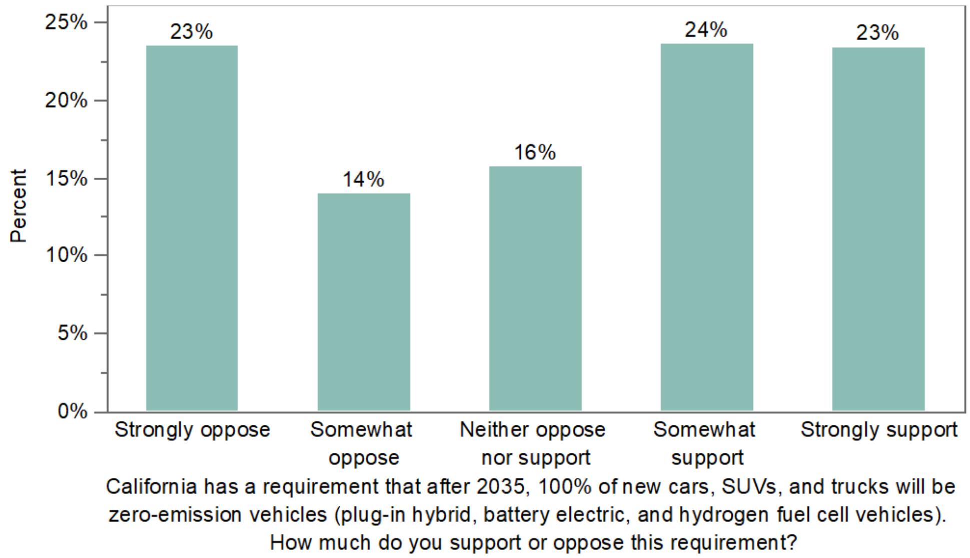

Figure 32: Support or opposition for 100% ZEV sales by 2035 among survey respondents.

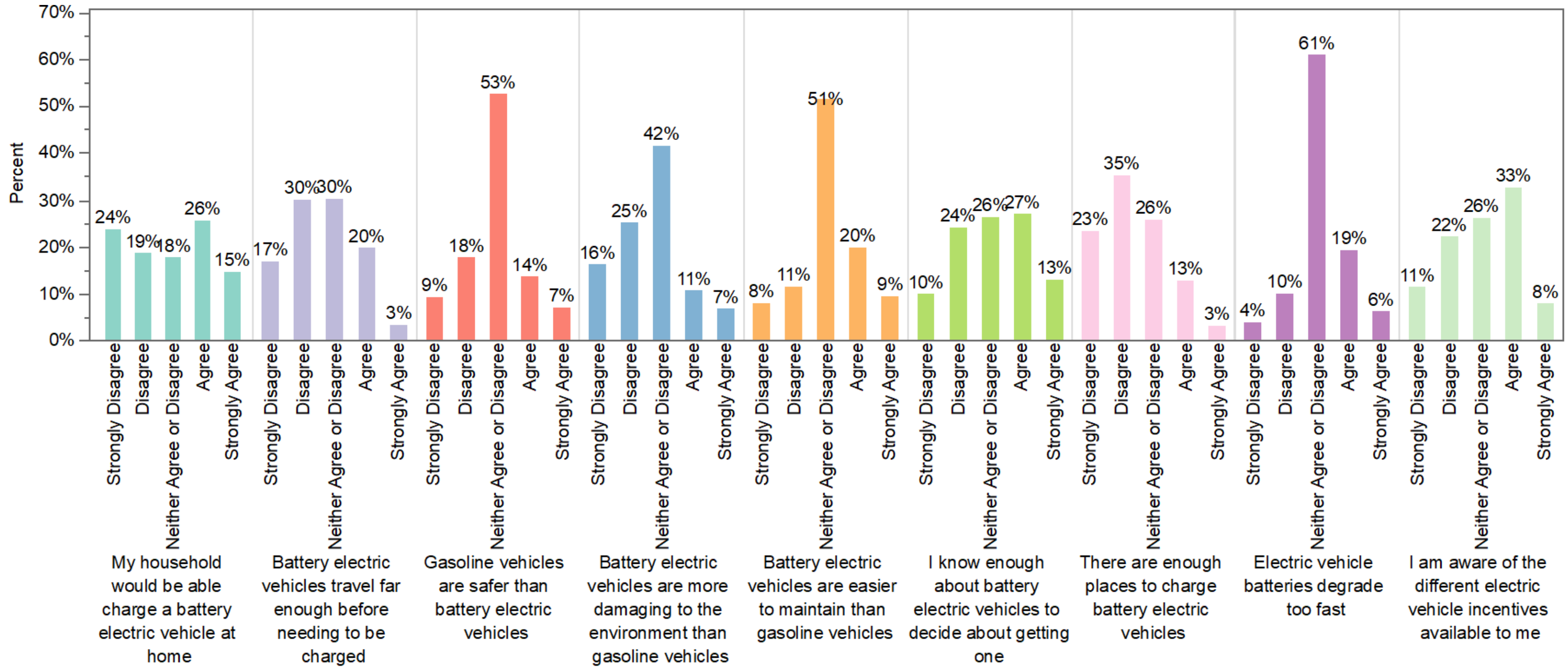

Figure 33: Responses to BEV related statements.

Consideration to purchase a PEV

Figure 34 shows responses to questions of whether respondents had considered buying a BEV (left) or a PHEV (right). Most survey respondents had not considered either. For both BEVs and PHEVs more than half of the respondents indicated they either had not and would not consider a BEV/PHEV or had not yet but maybe would someday consider it. Of the respondents, 25% and 30% indicated considering the idea to buy a BEV or PHEV, respectively, but they had not taken any steps to shop for one. In addition, 11% and 9% indicated they had started to gather information about buying a BEV or PHEV, respectively. Next, 4% indicated they had actively shopped for a BEV, and 5% indicated they had actively shopped for a PHEV. Lastly 7% indicated they own or have owned a BEV, while 5% own or have owned a PHEV.

These results are similar to a 2021 statewide survey (not specifically on priority populations) (Kurani, 2022b). Though in this 2024 sample slightly fewer indicated they have not considered a BEV but maybe will, and more respondents indicated they own or have owned a BEV or PHEV.

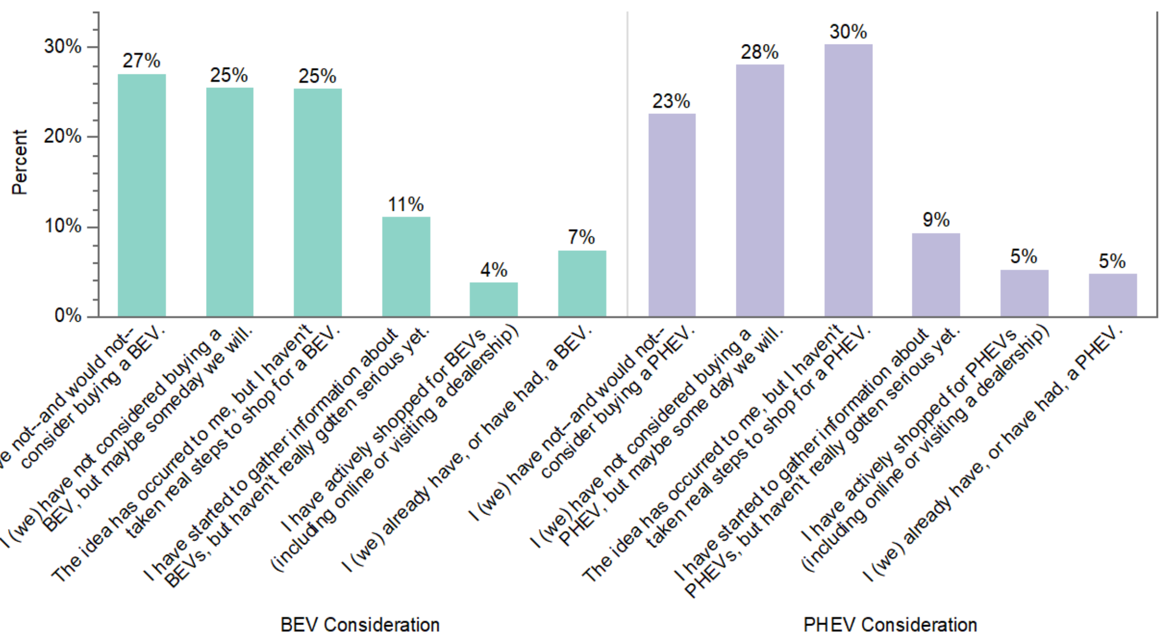

Figure 34: Whether respondents have considered buying a PHEV or BEV for their household.

Figure 35 shows whether those who have started to gather information or actively shopped for BEVs and PHEVs have made a decision. Respondents who had considered purchasing a PHEV or BEV were asked up to two follow up questions. This was “Have you made a decision about a battery electric vehicle?” or “Have you made a decision about a plug-in hybrid vehicle?” (see Figure 35). For both PHEVs and BEVs, a majority have not decided yet. Of the respondents, 28% decided they would purchase a BEV but have not done so yet, and 21% decided they would purchase a PHEV but have not done so yet. In addition, 18% decided they would not purchase a BEV or PHEV. Survey takers who reported they decided against a BEV or PHEV asked to explain why they did not purchase a BEV or PHEV. These results help show barriers to PEV purchase when buyers have considered a PEV and reveal *experienced* barriers, rather than perceived barriers among the whole sample. Figure 36 shows reasons respondents who considered a BEV did not purchase one. The most commonly reported reason was a lack of charging infrastructure, including a lack of charging access at home or in public. The next most common reason was purchase cost, followed by driving range. Next the availability of a vehicle to purchase was reported as a reason six respondents did not choose a BEV. Six respondents reported that the high cost to install a home charger was a reason they did not purchase a BEV. Figure 37 shows why respondents who considered a PHEV did not purchase one. The most reported reason was that respondents purchased a BEV instead. Only one respondent who considered a BEV reported buying a PHEV. Like the barriers to BEV purchase, vehicle cost was one of the most reported reasons respondents did not purchase a PHEV. The availability of a vehicle to purchase was also a highly reported barrier to PHEV purchase. Lack of charging was less frequently reported as a barrier for PHEV purchase, as would be expected because these vehicles are not solely dependent on charging for energy.

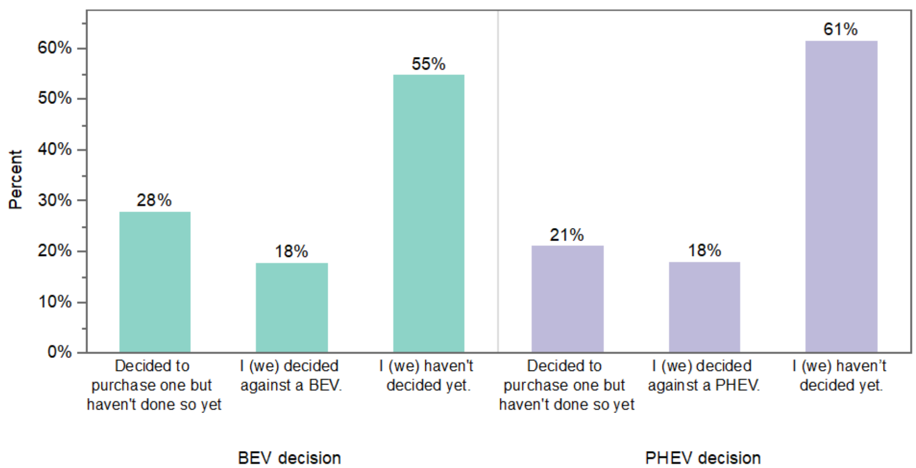

Figure 35: Whether respondents who have started to gather information about BEVs or PHEVs, actively shopped for BEVs or PHEVs, or have made a decision about BEV or PHEV purchase, and what that decision is (n=289 for BEV decision, 282 for PHEV decision).

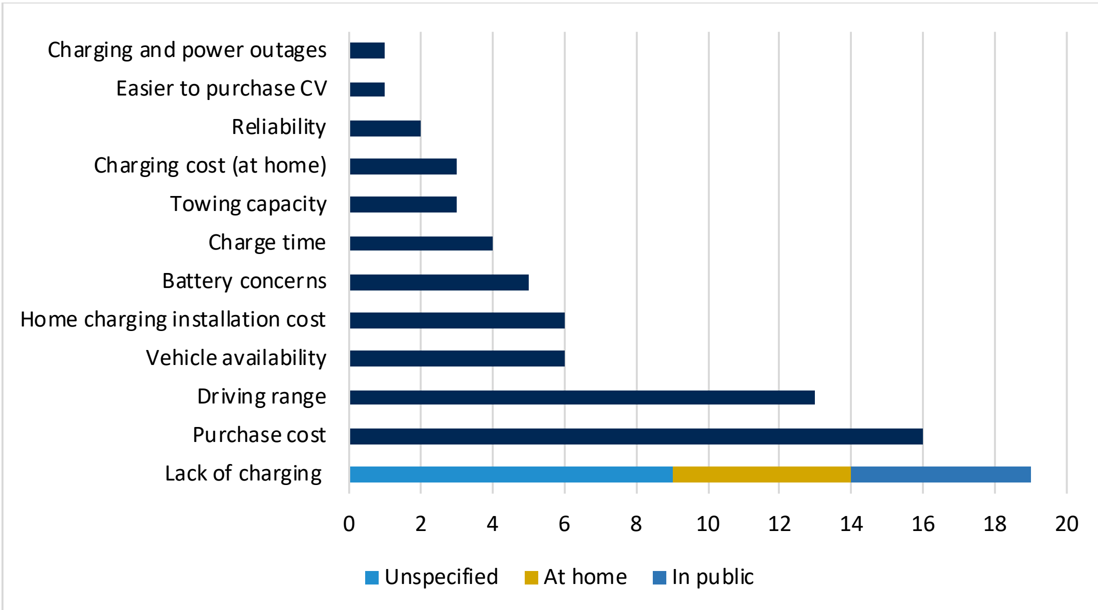

Figure 36: Reported reasons why respondents did not purchase a BEV after considering purchasing one (n= 49). Responses are coded based on responses to an open text box question.

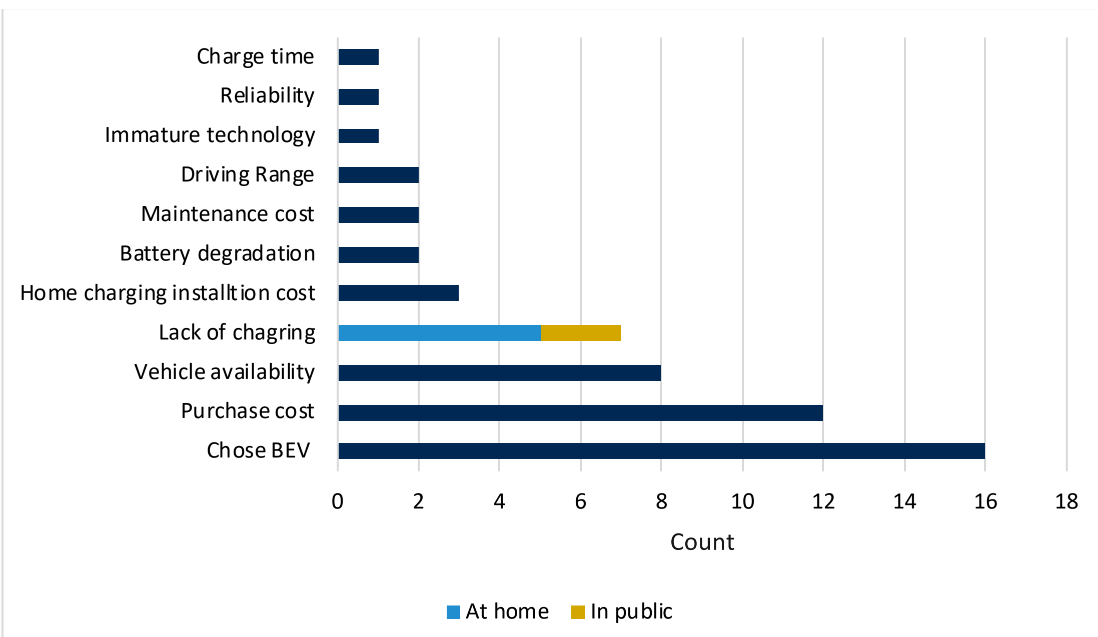

Figure 37: Reported reasons why respondents did not purchase a PHEV after considering purchasing one (n= 49). Responses are coded based on responses to an open text box question.

Classifying respondents based on knowledge, perceptions, and consideration of electric vehicles

Here we explore results of the latent class analysis of respondent knowledge, perceptions, consideration, and support for ZEV regulations. This helps better understand how these relate to each other. The inputs to the clustering are shown in Figure 31 through Figure 34. Several latent class models were generated, with five classes appearing to be the optimal number of classes as seen in Appendix 2. Figure 38 shows the proportion of respondents in each class, and Figure 39, descriptive statistics for each class and the variables used in the clustering. We name classes based on whether they are Active or Passive, Resistors and Supporters, or whether they are unengaged. Active or Passive is used to identify whether classes appear to have previously been active in thinking about BEVs and a measure of how strong perceptions are, with Active representing stronger opinions. Resistance and Support is used to name classes based on whether respondent have negative perceptions or opposition (resistance), or positive perceptions or support of BEVs and ZEV regulation. Unengaged is used to identify a latent class that does not exhibit any resistance, support, or activity. Most respondents were classified as Passive or Unengaged, while 7% and 14% of respondents were classified as Active Support and Resistance, respectively. Below we describe class attributes:

- Class 1 (Passive Supporters) is characterized by mixed knowledge and neutral to positive perceptions of BEV attributes. However, perceptions of charging availability are predominantly negative, while perceptions of home charging access, BEV range, self-knowledge, and incentive awareness are mixed. Perceptions of BEV battery degradation, safety, and maintenance are predominantly neutral. BEV purchase consideration varies predominantly from "maybe someday consider" to "idea has occurred." Support or opposition to ZEV policy is mostly in support. This class slightly or strongly supports 100% ZEV sales regulations.
- Class 2 (Active Supporters) is characterized by high knowledge and positive perceptions of BEV attributes, including access to home charging, safety, environmental impact, maintenance, self-knowledge, and incentive awareness. The only BEV attribute with more negative than positive perceptions is whether there are enough places to charge. Perceptions of BEV range and battery degradation are also neutral or mixed. BEV purchase consideration ranges from either *seriously considering a BEV* or *already owned or own* one. This cluster also has strong support for the 100% ZEV sales regulation.
- Class 3 (Unengaged) is characterized by low knowledge, neutral perceptions, and neutral opinions about ZEV policy. Perceptions of home charging access and self-knowledge range predominantly from negative to neutral. BEV purchase consideration ranges from "won't consider" to "idea occurred."
- Class 4 (Active Resisters) consists of individuals with mixed knowledge of BEVs, though a majority could not correctly name a BEV. This class has strong negative perceptions of BEV attributes, yet positive perceptions of their self-reported knowledge and awareness of incentives. Responses in this class report they have not and will not consider a BEV and have strong opposition to the 100% ZEV sales legislation.

- Class 5 (Passive Resisters) consisted of a split of individuals who could correctly or incorrectly name a BEV or could not name one. Respondents has mostly slightly negative perceptions and slight opposition to 100% ZEV sales. Perceptions for home charging access, BEV range, their knowledge of BEVs, whether there are enough places to charge BEVs, and battery degradation were more negative. Most respondents had not considered a BEV, and just less than half of these respondents said they would never consider buying a BEV.

All classes perceive there are not enough places to charge a BEV, while Active Supporters are the only class with strong positive perceptions of access to home charging. Range is also perceived negatively for most classes, with even Active Supporters having mixed perceptions of driving range. Respondents across all classes appear to have neutral perceptions of battery degradation, with even Active Resistors and Active Supporters having some degree of neutrality around this attribute.

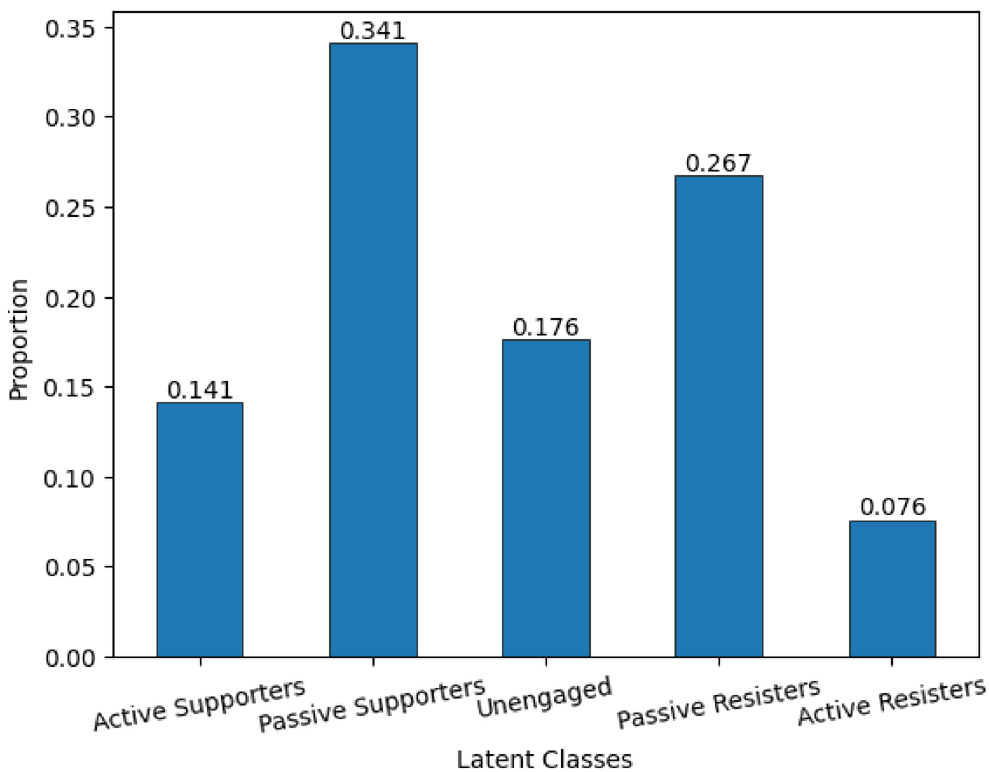

Figure 38: Size of each latent class within the survey sample, values indicate the proportion of respondents in each class.

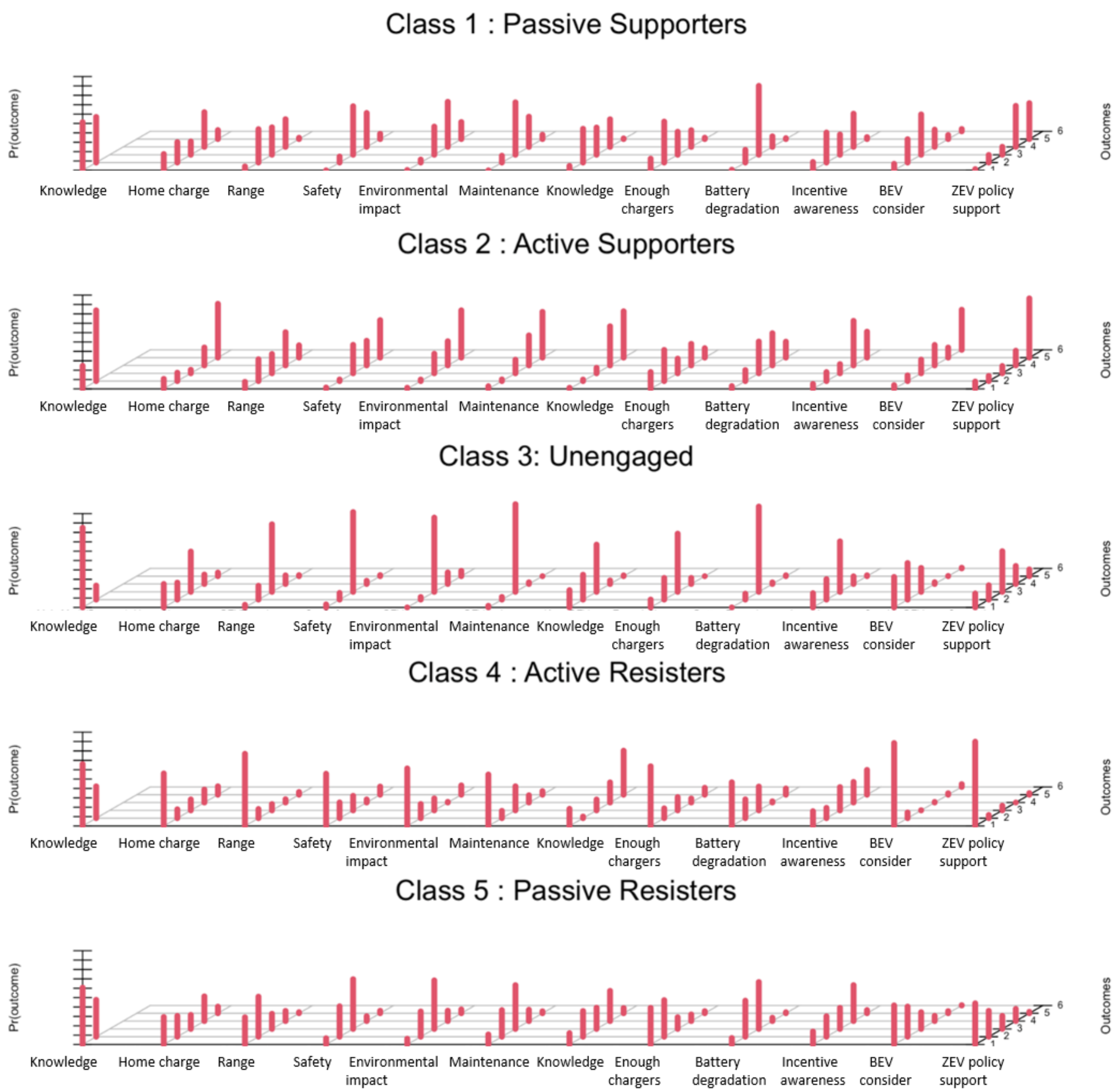

Figure 39: Distribution of variables used to build latent classes by class. Y axis labels are categorical variables shown in Table 4. Higher values represent more positive perceptions, greater consideration to purchase a BEV, greater support for ZEV policy, and greater knowledge. Note some perceptions are the inverse of responses, specifically questions where agreement represented a negative perception and disagreement was a positive perception are inverted.

Investigating Class Attributes

The results from the MNL model, which explore attributes related to class membership, are presented in Table 18, in the form of log-odds. The results are interpreted as the change in log-odds of being in any particular class compared to being an Active Supporter", given a one-unit increase for continuous variables, and compared with the reference category for dummy and categorical variables. More generally, the results indicate whether there is a statistically significant relationship between a dependent variable and being in a particular latent class compared to the reference category of Active Supporters.

Socio-demographics

Compared to all other classes, Active Supporters have higher log-odds of owning their home, being male, and having a college education. For all classes except Passive Supporters, the log-odds of being an Active Supporter also increases for households with fewer vehicles per driver, and younger respondents. Compared to Active Supporters, Active Resisters have a higher log-odds of buying used cars, while Passive Supporters have a higher log-odds of buying new cars. Households with incomes of $150,000 or above are more likely to be Active Supporters than any other class compared with households earning between $100,000–$149,999. However, households with incomes ranging from less than $50,000 to $99,999 are less likely to be Active Resisters, suggesting Active Resisters are higher income than most classes, except for the Active Support class. Being any race other than White predominantly decreases the log-odds of being an Active Supporter compared with all other classes, except for Asian respondents, who are less likely than White respondents to be Active Resisters.

Attitudes

Several attitudinal variables increase the log-odds of being an Active Resister compared with all other classes, including having anti-environmental attitudes, not having attitudes in favor of mixed land use, and finding waiting to be a waste of time. Passive Supporters and Unengaged classes are more likely than Active Supporters to be anti-technology and less social. Active Resisters have a higher log-odds than Active Supporters of being too busy for leisure. Having pro-car attitudes increases the log-odds of being an Active Supporter for all classes except for Active Resisters, who are also more likely than Active Supporters to have pro-car attitudes.

Built Environment

Compared with Active Supporters, respondents living in a rural census tract have a higher log-odds of being an Active or Passive Resister. Active Supporters are more likely than all classes to have more fast chargers near where they live than all other classes, except for Active Resisters (for which there is no difference in access). Active Supporters are also more likely than all other classes to have more PEVs per 1,000 households and higher levels of access to home charging.

Table 18: Multinomial logistic regression (MNL) model results, where the dependent reference category is Active Supporters. The model compares various demographic, built environment, and attitudinal variables across classes. Estimates are shown outside of the brackets with significance stars to indicate level of statistical significance based on p values (*p<0.1; **p<0.05; ***p<0.01), numbers in parenthesis are standard errors.

	Dependent variable:			
	Active Resisters (1)	**Passive Resisters (2)**	**Passive Supporters (3)**	**Unengaged (4)**
Vehicles per driver	0.351*** (0.013)	0.271*** (0.059)	0.011 (0.052)	0.277*** (0.019)
New car buyer dummy	-0.295*** (0.005)	0.041 (0.047)	0.114** (0.057)	-0.025 (0.015)
Race (Reference: White)				
Other	1.456*** (0.002)	1.284*** (0.006)	0.474*** (0.006)	1.585*** (0.002)
Asian	-0.034*** (0.002)	0.214*** (0.006)	0.466*** (0.010)	0.734*** (0.005)
Hispanic/Latinx	0.902*** (0.003)	1.265*** (0.007)	0.908*** (0.007)	1.532*** (0.006)
Multi-Racial	0.285*** (0.001)	0.786*** (0.003)	0.454*** (0.003)	0.669*** (0.001)
Age	0.040*** (0.007)	0.010** (0.005)	-0.005 (0.005)	0.012** (0.006)
Income (Reference: ≥ $150,000)				
$100,000-$149,999	0.127*** (0.003)	0.438*** (0.022)	0.073*** (0.025)	0.670*** (0.006)
$50,000-$99,999	-0.194*** (0.002)	0.552*** (0.049)	0.247*** (0.062)	1.288*** (0.011)
Less than $50,000	-0.185*** (0.003)	0.247*** (0.027)	0.090*** (0.036)	1.381*** (0.018)
Prefer not to say	0.522*** (0.003)	1.076*** (0.010)	0.477*** (0.009)	1.561*** (0.004)
Male dummy	-0.651*** (0.006)	-0.723*** (0.056)	-0.822*** (0.067)	-1.490*** (0.008)
College education dummy	-0.703*** (0.004)	-0.857*** (0.020)	-0.717*** (0.021)	-1.080*** (0.011)
Home ownership (Reference: Own)				
Other/Prefer not to say	0.963*** (0.002)	0.257*** (0.005)	0.340*** (0.005)	0.735*** (0.004)
Rent	0.585*** (0.004)	0.189*** (0.027)	0.470*** (0.030)	0.430*** (0.026)
Anti-environment	0.710*** (0.045)	0.491*** (0.046)	0.094** (0.045)	0.325*** (0.049)
Pro-car	0.433*** (0.026)	-0.293*** (0.046)	-0.330*** (0.044)	-0.336*** (0.047)
Pro-mixed land use	-0.638*** (0.059)	-0.347*** (0.041)	-0.108** (0.042)	-0.263*** (0.049)
Anti-tech	0.025 (0.065)	0.262*** (0.047)	0.317*** (0.047)	0.329*** (0.054)
Pro-too busy	0.154** (0.055)	0.013 (0.045)	-0.135*** (0.044)	-0.039 (0.051)
Pro-social	-0.006 (0.054)	-0.073 (0.048)	-0.177*** (0.047)	-0.230*** (0.052)
Anti-waiting	0.253*** (0.041)	0.241*** (0.049)	0.075* (0.047)	0.139*** (0.050)
Anti-exercise	0.160*** (0.026)	0.191*** (0.046)	0.012 (0.047)	0.233*** (0.046)
People per sq km, 2010	-0.00001 (0.0001)	-0.00002 (0.00003)	-0.00003 (0.00003)	-0.0001 (0.00004)
DCFC within 5 mins of residence	-0.047 (0.047)	-0.131*** (0.039)	-0.091** (0.036)	-0.144*** (0.045)
Urban dummy	-0.068*** (0.003)	-0.377*** (0.007)	0.246*** (0.007)	0.120*** (0.003)
PEVs per 1000 households, 2010	-0.016*** (0.005)	-0.010*** (0.003)	-0.003 (0.002)	-0.007** (0.003)
Home charging access (Reference: PEVs)				
Level 1	1.865*** (0.005)	2.416*** (0.046)	2.161*** (0.049)	3.893*** (0.035)
Level 2	1.202*** (0.002)	1.754*** (0.024)	1.308*** (0.027)	2.633*** (0.006)
No charging	2.816*** (0.006)	3.046*** (0.046)	2.300*** (0.045)	4.577*** (0.042)

	Dependent variable:			
	Active Resisters (1)	**Passive Resisters (2)**	**Passive Supporters (3)**	**Unengaged (4)**
Constant	-7.568^{***} (0.004)	-1.839^{***} (0.004)	1.623^{***} (0.003)	-3.344^{***} (0.003)
Akaike Inf. Crit.	4,518.614	4,518.614	4,518.614	4,518.614

Latent Class Analysis Summary

The latent class clustering provides more nuance to understanding perceptions of ZEVs and barriers to adoption. Classifying respondents through multiple dimensions, including knowledge, purchase consideration, perceptions, and support for 100% ZEV sales reveals five classes. We then specify an MNL model to investigate how each of the classes relate to socio-demographic features, such as income, age, gender, vehicles per driver and more, attitudes relating lifestyle and the environment, and built environment characteristics such as charging accessibility and rurality.

The analysis identifies one of five classes as having particularly strong resistance to ZEV-related legislation and to BEV adoption, while the remaining classes (92.4% of our sample) are more likely to consider BEV adoption at some point. We also find all classes of supporters and resisters have concerns about whether there are enough public charging locations. Active Supporters are the only class with strong positive perceptions of home charging access. Regarding the built-environment, Active Supporters are more likely to live in regions with higher levels of ZEV adoption, more public fast chargers, and are more likely to have home charging access. This class is also more likely to have positive attitudes toward pro-environmental behavior, new technology, and mixed land use. Lastly, compared to the other groups, Active Supporters are more likely to be younger, own their home, and to be White.

While Passive Resisters and Passive Supporters both exhibit mixed knowledge and perceptions, Unengaged respondents have likely never thought about BEVs and not yet formed opinions on them. Active Resisters appear unlikely to ever purchase a BEV, at least based on their current perceptions, and appear to have high levels of self-knowledge regarding BEVs. Understanding why these respondents perceive BEVs so negatively and why they strongly oppose 100% ZEV sales may be important in preventing this type of consumer from disrupting policy processes.

Survey experiment results

Here we explore results of the beta regression analysis of the survey experiment presented in Table 19. We present results from 5 different models, first controlling only for policy interventions, then only socio-demographics, followed by BEV perceptions, then general attitudes, and a final model that controls for all variable categories together, in addition to two contextual variables. The final model has the highest adjusted R-square of 0.36, in addition to having the highest value for the precision parameter, and Log-likelihood. Of the other four models, the BEV perception-only model yields the second highest adjusted R-squared and precision parameter value, comparable to those of the final model. The vignette-only model yields an adjusted R-squared close to 0 indicating consideration to purchase a BEV is likely explained by factors other than the availability of incentives, infrastructure, or battery assurance measures.

The coefficients are presented as odds ratios, and interpreted as the relative change in the odds of having a higher (odds ratio greater than 1.0) or lower (odds ratio less than 1.0) odds of a higher outcome in response the experiment which asked respondents *"In this scenario how likely would you be to consider purchasing a battery electric vehicle?"*, for a one-unit change in continuous predictor variables, or relative to a reference category for categorical variables.

We focus our discussion primarily on the final model. This model controls for aspects known to influence BEV adoption or preferences and has the highest R-square value. Beginning first with policy interventions related to financial incentives, compared with not being presented any information on incentives, the odds of having higher likelihood of purchase consideration increases by 25% when presented with the Clean Cars 4 All incentive. The impact of the 1/3 reduced incentive is statistically significant only at a 10% significance and increases the odds by 13%. We also tested the interaction effect of income, in addition to household federal poverty level and the CC4A incentive to see if it is less effective (therefore potentially less necessary) for higher income or households or households in poverty. This analysis found no significant differences in the effect sizes of incentives by income category or federal poverty line levels, indicating in this sample of only priority population households, the incentive influences consideration no differently regardless of income.

Regarding charging infrastructure, compared to public Level 2 charging, access to charging at home, destination (work, school, etc.), and home and destination (work, school, etc.), increases the odds of having higher BEV purchase consideration likelihood increase by 22%, 20%, and 26%, respectively. We do not find any statistically significant differences between the presence of public fast charging by itself versus public Level 2 charging, and the presence of fast charging combined with home charging is only significant at the 10% significance level. We also test for the various interactions and find that the presence of fast charging and the Clean Cars 4 All incentive is also significant at only the 10% significance level.

Regarding battery-related interventions, we find no statistically significant relationship between battery replacement rebates or warranties and BEV purchase consideration likelihood, compared with being presented with no information on these interventions. We also tested for any differences between new and used car buyers but did not find any statistically significant differences.

There are also significant effects related to socio-demographic variables. Younger respondents are more likely than older respondents to have higher likelihood to consider purchasing a BEV. Compared with the highest income households, the odds of having higher purchase consideration likelihood are 24% lower for household incomes less than $50,000, and 19% lower for households with incomes between $50,000 and $99,999. Households which typically buy new rather than used car are 1.19 times as likely to consider buying a BEV. Notably, the coefficient values for income are much larger, and more significant in the socio-demographics-only model than in the final model, in addition to variables related to vehicle access no longer statistically significant in the final model. We tested for the significance of other travel-related variables including number of trips respondents made the day prior but found no significant effects in either the demographics-only model or final model. A one-unit increase in the density of electric vehicles per 1,000 vehicles increases the odds of higher purchase consideration likelihood by 1%.

We find BEV perceptions are largely associated with increased odds of higher likelihood of purchasing a BEV, and in particular favorable perceptions of battery quality, with odds of higher consideration increasing by 75% for every one-unit increase in this perception factor. For every one-unit increase in respondents' perceptions of charging and range, and their ability to charge from home, the odds of having higher purchase consideration likelihood additionally increase by 30% and 15%, respectively.

Lastly, several of the attitudinal factors and indicators yield statistically significant results. Having attitudes aligned with being pro-environment, a modern urbanite, waiting tolerant, and travel-liking all positively increase the odds of having higher likelihood to purchase a BEV.

We also estimate the marginal effects of the policy interventions, shown in Figure 3. These represent the change in predicted mean likelihood to consider purchasing a BEV, relative to the reference category, and holding all other variables at their reference, or mean levels. The presence of the Clean Cars 4 All incentive increases the predicted likelihood of BEV purchase consideration by 5.3%, relative to no information. Access to home, work, and home and work charging increases predicted likelihood by 5.0%, 4.6%, and 5.7%, respectively, compared with public Level 2 charging. Notably, relative to their respective reference levels, the Clean Cars 4 All incentive and access to home and work charging increase likelihood to consider buying a BEV from closer to very unlikely, to closer to very likely to consider a BEV.

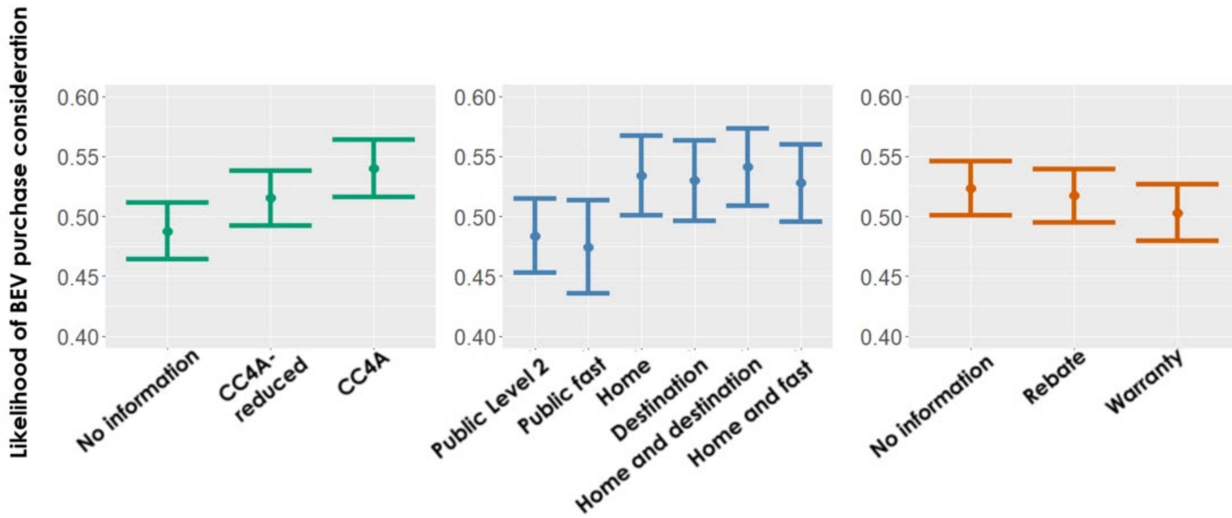

Figure 40: Marginal effects of policy interventions on predicted likelihood to consider purchasing a BEV

Table 19: Beta regression odds ratios (Dependent variable: likelihood to consider buying a BEV between 0 (very unlikely) to 1 (very likely). Final model controls for all variables while others control for variables separately (see Appendix 2 and the Methods section for more detail on model specifications).

Category	Variable	Final model		Interventions		Socio-demographics		BEV perceptions		Attitudes	
	(Intercept)	0.20	***	0.82	*	1.00	***	1.05	*	0.12	***
Incentives	Reduced CC4A	1.13		1.13							
(reference: none)	CC4A	1.25	**	1.25	***						
Charging infrastructure	Home	1.22	**	1.22	*						
(reference: Public L2)	Destination	1.20	**	1.11							
	Fast	0.96		1.00							
	Home and destination	1.26	**	1.25	*						
	Home and fast	1.19		1.14							
	CC4A x fast charging	1.32									
Battery assurance	Battery rebate	0.98									
(reference: none)	Battery warranty	0.92									
Socio-demographics	Age (ref: 70 or older)										
	29 or younger	2.14	***			1.84	***				
	30 to 49	1.57	***			1.38	***				
	50 to 69	1.35	***			1.20	***				
	Male	1.00				1.08					
	College educated	1.17	*			1.31	***				
	Income (ref: $150,000 and over)										
	less than $50,000	0.76	**			0.62	***				
	$50,000 - $99,999	0.81	*			0.64	***				
	$100,000 - $149,999	0.86				0.72	***				
	Prefer not to answer	0.90				0.64	**				
	Vehicles per driver	0.95				0.84	*				
	New car buyer	1.19	**			1.20	**				
Context	EVs per 1,000 households	1.01	***								
	Urban dummy	0.98									
Perceptions	Charging and range	1.30	***					1.34	***		
	Awareness and knowledge	0.99						1.00			
	Battery quality	1.75	***					1.84	***		
	Home charge assess	1.15	***					1.14	***		

Attitudes	Life style: Tech savvy	1.00								1.07	*
	Work oriented	1.03								1.03	
	Pro-exercise	0.99								1.01	
	Family/friends orientated	1.03								1.07	*
	Materialistic	0.98								1.05	
	Travel: Non-car alternatives	1.00								1.10	***
	Pro-car owning	1.00								1.00	
	Commute benefit	0.99								1.01	
	Travel-liking	1.06	*							1.01	
	Land use: Pro suburban	1.01								0.98	
	Modern urbanite	1.06	*							1.19	***
	Personality: Pro environmental	1.06	*							1.18	***
	Polychronic	0.99								0.96	
	Waiting-tolerant	1.04	*							1.00	
	Sociable	1.06								1.06	
	Phi coefficient	1.49	***	0.97	***	1.03	***	1.34	***	1.04	***
	Log-likelihood	897.8		560.8		670.7		872.7		637.8	
	Adjusted R-squared	0.356		0.010		0.064		0.301		0.090	
	num. observations	1,888		1,963		1,888		1,963		1,963	

Statistical significance: 0 ‘ *** ’ 0.001 ‘ ** ’ 0.01 ‘ * ’ 0.05

Summary of survey experiment results

Regarding financial incentives, we find that presenting respondents with incentive information that represents the $7,500-$12,000 Clean Cars 4 All incentive increases likelihood to consider purchasing a BEV by approximately 5%, aligning with a range of 0.7% to 0.4% increase in likelihood to consider purchasing a BEV for every $1,000 offered in incentives, depending on whether the incentive is larger for trading in another vehicle. This value is smaller than other U.S based studies (Clinton and Steinberg, 2019; Jenn et al., 2018; Wee et al., 2018b) but larger than a study based on 30 countries (Sierzchula et al., 2014). Notably, these studies investigate the impact of incentives for PEV adopters, as opposed to non-PEV owners. While the effect size in our study may seem small, it is approximately the same as a $100,000 increase in household income or being a new versus used car buyer. Related to this, strategies that build wealth in communities may have an indirect effect of increasing BEV consideration. However, we do not find the incentive to be more impactful for lower income households in this sample. This contrasts with a study of rebate recipients which found lower-income adopters to place higher average importance on the state rebate regarding their decision to adopt (Williams and Pallonetti, 2023). However, a New York- based study found no significant differences between DAC and non-DAC adopters in the reported importance of incentives (Williams and Anderson, 2024), and a recent evaluation of the California CVAP program also found all program participants were highly dependent on incentives in purchasing their PEV (Chakraborty et al., 2024b).

The results indicate that compared with access to home and destination charging, public fast charging does not have any positive effect on likelihood to consider a BEV among priority populations compared to the reference category of only public slow charging (level 2 charging). The presence of fast charging is only significant at the 10% level when combined with access to home charging or the Clean Cars 4 All incentive. Thus, while a robust network of public charging is necessary to facilitate more electric-vehicle miles traveled, public charging may not be an equal substitute, or way to encourage BEV adoption, compared to charging at home, work, or school. Finding public charging is uninfluential in increasing BEV consideration is not new to this study. Hoogland et al. (Hoogland et al., 2024) and Bailey et al. (Bailey et al., 2015b) find no relationship between awareness of public charging and adoption intent. Similarly, Hardman et al. (Hardman et al., 2020) and Brückmann et al. (Brückmann et al., 2021) find density of public charging to have no significant effect on adoption intent. Rather, all four studies find measures of home charge access to positively impact adoption intent, which the results from this experiment agree with. Prior research has also found home charging to be the most influential charging location in the decision to purchase a BEV (Hardman et al., 2018), and that BEV adopters who do not have access to charging from home are more likely to discontinue owning a BEV, potentially due to poor experiences with public charging (Hardman and Tal, 2021).

The lack of significance for battery-related interventions indicates that warranties may not currently have a direct effect in increasing consideration to purchase a BEV in this population. Descriptive statistics reveal that many used car owners purchase vehicles older than 8 years or with more than 100,000 miles. While respondents in general have neutral perceptions regarding battery quality, respondents with positive perceptions of battery quality are much more likely to consider purchasing a BEV.

Priority populations preferences for transportation investments

To understand which transportation investments are priorities for underserved communities, respondents were asked to rate different transportation options on a scale from Lowest Priority (1.00) to Highest Priority (7.00). This included 8 transportation investments and investments in roads as a baseline to compare to. Figure 41 displays the median and interquartile range for each investment priority. Overall transit investments were ranked the highest priority, followed by investments in walking infrastructure, new roads, then electric vehicles, followed by mobility wallets, and then biking infrastructure. Electric bike or scooter incentives, shared bikes and scooters, and car sharing were ranked as lower priorities than those above, potentially due to unfamiliarity with these options.

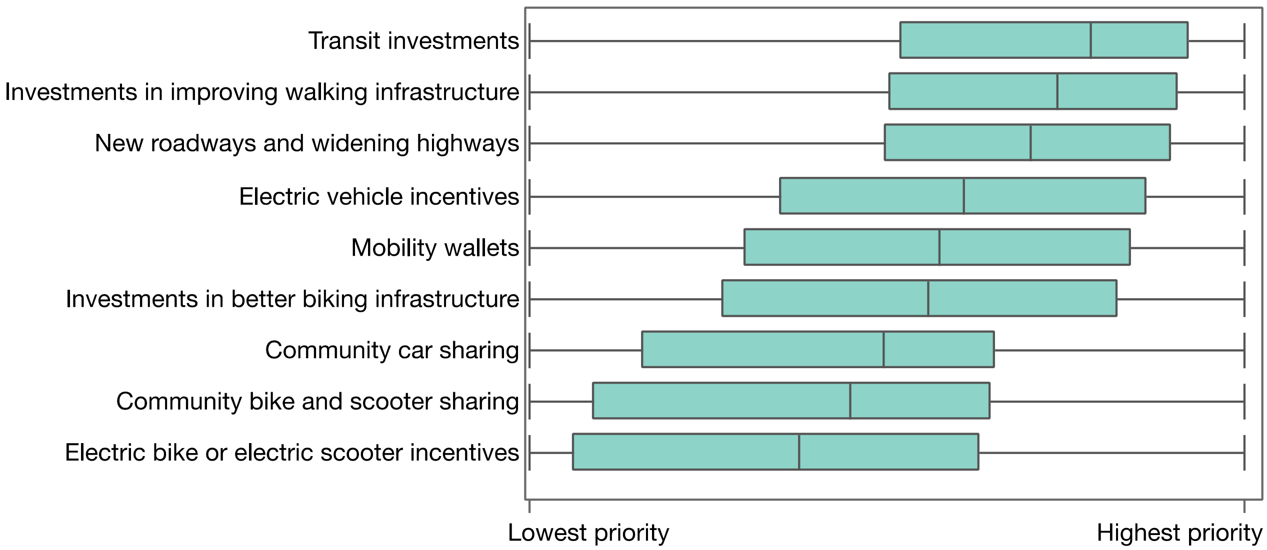

Figure 41: Quantile box plots for each transportation investment priority. The line in the middle of the box represents the median. The box is the interquartile range, 50% of values fall inside this box. We explored differences in transportation investment priorities across geographic areas of California. Table 20 shows mean rankings for different regions for each transportation priority.

- Investments into improving public transit (including bus, rail, etc.) recorded the highest mean rankings overall (mean = 5.11). The highest rankings were in regions with large urban centers, such as Los Angeles (mean = 5.46) and San Francisco Bay (mean = 5.49), and suburban areas, such as Inland Empire (mean = 5.33). Almost all regions recorded mean rankings closer to highest priority (7.00) than lowest priority (1.00). Notably, the Southern San Joaquin Valley recorded lowest mean ranking, but this was still high (mean = 4.66) relative to other transportation investment options.
- Investments in improving walking infrastructure (e.g. sidewalks, lighting, crossings) also recorded uniformly high rankings statewide with little variation across the state. Rankings in all regions were close to a mean of 5.00.

- Investments in better biking infrastructure (e.g. bike lanes, lighting, bike storage, etc.) were generally high across the state (mean = 4.23). The San Diego-Imperial region recorded the lowest rankings mean (mean = 3.74) for this investment priority.
- Money towards new roadways and highways was ranked closer to highest priority throughout all California regions (mean = 4.86). The Southern San Joaquin Valley region, which has few urban hubs (Fresno and Bakersfield) and consists mostly of rural communities, reported the highest mean ranking (mean = 5.25) for this priority. Most other regions reported similarly high rankings for this priority. The Central Coast, which consists of moderate-sized coastal cities (e.g. Monterey, Santa Barbara, Santa Cruz) and development along the US-101 corridor, reported the highest rankings for electric vehicle incentives (mean = 4.57). Apart from Superior California, all other regions recorded slightly lower rankings.
- Money toward the purchase of an electric bike or electric scooter received the lowest rankings (mean = 3.28) when compared to all other priorities, and rankings were low in all regions.
- Services that allow members to use shared bikes or electric scooters for a small fee were also a lower ranked priority (mean = 3.39), with little regional variations. The same was true for services that allow members to use shared cars for a small fee (mean = 3.53).
- Finally, mobility wallets (providing low-income persons with money each month towards spending on public transportation) received mixed rankings, with means from below average to slightly above average across the state. The lowest rankings mean for mobility wallets (mean = 3.93) was recorded in Superior California, while most other regions generally ranked this priority slightly higher.

Table 20: Mean ranking for transportation improvements by California regions.

Region	Q1_Road Highways	Q2_ZEV Incentive	Q3_Ebike Escooter	Q4_Shared Micromob	Q5_Car Share	Q6_Publc Transit	Q7_Bike Infra	Q8_Walk Infra	Q9_Mob Wallet
Central Coast	4.82	4.57	3.08	3.39	3.34	4.93	4.52	5.15	4.37
Inland Empire	4.78	4.53	3.36	3.36	3.50	5.33	4.37	5.05	4.32
Los Angeles	4.89	4.63	3.61	3.81	3.95	5.46	4.34	5.23	4.76
North Coast	4.57	4.35	3.35	3.44	3.54	5.14	4.50	5.04	4.09
Northern SJV	5.17	3.97	3.37	3.39	3.44	4.98	4.01	4.94	4.18
Orange	4.79	4.65	3.14	3.14	3.52	5.17	4.13	4.83	4.16
San Diego-Imperial	5.02	4.34	3.15	2.94	3.42	4.94	3.74	4.96	4.10
SF Bay Area	4.47	4.55	3.36	3.56	3.63	5.49	4.30	5.18	4.64
Southern SJV	5.25	4.21	3.27	3.42	3.45	4.66	4.13	4.72	4.20
Superior CA	4.82	4.00	3.14	3.46	3.54	4.96	4.29	4.90	3.93

Policy Implications

In Table 21 we explore policy implications of this project. Many of these align with the findings of studies conducted in previous years and studies conducted among the general population (CARB, 2018; Kurani, 2022b). This study gathered data specifically from priority populations in 2023 and 2024 and found many previously identified barriers apply to this population. For example, vehicle cost, a lack of charging infrastructure access, and low knowledge are frequently identified barriers to PEV adoption, and this study finds these are still barriers to PEV adoption among priority populations in 2024. Since the study surveys a random sample of households in this population, something not previously done, it provides more evidence of these barriers and can provide more nuance on these barriers and how to overcome them. Finally, we identified some barriers not widely reported prior to this study, including a lack of perceived benefits of PEV adoption (related to high charging costs) and concerns about PEV battery degradation.

There are already various efforts in California designed to support a more equitable PEV transition. There is a need to continue, expand, or improve these policies and add new ones. We outline in Table 21, where possible, whether there is a need to expand, continue, or revise existing policy and identify areas where there may be a need for new policy. The table outlines some general overarching recommendations, recommendations related to wealth building, infrastructure access, electricity cost, incentives, engagement, battery assurance, issues related to electric vehicle attributes, and issues related to vehicle supply. In Table 22, we outline policy implications of this project related to mobility and transportation in general. These recommendations cover topics related to transit, walkability, bikeability, community engagement, and vehicle ownership.

Incorporating metrics of success in programs is a key part of allowing these programs to reach target communities and achieve their intended goals. There may also be a need to institute structural reforms to encourage better interagency coordination and funding to maximize available resources for investments in PEVs, clean mobility, and associated community engagement. California has multiple state, regional, and municipal agencies pushing forward their own clean mobility programs and investments—all with varying designs, applications processes, and approaches to equity. Better interagency coordination may yield better outcomes for priority populations and may be less confusing to populations who are supposed to benefit from programs. Table 21 provides an overview of policy implications and how these relate to this project's research findings.

We acknowledge many of the efforts we suggest may not be able to continue indefinitely, policymakers should work with researchers and stakeholders in the PEV transition to identify metrics that can serve as an indication that policies (e.g., incentives) could begin to be phased out for certain communities.

Table 21: Plug-in electric vehicle policy implications and the rationale and/or finding from this study supporting each implication.

Category	Finding/rationale	Policy implication	Policy action
General	Survey analysis, listening sessions, and survey experiment: • Perceptions, knowledge, consideration, needs, infrastructure access, vehicle ownership etc. differ between households, and between communities. • Perceptions, knowledge, and consideration of PEVs is highly correlated with income, race, education, and the built environment.	• Different approaches and solutions may be needed for different households and communities.	• Continue engaging with communities and community organizations, and conduct research with communities to understand community and household specific needs
		• PEV programs should focus on communities and households that need the most support in PEV adoption, including those that are car dependent, have lower incomes, members who are BIPOC, lower levels of education, lower levels of home ownership, and higher levels of rented homes and multiunit homes.	• Target programs to communities with the most need. The current definition of priority populations treats all low income, disadvantaged, and tribal communities similarly. • Explore methods to better identify communities that need transportation investments, and how they should be prioritized.

Category	Finding/rationale	Policy implication	Policy action
Wealth building	Survey analysis: • Perceptions, knowledge, and consideration to purchase a PEV correlate with respondents household income and home ownership Survey experiment: • Likelihood to purchase a BEV is significantly related to income and home ownership.	• Programs that build community and household wealth may help increase PEV adoption potential	• Support programs that develop the economy of priority population communities, invest in workforce development and programs and strategies that build community wealth: for example, build community owned charging, collaborate with community based organizations, contracts with BIPOC owned businesses, support entrepreneurship, transfer grant-funded assets (e.g., electric vehicles) to community partners at no cost when a program or project is discontinued.
Infrastructure Access	Listening sessions: • A lack of home charging access was identified as barrier to PEV purchase by participants. Descriptive statistics:	• Public slow or fast charging *alone* should not be considered sufficient infrastructure access to support adoption, though it is important. Increase access at home and work. (See below for home charging access and	

<table>
<tr><th>Category</th><th>Finding/rationale</th><th>Policy implication</th><th>Policy action</th></tr>
<tr><td rowspan="3"></td><td rowspan="3">• Lack of home charging access is a reason for not choosing a PEV after considering one.
• A minority of survey respondents, especially apartment dwellers, have home charging access. Of the respondents who do, access is predominantly Level 1 charging.
• High cost of home charging installation was a reason respondents did not purchase a BEV or PHEV.
• Respondents spend different amounts of time at locations depending on their activities. Work and social/recreational locations may be amenable to slow charging due to long dwell times.

Survey experiment:

• Home and work charging access are significantly related to BEV purchase consideration.</td><td>necessary public charging for long trips and occasional needs.)</td><td></td></tr>
<tr><td>• Increase access and reduce barriers to home charging access (homeowners).</td><td>• Continue and expand programs that offer incentives for home charging (for example the home charger rebate offered in Clean Cars for All).
• Provide home charging incentives at point of payment for charging installation.
• Provide incentives to cover all costs associated with home charging installation (including panel upgrades, labor, etc.).</td></tr>
<tr><td>• Increase access and reduce barriers to home charging access (renters).</td><td>• Expand programs that allow the right to install charging by including more dwelling types, parking situations, and rent controlled housing.
• Provide home charging incentives at point of payment for charging infrastructure installation at rented dwellings.
• Explore establishing a program that allows renters to request</td></tr>
</table>

Category	Finding/rationale	Policy implication	Policy action
	• Fast charging alone is not significantly related to BEV purchase consideration.		charging installation if they own a PEV or are considering one. • Provide incentives to cover costs associated with home charging installation (including panel upgrades, labor, etc.).
		• Increase access and reduce barriers to home charging access in existing buildings.	• Explore introducing minimum requirements for installation of PEV charging at existing buildings. • Continue and expand programs that provide funding for the installation of infrastructure at multi-unit developments.
		• Increase access to charging at locations that respondents frequently travel to and spend substantial time at.	• Increase access to slow charging at workplaces, shopping/errand locations, schools, and locations of social/recreational activities.

Category	Finding/rationale	Policy implication	Policy action
Electricity cost	Listening sessions: • Participants didn't perceive substantial benefits to PEV adoption, partially due to high charging costs. Literature: • In some circumstances PEV fueling costs per mile are similar or more than the fueling costs per mile of conventional vehicles (Chakraborty et al., 2024a).	• Subsidize home or public charging costs.	• Continue and expand programs that provide incentives (e.g., charging cards) that offset charging costs.
Incentives	Listening sessions: • Participants were confused by how to apply for incentive programs. • Participants reported incentives as necessary to allow PEV purchase. Descriptive statistics: • Purchase price is a barrier to PEV adoption for those who considered buying a PEV. • A minority of survey participants reported they were unaware of incentives available to them.	• Incentives are needed to reduce upfront costs for most priority population households and should be simplified.	• Continue to provide incentives that offset upfront costs of PEVs. • Continually provide incentives (i.e., identify sustainable and continuous sources of funding). • Reduce the administrative burden of incentive applications and create one state-wide incentive program (rather than the current fragmented approach).
		• Broaden availability of incentives to include households that need incentives to purchase PEVs.	• Return to prior 400% FPL rather than 300% FPL criteria for CC4A.

Category	Finding/rationale	Policy implication	Policy action
	• Not all priority population households purchase vehicles at dealerships; the lowest income households buy their vehicles from private parties. Survey experiment: • The full CC4A incentive significantly related to BEV purchase consideration; however, the increase in the likelihood to consider buying a BEV is on average the same across income groups, and there is no difference in incentive effects by FPL. Literature (Chakraborty et al., 2024b): • The effect of CVAP on purchase decisions for program participants does not substantially differ at different FPL levels or income levels. Those who are no longer eligible (300-400% FPL) are highly dependent on incentives for PEV purchase.	• Provide incentives to buyers regardless of vehicle purchase location.	• Expand availability of incentives such as CC4A to locations other than just dealerships.
		• Increase awareness of incentives.	• Continue and expand programs that increase awareness of incentives among priority populations.

Category	Finding/rationale	Policy implication	Policy action
Engagement	Listening sessions: • Participants had low knowledge and awareness of PEVs, though desired to learn more. • Participants reported education efforts as things to focus on and appreciated listening sessions as an opportunity to learn about PEVs • Participants valued sessions in their own language. Descriptive statistics: • Awareness, knowledge and prior consideration of PEVs in the survey is low. • Different classes of consumers have different levels of knowledge and perceptions of PEVs and will require different information.	• More investments are needed into engaging consumers with PEVs, PEV policy, and PEV infrastructure.	• Continue and expand programs that engage with communities and provide education and enhance awareness of PEVs. • Information should come from trusted sources of information and in the spoken language of households.
		• Information and efforts should be tailored based on whether the goal is increasing engagement, encouraging PEV purchase, or addressing the concerns of those resistant to PEVs and PEV policy.	• Target resistors with information that increases support for PEV regulations. • Target those who are unengaged with information to engage them with PEVs. • Target supporters with information that specifically addresses perceived barriers to encourage PEV purchase (on infrastructure, cost, and driving range).

Category	Finding/rationale	Policy implication	Policy action
	Survey experiment: • Positive perceptions of electric range and charging availability are associated with a higher likelihood of purchase consideration.	• Provide up to date information to consumers on PEVs, their attributes, and their compatibility with travel behavior.	• Invest in efforts to increase outreach and engagement with PEVs. • Continue to support organizations, including community-based organizations that provide information to and engage with communities. • Continue programs like advanced clean cars 2 (ACC2) that may encourage automakers to also invest in engaging consumers with PEVs when they need to comply with the regulations higher ZEV sales targets.

Category	Finding/rationale	Policy implication	Policy action
Battery assurance	• Descriptive statistics: • 40% of used car buyers may receive no benefit from PEV warranties since they buy older vehicles with more miles. • • Survey experiment: • New car buyers are more likely than used car buyers to consider buying a BEV. • No relationship between (a) the presence of battery replacement rebates and warranties and (b)	• Expand warranty offerings in ACC2 and explore other ways to increase confidence in purchase of a used PEV.	• Lengthen outreach and engagement with PEVs. • Continue to support organizations, including community-based organizations, that provide information to and engage with communities. • Continue programs like ACC2 that may encourage automakers to also invest in engaging and increase mileage limits of PEV warranties (e.g., to 10 years and 150,000 miles).

Category	Finding/rationale	Policy implication	Policy action
	likelihood of considering a BEV purchase, for either new or used car buyers. • Respondents with the most positive perceptions of BEV battery quality are more likely to consider buying a BEV than those with the most negative perceptions. • Warranties and rebates may still be necessary to avoid financial burdens on adopters due to potential battery failures. • Warranties may not be effective at present because many buyers purchase older vehicles with more miles.	• More support may be needed to encourage used PEV adoption.	• Continue and expand programs to support adoption of used PEVs (including those outlined above), and support the new market to create used PEV supply.
Electric vehicle attributes	Listening sessions: • Participants didn't perceive substantial benefits to PEV	• Pursue policies to increase availability of affordable, efficient, and longer range new PEVs.	• Consider programs that incentivize efficiency, range, or purchase price in the PEVs offered for sale in California.

Category	Finding/rationale	Policy implication	Policy action
	adoption, partially due to high charging costs. Listening sessions and descriptive statistics: • Range is a perceived barrier to PEV purchase. • High purchase price is a barrier to PEV purchase.	• Provide information on the compatibility of PEVs attributes with travel behavior.	• Continue to support organizations that provide information to and engage with communities. • Allocate more funding to engagement efforts.

Table 22: Transportation policy implications and the rationale and/or finding from this study supporting each implication.

Category	Finding/Rationale	Policy implication	Policy Action
Community Engagement	• Preferences for transportation improvements and modes use differ between and within communities.	• Different approaches and solutions may be needed for different households and communities.	• Continue engaging with communities and conducting research on and with communities to understand specific needs, this includes statewide studies and community needs assessments. • Prioritize funding to programs that center on community engagement and understanding local mobility needs. • Build off existing, community-trusted programs that already have community buy-in and support, instead of creating a brand new program that requires additional outreach and implementation.
Mobility	Listening sessions • Participants reported difficulties accessing locations they want or need to travel to, due to lack of vehicles, poor transit service, and inadequate walking infrastructure.	• Invest in improvements to transportation, including transit, walkability, access to vehicles, and measures to reduce vehicle dependence.	• Prioritize improvements on an equitable needs basis, such as where the quality of the infrastructure is poorest, in priority populations.

Category	Finding/Rationale	Policy implication	Policy Action
	Survey Analysis: • Almost 40% of survey respondents reported there were locations they have difficulty accessing.	• Support planning and development that promotes density and proximity to transportation hubs, while also mitigating displacement of the community.	
Vehicle ownership	• Households have a high level of vehicle ownership, especially in areas away from transit and in rural areas. • Household travel is highly dependent on privately owned vehicles.	• Supporting the transition to PEVs among priority population communities and households is necessary.	• Support households in transitioning from conventional vehicles to plug-in electric vehicles (see PEV policies table [Table 21]).
		• Investing in transit, walkability, bike- ability, and other clean mobility options may reduce car dependence.	• Strengthen SB 375 requirements for coordinated land use and transportation planning. • Increase support for multimodal mobility hubs and innovative transportation access programs, such as mobility wallets.

Category	Finding/Rationale	Policy implication	Policy Action
Transit	Listening sessions: • Participants want greater investments in transit services, including expanding transit coverage, increasing frequency of service, longer service hours, expanding paratransit; investment in infrastructure, microtransit and transit-on-demand, electronic payment, lighting at bus stops, and increased safety at stops and on transit. Survey analysis: • The reported need for greater access to transit and more frequent transit service correlated with lower household vehicle ownership. • The reported need for investments in transit was a top ranked priority for transportation improvements among households in priority populations.	• Invest in transit to provide opportunities to travel without dependence on private vehicles.	• Invest in transit including expanding transit coverage, increasing frequency of service, longer service hours, expand paratransit, investment in infrastructure, micro transit and transit on demand, electronic payment, lighting at bus stops, and increase safety at stops and on transit. • Prioritize improvements on an equitable needs basis, such as where the quality of infrastructure is poorest, where there are a high concentration of priority populations who rely on transit.

Category	Finding/Rationale	Policy implication	Policy Action
Walkability	Listening sessions: • Participants wanted more investments to make communities better places to walk, including expanding sidewalks and adding crosswalks and lighting. Survey: • Investments in walkability was a top-ranked priority for transportation improvements for households in priority populations.	• Invest in walkability to provide access to transit and amenities within communities.	• Expand and build sidewalks, crosswalks, and lighting. • Invest in programs that provide alternatives to personal vehicle ownership, such as carsharing, bikesharing, and micromobility sharing. • Prioritize improvements on an equitable needs basis, such as where the quality of the infrastructure is poorest, where there are frequent bicyclist collisions.
Bikeability	Listening sessions: • Participants wanted investments in new bike lanes and existing lanes, including increased lighting, bike lanes, and safety of existing lanes.		

Conclusions

This project aimed to understand the mobility needs of underserved communities and understand whether and how ZEVs can cost-effectively meet those needs. We investigated this using listening sessions and a survey to answer five research questions. Our analysis focused mostly on BEVs and PHEVs, and sometimes only on BEVs. Here we discuss how the research findings from this project relate to the project's five research questions shown below:

- RQ1. What are the mobility needs of underserved communities, are these being met, and how are they met? (e.g. where do they travel, by what travel mode, etc.)
- RQ2. What are households' awareness, knowledge, and perceptions of ZEVs?
- RQ3. How do attributes of ZEVs (price, range, charging time, etc.) impact the viability of their adoption?
- RQ4. How do attributes of the built environment impact ZEV viability (including house type, home charging access, public charging access, walkability, etc.)?
- RQ5. What can be done to increase ZEV adoption potential in these communities? (including incentives, infrastructure, outreach and education)

Answers to the research questions (RQs) follow.

What are the mobility needs of underserved populations and how are they met? (RQ1)

The transportation needs of priority populations vary, as with any population. Most trips are made by private car, and many respondents also walk regularly. Transit use was not frequently reported, potentially due to a lack of sufficient access. Relatedly, transit improvements were reported as a high priority. A substantial portion of respondents (37%) report that their transportation needs are not satisfactorily met. Reported trip distances may not preclude a BEV or PHEV from meeting travel needs, as almost all trips are within the driving range of new or used BEVs. However, technical compatibility of BEVs (i.e. their ability to meet travel need) is not the same as perceived compatibility (i.e. whether people think BEVs are suitable to meet their needs).

What are households' awareness, knowledge, and perceptions of ZEVs? (RQ2)

Most survey respondents have not thought about purchasing a BEV or PHEV, most report not knowing enough about BEVs to decide about getting one, and most are not aware of incentives. Perceptions of BEV attributes are mixed, with the most negative are on the availability of charging infrastructure, home charging access, and driving range. More survey respondents support 100% ZEV sales than are opposed to it. The listening sessions also indicated that infrastructure, range, vehicle cost, and vehicle availability are substantial barriers to PEV purchase. Many of these trends may be due to the early stage of the PEV market, though will need to change as California progresses towards 100% ZEV sales and eventually to an all-ZEV fleet.

Using latent class analysis, we identified classes of respondents based on knowledge, perceptions, consideration, and support for ZEV policy. We identified five clusters and named them Active Supporters, Passive Supporters, Neutral, Active Resisters, and Passive Resisters. Across these classes, a lack of infrastructure is perceived negatively. The classes highlight variation in perceptions, consideration, support, and knowledge for PEVs in this population. Addressing the needs of each class may require different approaches. Active Supporters may be the closest to purchasing a BEV. Addressing the concerns of this group may facilitate BEV adoption in the short term. Respondents in the neutral class may be open for engagement; this class appears to have not formed opinions of BEVs. Active Resisters appear unlikely to ever purchase a BEV. Understanding why these respondents perceive BEVs so negatively and why they strongly oppose 100% ZEV sales may be important in preventing this type of consumer from disrupting pro-ZEV policy.

How do attributes of ZEVs impact their viability for adoption? (RQ3)

Perceptions of ZEV attributes that may impact their viability include vehicle cost, driving range, lack of vehicle availability, charging cost, a lack of benefits of PEV adoption, the cost to install a home charger, and less frequently cited issues such as battery degradation and vehicle reliability. Many of these barriers are from respondents with limited knowledge of PEVs. Some perceived attributes—such as limited range and a lack of benefits—may be diminished as barriers when and if people become more knowledgeable about PEVs. However, some PEV attributes, such as charging access and vehicle cost, will themselves need to be changed to become less prominent barriers.

How do attributes of the built environment impact ZEV viability? (RQ4)

Home type and ownership are significantly related to the viability PEV adoption. While the communities covered in the study differed in their actual access to public charging infrastructure, the respondents from these communities did not significantly differ in perceptions of this access. This discrepancy may be due to a lack of awareness of infrastructure and because public charging is not significantly related to likelihood to consider a BEV. Respondents in rural vs. urban areas did differ in their current perceptions, knowledge, and consideration of purchasing a BEV, but not in responses to the survey experiment, which is more forward looking. This suggests that while to date fewer rural households have considered a BEV, holding all else constant, rural households are similarly likely to consider a BEV at some point. The most substantial built environment barrier to PEV adoption may be a lack of home charging—either due to living in an apartment, condo, or a rented home—or being unable to install a home charger. Finally, when household attributes are controlled for we find few differences in perceptions, knowledge, or consideration to purchase a ZEV by census tract type. Overall, we find individual household characteristics are more significantly related to various issues related to ZEVs, rather than the census tract a household resides in. This means programs with an equity focus may want to target interventions based on household attributes rather than census tracts.

What can be done to increase ZEV adoption potential in these communities? (RQ5)

Increasing ZEV adoption in underserved communities may require substantial incentives (e.g., the Clean Cars 4 All incentive); charging access at home and/or work, (public charging alone will be insufficient); and efforts to educate and engage with households and communities. Overall, there is a need for continued policy support, and the revision of existing programs to better align with the needs of underserved populations.

Summary

Overall, we do not find reasons for why PEVs could not meet the mobility needs of underserved communities. Whether they do so cost effectively and conveniently will depend on whether sufficient support is given to these communities to help them transition to PEVs. Current policy support may partially meet these needs; however, some policies need to be expanded, revised, and continued to provide support.

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