Environmental Justice Impacts of Zero Emission Vehicles

How Governments Can Enhance Equity Outcomes of their Zero Emission Vehicle Policies

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Table of Contents

- **Executive Summary** 1
- **Background and Motivation** 8
- **ZEV Ownership and Sociodemographic** 11
  - Data Sources and Methodology 11
  - California 13
  - Michigan 18
  - England 22
- **Environmental Justice Impacts of ZEVs** 27
  - State Level Benefits 28
  - County Level Monetized Health Benefits 29
- **Role of Policies in Enhancing Environmental Justice** 34
  - Barriers 34
  - Role of Policies and Programs 38
- **Recommendations** 43
  - Leverage the Expanding Pre-Owned ZEV Market 43
  - Public Charging and Fueling Infrastructure 44
  - Targeted Incentives toward Lower Income Regions 44
  - Community-Driven Decision-Making 45
  - Support Regions' Mobility Alternatives 45
  - The Role of Electrifying Medium- and Heavy-Duty Trucks 46
  - Resilience and Ability to Manage Change 49
  - Job Transition 49
- **Appendix A: More on National Health Benefits from ZEVs** 50
- **Appendix B: Emission and Health Benefits of Increased ZEV Adoption in the U.K.** 56
- **Appendix C: Engagement with EJ Experts** 58
- **References** 61

Executive Summary

In 2021, global sales of zero-emission vehicles[1] (ZEV) reached almost 6.6 million, representing almost 9 percent of the global auto market and more than double the market share from a year earlier. Despite such growth, only a small number of countries, mainly the United States (U.S.), China, and in Northern Europe, claim most of the ZEV market share, while ZEV sales in other nations have less momentum. Even within countries with high ZEV sales, there are significant disparities between lower income (e.g., bottom 20 percentile) and higher income (e.g., top 20 percentile) regions[2] with respect to ZEV ownership and operation[3]. As indicated in the 2019 report by the International Council on Clean Transportation (ICCT) on behalf of the International ZEV Alliance (IZEVA)[a], there are differences between commercializing ZEVs in a mainstream market versus reaching historically marginalized groups[4] where the barriers to ZEV adoption are significantly greater. ZEVs have great potential to improve public health, air quality, energy independence, and sustainability; however, challenges do exist with respect to affordability of ZEVs and equitable access to charging infrastructure. In addition to technological and infrastructure challenges, there is the question of how to best align policy interventions with equity (e.g., ensuring access for lower income groups), environmental justice[5] (EJ), and global public good (e.g., emissions reductions).

The goals of this research are to highlight the existing disparity in ZEV ownership, quantify the EJ benefits of ZEVs, and provide policy and program

[1] In this report, ZEVs include battery electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV).
[2] For the purpose of this report, we used different spatial resolutions to assess the ZEV ownership. For the U.S., we relied on zip code level information, whereas for the U.K., we relied on geographic index level information from the Office of National Statistics (ONS).
[3] Ownership refers to vehicles that are owned by residents of a specific region, whereas operation refers to vehicles that are operating within that region but are not necessarily owned by residents of that region.
[4] According to the European Institute for Gender Equality, marginalized groups are defined as different groups of people within a given culture, context and history at risk of being subjected to multiple discrimination due to the interplay of different personal characteristics or grounds, such as sex, gender, age, ethnicity, religion or belief, health status, disability, sexual orientation, gender identity, education or income, or living in various geographic localities.
[5] According to the U.S. Environmental Protection Agency (EPA), "Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." https://www.epa.gov/environmentaljustice

recommendations that various government agencies can implement to enhance the EJ outcomes of their ZEV policies. To do so, the project team first selected three ZEV markets - California, Michigan, and England - to conduct quantitative analyses and qualitatively explain certain observations. We chose Michigan and California as representative North American markets due to their differences in ZEV uptakes and policies. California is considered a national leader in ZEV uptake due to progressive policies and has dedicated funding to increasing access to ZEVs for disadvantaged communities[6]. Michigan is an interesting comparison to California because it has not adopted California's Advanced Clean Car Standards, has high influence from automakers, and has a different EJ landscape than California. While Michigan's disadvantaged communities are spread across the state, the majority of those communities are centered around metropolitan areas such as Detroit, Grand Rapids, Flint, and Lansing. England within the United Kingdom (U.K.) is selected as a representative European market due to median ZEV sales and a broad spectrum of sociodemographic conditions. While the focus of this report is on the California, Michigan, and England markets, the outcomes of this research could be useful to other jurisdictions as they seek to increase accessibility and equity of ZEVs.

To quantify the ZEV ownership distribution, our team leveraged publicly available ZEV registration data within these three markets and compared the ZEV ownership (in units of number of ZEVs per 1000 people) to various socio-demographic and EJ indicators. The analysis clearly showed that in all three markets, ZEV ownership is mainly driven by the economic position of regions. Regions with average higher income and education consistently show higher rates of ZEV ownership as compared to on average lower income and education. Quantitatively, the disparity in ZEV ownership rates can be explained by immediate obstacles, such as high upfront costs of new ZEVs, lack of pre-owned ZEVs, and lack of access to charging or fueling infrastructure. Qualitatively, there are underlying reasons for the difference in ZEV adoption rates between lower and higher income regions, and not all are fully understood. In example, driving to an out-of-the-way public charging station, may be less attractive to those who are time-burdened by long work hours or personal circumstances. In addition to income and education, the project team also studied the relationship of ZEV ownership to race and ethnicity. Specifically, we looked at the relationship of ZEV ownership to percent people of color (POC). We did not find a statistically significant and consistent relationship between ZEV ownership and race or ethnicity in all three markets (e.g., communities with higher percent POC population were not necessarily the communities with low ZEV adoption). While the ZEV ownership varied in white dominant or POC dominant regions, there did not exist any specific relationship. In some sense, this finding may qualitatively suggest that awareness of ZEV options among diverse racial and ethnic groups may be

[6] For the purpose of this report, disadvantaged communities are defined as areas and regions which most suffer from a combination of social, economic, health, and environmental burdens. These burdens include poverty, social exclusion, discrimination and violence, air and water pollution, presence of hazardous wastes as well as high incidence of asthma and heart disease.

trending upwards. Of course, there are some areas of the market not seeing adequate uptake in ZEV awareness or options, and it is highly recommended that more be done to further outreach in marginalized communities, including but not limited to: African American, Asian American, tribal, rural, and agricultural and physically disabled communities.

In addition to studying the ZEV ownership distribution and its relationship with socio-demographic metrics, we also evaluated the health benefits of increased ZEV adoption, especially in lower income regions and disadvantaged communities. We leveraged previous work conducted by ICF on behalf of the American Lung Association[b] (ALA) where the project team quantified the health benefits of widespread adoption of ZEVs across the United States. This comprehensive analysis quantifies the health benefits, in terms of both number of health incidents and monetized health benefits, based on the electrification of light-duty and heavy-duty vehicles at the U.S. county level. Using the outcomes of this study, we quantified the public health impacts of increased ZEV adoption in both California and Michigan and evaluated monetized health benefits per capita at county level in relation to county level sociodemographic and air quality. While our analysis shows that there is no direct correlation between the monetized health benefits and county level incomes (most likely due to coarse spatial resolution), it did reveal that often counties with higher levels of air pollution (especially fine particulate matters such as PM2.5) will have higher monetized health benefits per capita as compared to those with better air quality (i.e., lower concentrations of PM2.5). Utilizing census level tract data from the U.S. Environmental Protection Agency (EPA) EJScreen, we also demonstrated that lower income regions are often the ones that have higher levels of debilitating air pollution (e.g., PM2.5) concentrations, and adoption of policies that accelerate ZEV deployments in these regions often leads to higher per capita monetary health benefits than other regions[7]. In addition to California and Michigan, the project team also explored the monetized public health benefits of ZEV adoption for the broader United Kingdom, as illustrated in Appendix B – Emission and Health Benefits of Increased ZEV Adoption in the U.K.

Following our quantitative analyses, we conducted a comprehensive EJ stakeholder engagement in all three markets to recognize the major barriers in adoption of ZEVs within lower income regions and disadvantaged communities. The EJ stakeholder engagement identified policy recommendations that local jurisdictions and governments could adopt to increase ZEV adoption and operation in disadvantaged communities. We conducted semi-structured interviews and online workshops with 15 EJ experts and engage with 24 organizations dedicated to EJ across these three markets (see Appendix C for complete list of EJ experts and stakeholders). As part

[7] Here in this report, we focused our assessment on health benefits from reduced exposure to ambient PM2.5 through reductions of directly emitted PM2.5, and PM2.5 precursors (i.e., NOx). This is mainly because the health outcomes of exposure to ambient PM2.5 are much more significant than ozone. According to a study conducted by MIT researchers (Caiazzo et al., 2013), the mortality effects of PM2.5 are likely to be much larger than those of ozone, 10 times as large for all road transportation in 2005.

of this engagement, the project team identified three major barriers:

- **Affordability**: Despite a significant increase in ZEV adoption globally, ZEVs continue to remain unaffordable for lower income households. According to our assessment, the average new ZEV sold in California (i.e., a mature ZEV market) in Q1 2022 was almost $13,000 more expensive than the average new internal combustion engine (ICE) vehicle sold in 2021. EJ stakeholders also shared that the existing incentive portfolio has not made ZEVs sufficiently affordable. In some past instances, financial incentives have benefitted affluent groups more than disadvantaged groups.
- **Access to Charging Infrastructure**: Lower income regions, especially those who rent or live in multi-family housing, often do not have access to home charging. This means that lower income regions have no other options except to rely on either workplace or public charging infrastructure if they decide to transition to ZEVs. A recent study conducted by Hsu and Fingerman (2021)[c] on the California market demonstrated that public charger access is lower in block groups with below-median household incomes and in those with large Black and Hispanic populations. At the same time, while lack of access to charging infrastructure is a significant barrier to ZEV adoption in lower income regions, EJ experts shared that there are also concerns with charging infrastructure being a factor that increases potential crime, gentrification, and displacement in disadvantaged communities. A curated mix of investments is essential to meeting unique needs across people's working and living environments.
- **Availability of Mobility Options**: Access to mobility options, especially in lower income regions, is another challenge when exploring clean transportation within these regions. EJ stakeholders from North America and Europe shared that not every community member is interested in owning a car if there are alternative mobility options that are preferable. For example, some folks prefer ride hailing or car sharing services for the flexibility of transportation by passenger vehicle. For others, public transportation is preferable due to lower fare costs and network connectivity in metropolitan areas. Therefore, policies that solely focus on ZEV ownership, as opposed to alternative mobility options, may not be most effective in encouraging ZEV adoption in lower income regions and disadvantaged communities.

There are currently various ZEV policies, in the form of regulations and incentive programs, implemented in North America and Europe. Many of these equity and EJ ZEV programs offer grant or incentive structures to provide immediate cash assistance towards the purchase of ZEVs. Despite that, significant disparities in ZEV ownership still persist. As part of this research, we leveraged inputs from the EJ stakeholders and developed a list of policy recommendations that various government agencies and policymakers can consider. Some of these key recommendations are:

- **Leverage the Expanding Pre-Owned ZEV Market**: The pre-owned vehicle market can provide great opportunities for access to more affordable ZEVs.

Governments should leverage such opportunities and create targeted programs to subsidize pre-owned ZEVs for purchase by lower income households. For example, the U.S. government recently enacted the Inflation Reduction Act (IRA), which results in new and revised incentives for clean vehicles, including pre-owned ones. Currently, the IRA offers up to $4,000 in a tax credit or 30% of the vehicle sale price (whichever is lower) for pre-owned ZEVs for purchasers with income less than $75,000 (or $150,000 for a joint return). The efficacy of such a program will be considerably tested, especially as inflationary impacts of the COVID-19 pandemic continue to unfold.

- **Public Charging and Fueling Infrastructure**: Access to ZEV infrastructure (e.g., charging stations) is a key barrier to ZEV adoption in lower income regions, especially for households without home chargers. While many government agencies are investing in deploying ZEV infrastructure within lower income regions, deployment of infrastructure within regions often does not translate to increased accessibility. Governments should leverage data analytics and work collaboratively with community members to determine strategic placement of charging and fueling stations to increase accessibility to the ZEV infrastructure.
- **Community-driven decision-making**: One of the common themes that we heard through our EJ stakeholder outreach was the lack of engagement on the part of decision and policy makers. Governments and other representative agencies need to better engage with community members early on and communities need to be an on-going part of the decision-making process for policies and programs to realize the most equitable outcomes. Residents within low income and disadvantaged communities offer invaluable perspectives on what needs can be fulfilled by local governments and authorities, such as charging station placement within neighborhoods. Engagement at this level may also lead to local job creation, workforce development, and mitigation of certain burdens, such as reduced parking and rent increases. Governments should consider targeted outreach to regions (e.g., presenting in town hall meetings, conducting community surveys) throughout the policy and program development.

Marginalized communities are not the typical early EV adopters and will be at risk in the long term when government incentives are being phased out.

The phasing-out of incentives needs to be gradual and evolve to be more focused on low-income communities in the long term.

- **Targeted Incentives toward Lower Income Regions**: As clearly communicated by the EJ experts, the high upfront cost of ZEVs is one of the major barriers to adoption of these clean technologies in lower income regions or communities. This emphasizes the significant role that incentive programs will play over the next 10 – 15 years in transitioning the on-road vehicle market away from fossil fuels to zero-emission technologies. Of course, incentive funding is finite, so there would need to be more self-sustaining funding sources and subsidies developed in parallel. While general public access to incentives has helped with the initial commercialization of ZEVs, some programs have unintentionally benefited affluent groups more than disadvantaged communities. Now might be time for federal, state, and local governments to have programs specifically for lower income communities, whose current access to ZEVs is almost impossible due to significantly high upfront costs. Of course, such policy changes should come with more streamlined processes to ensure that funds can be expended as effectively and expeditiously as possible. Complex processes to verify eligibility could inhibit the successful implementation of incentive programs and thus reduce their effectiveness.

- **Support Regions' Mobility Alternatives**: As discussed earlier, many lower income regions and disadvantaged communities have limited mobility options, and even fewer zero-emission options. Through our EJ stakeholder engagement, we learned that not every community member is interested in owning a car if there are alternative mobility options that are preferable. Within the European market, many cities have adopted comprehensive approaches to establishing transit networks or more efficient passenger traffic. The North American market, on the other hand, often shifts focus to just passenger vehicle mobility, significantly inhibiting development of alternative transportation. We believe there is great opportunity for governments to invest in clean alternative modes of transportation, which not only will enhance mobility, but lead to reduced traffic congestion and air quality improvements.

> **Within the nexus of disadvantaged communities and the transportation sector, medium- and heavy-duty diesel trucks are some of the worst offenders.**
>
> Much of the overall approach taken to introduce more zero-emission light-duty vehicles onto the roads can be applied for medium- and heavy-duty vehicles, where grants and incentives can address immediate needs of drivers and zero-emission oriented policies can direct zero-emission truck supply and expectations.

- **The Role of Electrifying Medium- and Heavy-Duty Trucks**: Medium- and heavy-duty (MD, HD) vehicles are one of the major emissions sources contributing to public health issues in lower income regions and disadvantaged communities. Therefore, transitioning these vehicles to zero-emissions could go a long way in reducing emissions and improving public health in these regions. Much of the overall approach taken to introduce more zero-emission passenger vehicles onto the roads can be applied for medium- and heavy-duty vehicles, where grants and incentives can address immediate needs of drivers and zero-emission oriented policies can direct zero-emission truck supply and expectations. For example, U.S. EPA's Clean School Bus Program[d] prioritizes the deployment of zero-emission school buses in high need and low-income areas. In addition to policies that incentivize/require adoption of zero-emission MD/HD vehicles, zero-emission infrastructure could also play an important role in increasing the operation of zero-emission trucks within disadvantaged communities. When siting charging infrastructure for MD/HD vehicles, we need to ensure that the deployment of these infrastructure will have direct benefits in lower income regions and disadvantaged communities and will lead to increased operation of these ZEVs in lower income and disadvantaged communities.

Aside from these key recommendations, we also provided other suggestions on workforce development related to ZEV adoption, as well as ways for government to make policy changes related to incentive programs. Discussion on other key recommendations is available in the Recommendations section of this research report.

Acknowledgement

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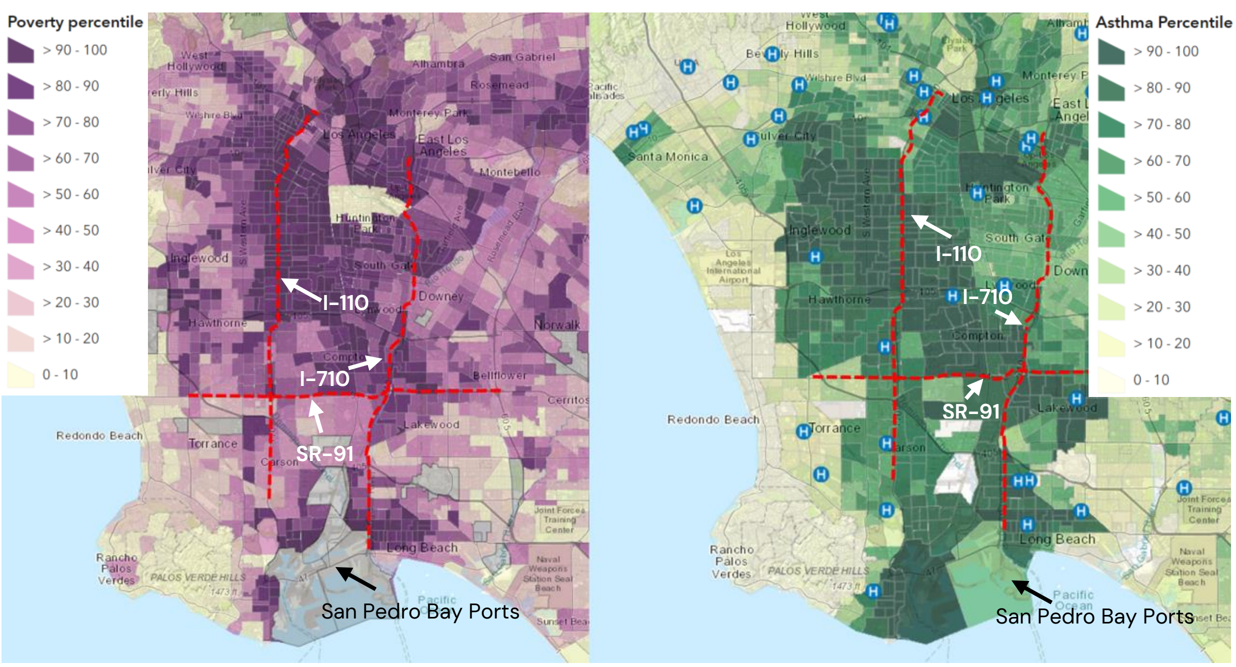
We would also like to provide a special acknowledgement to all the environmental justice stakeholders and experts whom their contribution formed the foundation of this research report and the recommendations embedded in it.

Background and Motivation

Despite significant improvement in air quality and public health over the past decades, there are still many regions around the world, especially low-income and disadvantaged communities, who are suffering from high levels of air pollution. Among all sources of air pollution, emissions from the transportation sector are a leading contributor to ambient air pollution and adverse public health. Tailpipe emissions from cars and trucks contribute to nitrogen oxides (NOx) emissions, a precursor to ozone, as well as fine particulate matters (e.g., PM2.5). Exposure to ozone can induce more frequent hospital or emergency room visits and in extremely prolonged cases lead to premature mortalities. Other air pollutants, such as PM2.5, are toxic to human health and can lead to heart and lung disease or cancer when exposed for long periods of time. The issue is much more aggravated in low-income and disadvantaged communities; many studies worldwide have shown that these regions often bear the greatest burdens of air pollution from the transportation sector. Part of this is because of their close proximity to major roadways and freight facilities. For example, Figure 1 compares asthma cases and poverty levels in South Coast region of California and illustrates how regions with higher levels of poverty, especially those surrounding ports and major roadways (I-110 and 1-710 corridors in Figure 1), are often the same regions suffering from high levels of asthma.

Figure 1. Poverty (top) and asthma cases (bottom) in Los Angeles County[8]



[8] Based on CalEnviroScreen 4.0. https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

Not only ZEVs brings significant air quality and public health benefits by zeroing out the tailpipe emissions, they also offer significant operational savings as compared to their counterpart ICE vehicles.

As of June 2022, driving a battery electric vehicle in the U.S. was almost 4 times cheaper than driving an average gasoline vehicle

The adverse air quality impacts from the transportation sector in disadvantaged communities often create a cycle of being unable to improve quality of life due to the public health impacts associated with the emissions. The transportation sector is also a major source of greenhouse gas (GHG) emissions, which demonstrably exacerbate climate change. The climate benefits that would result from curbing GHG emissions would be especially significant for disadvantaged communities, folks who on average are more vulnerable to extreme climate or natural disasters. All these reasons (i.e., pollution burden, public health, and climate impacts) led EJ advocacy groups to consider EJ policies that would lower transportation emissions via ZEVs. ZEVs offer a platform for large geographic regions to significantly curb their transportation tailpipe emissions and improve public health[9]. Additionally, with the recent energy crisis surrounding many countries across the world, ZEVs offer significant operational savings as compared to their counterpart ICE vehicles. This is especially important when considering that today in the U.S., driving a battery electric vehicle is significantly cheaper than driving the average gasoline vehicle (19 cents per mile for a gasoline vehicle versus five cents per mile for driving an EV). According to our assessment, with U.S. national gasoline price reaching $5 per gallon in June 2022—and U.S. national average residential electricity price fluctuating around 15 cents per kilowatt-hour—driving a battery electric vehicle is approximately four times less expensive than driving an average gasoline vehicle. Despite all these benefits, ZEVs have been notoriously expensive to adopt on a widespread scale, especially in lower income regions. These regions will often not have the capital, familiarity, or accessibility to ZEVs or the still-in-development charging and fueling infrastructure. Because the barriers of entry are still a challenge for the most polluted and racially or ethnically diverse sectors of the ZEV market, it is important to guide discussions on EJ policies intending to increase ZEV operation within these regions through objective analysis and collaborative engagements with EJ experts, regions, and governments. This report intends to shed light on some of the key barriers inhibiting low-income and disadvantaged communities across the globe to benefit from increased adoption of ZEVs and provide recommendations for policy makers on how to integrate EJ into the ZEV policies to chart a path for equitable transition to zero-emission transportation.

In collaboration with the IZEVA, the project team selected three markets to conduct a comprehensive stakeholder engagement to solicit inputs on the barriers, as well as the potential

[9] For example, according to American Lung Association (ALA) Zeroing in on Healthy Air report, a national shift to 100 percent sales of zero-emission passenger vehicles (by 2035) and medium- and heavy-duty trucks (by 2040) in the U.S., coupled with renewable electricity would generate over $1.2 trillion in public health benefits between 2020 and 2050.

solutions to enhance EJ outcome of ZEV policies. Additionally, through this research, the project team leveraged publicly available data sources and analyses to quantify and highlight the disparity in ZEV adoption across these three markets, and to demonstrate the potential benefit of increased ZEV adoption in low-income and disadvantaged communities.

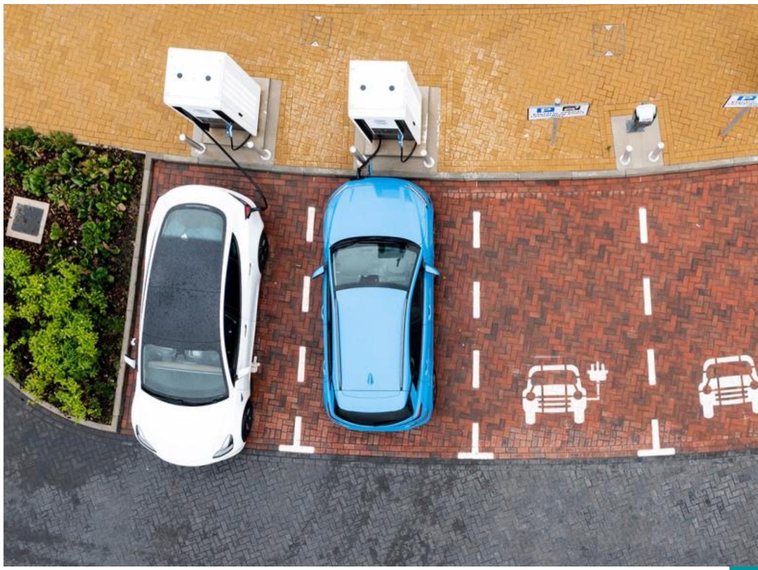
With respect to the three selected markets, we chose Michigan and California in North America as two distinct markets due to their differences in ZEV uptakes and policies. The maturity of California's ZEV market is globally recognized due to the state's progressive policies, including programs that have allocated funding to increasing access to ZEVs for disadvantaged communities. Important to acknowledge is the fact that despite California's comparatively mature ZEV market, the state does continue to struggle with air quality issues[10] and stark inequality issues. Michigan is an interesting comparison to California because it has not adopted California's Clean Car Standards, has high influence from automakers, and has a long history of environmental injustice. The third market is England, which represents one of the largest European passenger vehicle sales and a comparatively broad spectrum of sociodemographic conditions relative to the rest of Europe.

Through our stakeholder engagement, it became evident that there is no widely accepted definition of EJ nor a way to measure it. According to the U.S. EPA[e], "EJ is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies." This definition excludes other important parameters such as gender, age (considering both old and young age groups) and/or people with disabilities. For the latter group, who generally rely on personal vehicles more, the transition to ZEVs is more challenging. There are less ZEV options available in the market and charging is more challenging for them. Furthermore, this definition considers justice with respect to the background of individuals, but not necessarily the circumstances, choices and/or lifestyles. In this research report, we further elaborate on these points.

[10] Purportedly, California's increasing number and intensity of wildfires could be reversing decades of air quality improvements: https://ww2.arb.ca.gov/wildfire-emissions

ZEV Ownership and Sociodemographic

Data Sources and Methodology



First, the project team evaluated how ZEV ownership varies across disadvantaged communities. We looked at the distribution of ZEV ownership to develop an understanding of ZEV equity issues in disadvantaged communities. Despite significant progress, the European and North American markets have much work to do to deploy the infrastructure needed to keep pace with growing ZEV deployments. These technology and infrastructure challenges are especially prominent in lower income and disadvantaged communities, where the growth of electrified transportation has been demonstrably stunted. The project team seek to answer the question of what policy interventions would be best to enable air quality and public welfare benefits posed by ZEV adoption. To this end, publicly available data for select markets within North America and Europe are leveraged for this research.

EV Registration Data

For the U.S., the California Energy Commission (CEC) and Atlas EV Hub provide ZEV registration data at zip code level. The CEC's Light-Duty Vehicle Population tool reflects the total light-duty vehicle population "on the road" per zip code.[f] Atlas EV Hub makes select state Department of Motor Vehicle (DMV) ZEV registrations publicly accessible and provides Michigan's 2020 ZEV Market Snapshot for the number of ZEVs per zip code[g].

For England, we leveraged vehicle statistics from the U.K. Department of Transportation[h], which provides detailed vehicle registration data at Office of National Statistics (ONS) geographical index level[11]. This data set includes vehicles counts per ONS geocode by vehicle type for both Ultra Low Emissions Vehicles (including ZEVs) as well as conventional ICE (e.g., petrol/gasoline and diesel) vehicles.

[11] For England, the project team is using ONS geographic levels of E06 (Unitary Authority), E07 (Non-Metropolitan District), E08 (Metropolitan Borough), and E09 (London Borough).

Sociodemographic and EJ Data

For the U.S., the U.S. Census Bureau's 2020 American Community Survey (ACS) offers year-to-year population statistics per zip code, such as median income, race and ethnicity, and educational attainment. In this analysis, the project team defined POC as individuals of any racial or ethnic group except *Not Hispanic, White alone* individuals. Additionally, the project team leveraged data from CalEnviroScreen and EPA EJScreen to quantify air pollution burden and public health. The CalEnviroScreen is a mapping tool that identifies California's disadvantaged communities using indicative EJ scores proportional to pollution burden and population health characteristics[i]. The EPA EJScreen provides a nationally consistent dataset and approach for combining environmental and demographic indicators[j].

ZEV Ownership, in unit of vehicles registered per capita, is compared against:

- Median income levels
- Population below poverty levels
- Percent People of Color (POC) populations
- Educational attainment

For England, sociodemographic data are obtained from the 2021 U.K. Census[k]. Specifically, we extracted data from the Annual Survey of Hours and Earnings (ASHE), Population Estimates by Characteristics Research Report, 2019 English Indices of Deprivation, and 2011 Qualifications and Students. For England, we defined people of color as the population that are not white (regardless of whether they are British or not).

The data sources described above are used to assess ZEV ownership as a function of sociodemographic indicators within California, Michigan, and England. To conduct a comparative analysis across the three markets, the project team first calculated ZEV ownership per capita (i.e., the number of ZEVs per 1000 people) by zip code for California, Michigan, and ONS geocode (E06 through E09) for England. Using these data, the project team produced "heat maps" to show how ZEV ownership varies geographically. Based on the ZEV ownership heat maps, we then investigated relationships between ZEV ownership and four sociodemographic indicators: 1) median income levels, 2) population below poverty levels, 3) percent POC populations, and 4) educational attainment. EJ scores and indices by geographic region are analyzed where data are available. Median income levels offer a better crossroads between poverty and affluence than average income, which can be dramatically inflated by small groups in certain geographic regions. With respect to POC, at least in North American markets, POC populations have historically faced environmental injustice. Assessing the relationship between ZEV ownership and POC populations could qualitatively surface ZEV benefits potential against historic inequity issues. Lastly, population's education levels, based on the number of 25+ year old with a high school education, can offer both quantitative evidence and qualitative suggestions on awareness of ZEV technology, as well as inform local governments that more can be done to kick off the local ZEV market. The correlations between ZEV ownership and the specified socio-demographic indicators are interpreted using percentile bins to better visualize trends in the data.

California

In California, the total passenger vehicle[12] population at the end of 2021 was approximately 30 million, 87 percent of which are gasoline vehicles and only 3 percent are ZEVs, such as battery-electric vehicles (BEV), plug-in hybrid electric vehicles (PHEV), and fuel cell electric vehicles (FCEV). A summary of the ZEV and non-ZEV population statistics from the CEC are shown in Table 1.

Table 1. California Light-Duty Vehicle Population, end of 2021

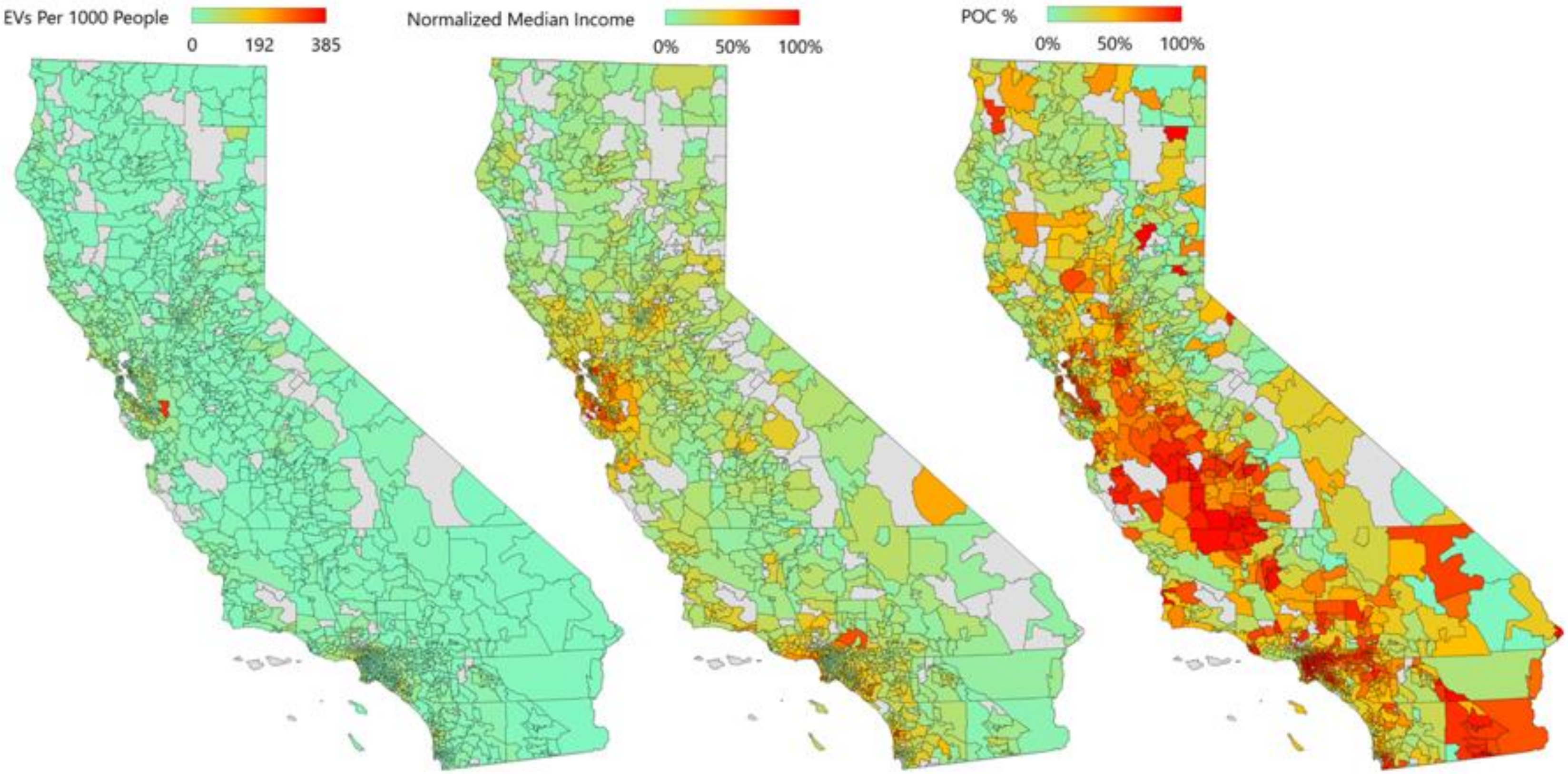
Vehicle	Technology	Population	Total Population
ZEV	BEV	522,445	837,887
	PHEV	305,315	
	FCEV	10,127	
Non-ZEV	Diesel	590,216	28,586,414
	Flex Fuel	1,280,970	
	Gasoline	25,998,618	
	Gasoline Hybrid	1,298,275	
	Natural Gas	8,461	
	Propane	90	

With the number of ZEVs per zip code, the project team cross referenced these data to U.S. Census Bureau's ACS statistics per zip code where applicable. Note that in some cases, ZEVs are registered to an invalid zip code, or the ACS has no population estimates for certain zip codes[13]. Consequently, there are some discrepancies when comparing ZEV ownership to ACS statistics. For California, we calculated the number of ZEVs per 1000 people for over 2600 zip codes. The results for the number of ZEVs per 1000 people, normalized median income, and percent POC population are shown as geographic heat maps in Figure 2.

The number of ZEVs per 1000 people ranges between 0 through 385. Certain regions, such as the San Francisco Bay Area along the north-western coast, have some of the highest ZEV ownership rates; for example, zip codes within Sonoma, Napa, and Santa Clara counties have between 1 through 385 ZEVs per 1000 people. Other regions, such as south-western California, have ZEV ownership rates that are comparable; zip codes within Los Angeles, San Diego, and Orange counties range between 1 through 178 ZEVs per 1000 people. Correspondingly, both the San Francisco Bay Area and Southern California regions have the highest median incomes relative to the rest of the state. Also illustrated in Figure 2 is California's sprawled diversity, showing that central and southern California have some of the largest POC populations across the state. Statewide, the ACS estimates a total population of 39,358,277 people, where POC represent 63 percent of the total population.

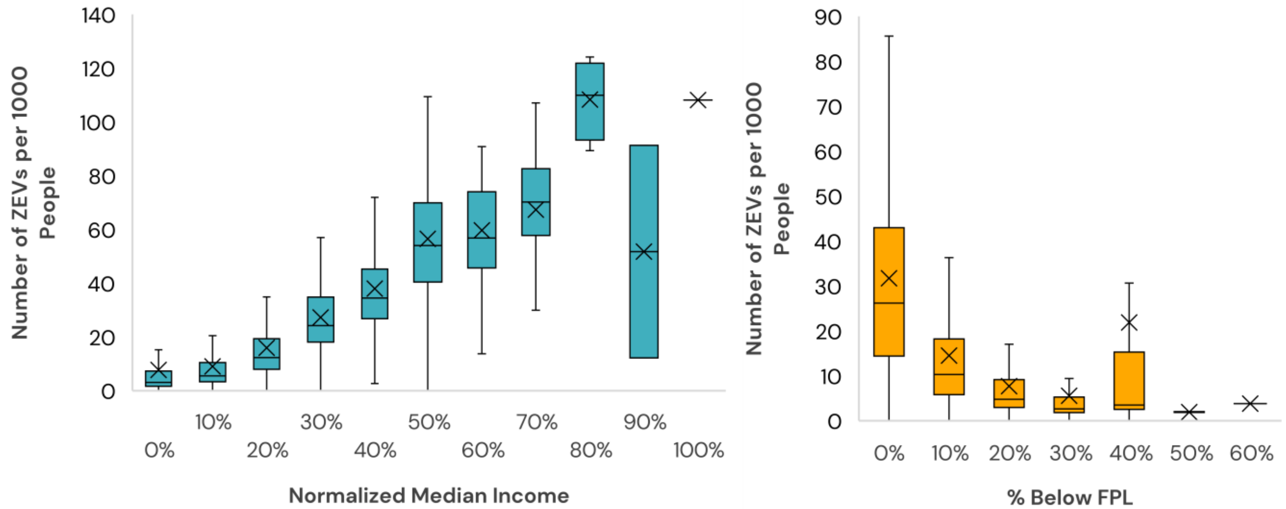
[12] Cars and light-duty pickup trucks with a gross vehicle weight rating (GVWR) under 8,500 pounds.
[13] The United States Postal Service (USPS) uses zip codes to facilitate more efficient mail routing. However, zip codes can reflect geographic regions that cross multiple cities or counties, and zip codes change at USPS's convenience. Moreover, zip codes do not always have demographic information associated with them (i.e., PO Box, military base, business address).

Figure 2. Number of ZEVs per 1000 People in California, Normalized Median Income, Percent POC Population (Left to Right)



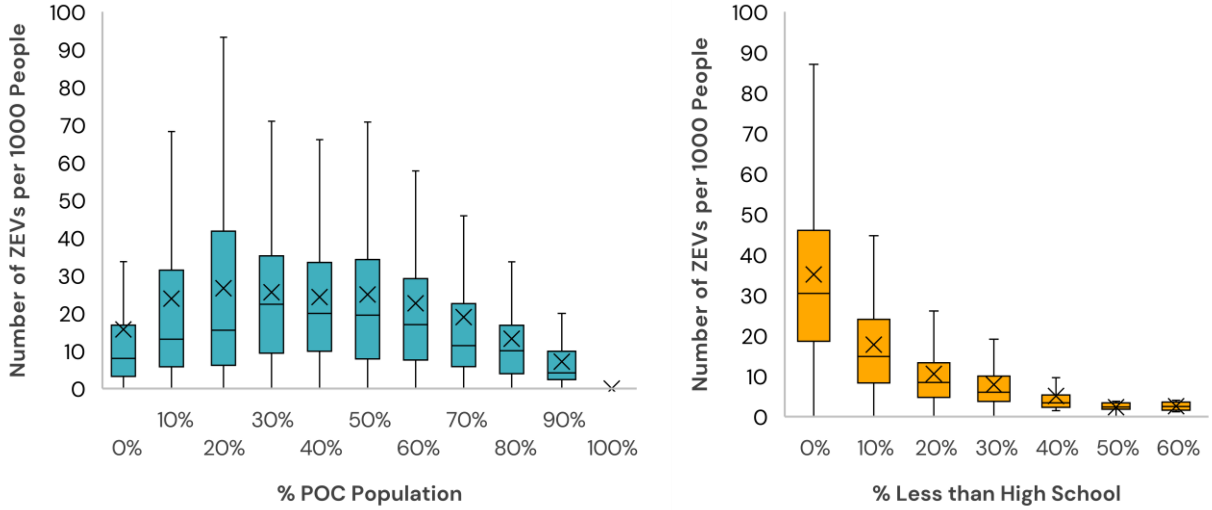
The number of ZEVs per 1000 people per zip code compared to normalized median income and percent population below the federal poverty line (FPL) per zip code are shown in Figure 3. The results suggest that ZEV ownership in California is significantly influenced by overall economic position. At high median income levels (e.g., 80 through 100 percent) average ZEV ownership is approximately 92 ZEVs per 1000 people, whereas at low median income levels (e.g., 0 through 20 percent), average ZEV ownership is approximately 12 ZEVs per 1000 people. There are over seven times as many ZEVs per 1000 people in the highest income zip codes as there are in the lowest income zip codes. Similarly, at low percent populations in poverty (e.g., 0 through 10 percent), the average ZEV ownership is approximately 24 ZEVs per 1000 people. At high percent populations in poverty (e.g., 50 through 60 percent), the average ZEV ownership is approximately 2 ZEVs per 1000 people.

Figure 3. ZEV Ownership Compared to Income Statistics by Zip Code in California



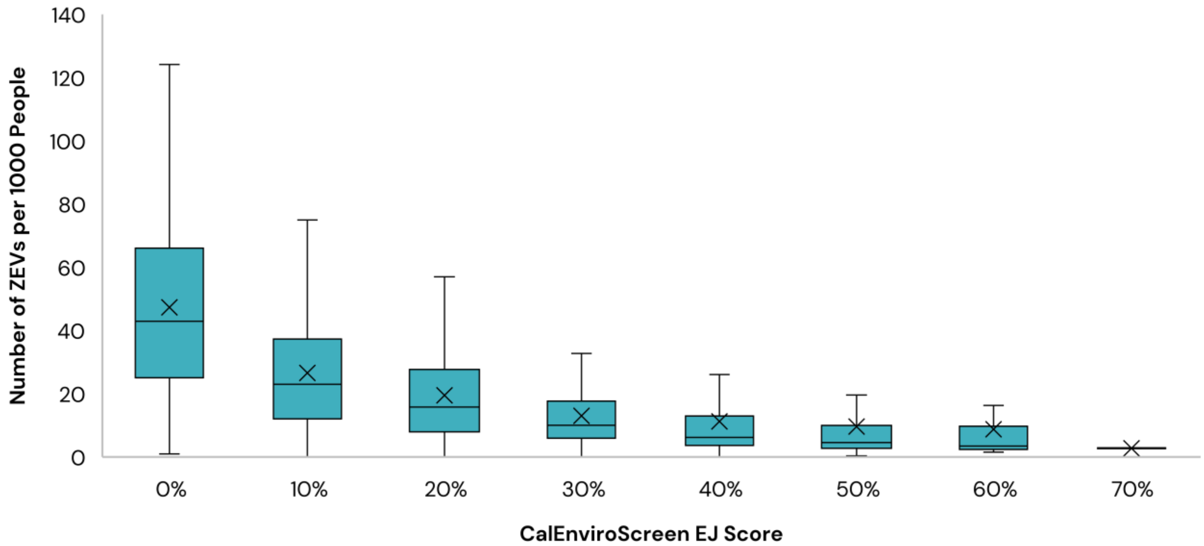
In addition to income and FPL, we compared ZEV ownership to percent POC populations and percent populations with less than a high school education per zip code, as shown in Figure 4. The results suggest that ZEV ownership is partially influenced by percent POC population. As the percent POC population increases (e.g., 30 through 100 percent), ZEV ownership tends to decrease. However, ZEV ownership within low percent POC populations (e.g., 0 through 20 percent) is observed to grow incrementally. In terms of educational attainment, the results suggest that ZEV ownership is influenced by percent population with less than a high school degree. At low percent populations with less than a high school degree (e.g., most of the population is high school educated, and between 0 to 10 percent are not high school educated), the average ZEV ownership ranges between 0 to 87 ZEVs per 1000 people. At high percent populations with less than a high school degree (e.g., at least half the population is not high school educated, between 50 to 60 percent), the average ZEV ownership ranges between 0 to 3 ZEVs per 1000 people.

Figure 4. ZEV Ownership Compared to Percent POC Population and Education by Zip Code in California



The project team also looked at how ZEV ownership changes with CalEnviroScreen EJ scores, as shown in Figure 5, which clearly shows how disadvantaged communities experience greater difficulties in adopting ZEVs. At low CalEnviroScreen EJ scores (e.g., low environmental and physical health burdens observed between the 0 through 20 percentile bins), the average ZEV ownership ranges between 0 to 124 ZEVs per 1000 people with an average of 48 ZEVs per 1000 people. At high CalEnviroScreen EJ scores (e.g., high environmental and physical health burdens observed between 50 through 70 percentile bins), the average ZEV ownership ranges between 2 to 20 ZEVs per 1000 people with an average of 9 ZEVs per 1000 people.

Figure 5. ZEV Ownership Compared to CalEnviroScreen EJ Score by Zip Code in California



> **The analysis clearly shows that ZEV ownership is mainly driven by the economic position of regions. Regions with average higher income and education consistently show higher rates of ZEV ownership as compared to those with lower income and education.**
>
> Interestingly, the analysis does not reveal a strong correlation between ZEV ownership and percent POC.

The assessment of California's ZEV market, arguably one of the largest across the U.S. and North America, reveals that even markets with accelerated ZEV adoption and supporting infrastructure still contain gaps in accessibility to electrified transportation. Comparisons of normalized median income as well as percent populations below FPL shows that not only are people more likely to own ZEVs when they are not poor, but zip codes with high median incomes also own as many as seven times more ZEVs per 1000 people compared to zip codes with lower median incomes. ZEV penetration in disadvantaged communities, whether that be due to lower educational attainment, environmental burden, or acute health effects, are also less likely to have ZEV ownership rates greater than 5 ZEVs per 1000 people. The comparison of ZEV ownership against various EJ indicators clearly showed that ZEV ownership has the highest correlation with income, education, and EJ score. Comparatively, ZEV ownership was demonstrably less correlated to race or ethnicity. However, when comparing ZEV ownership to changes in percent POC populations, some unique characteristics about the California market are observed. ZEV ownership initially increases with an increasing percent POC population, peaking at 93 ZEVs per 1000 people in zip codes with 20 percent of the population being POC, then decreases as the percent POC population increases. Looking more closely at zip codes within the 20-percentile bin, many of these zip codes are within Los Angeles, San Diego, and San Bernardino counties. These southern California counties are especially known to be large, car-oriented, and racially or ethnically diverse, as seen in Figure 2. The distribution of POC across southern California by itself may leave it open to interpretation whether there is a correlation between accessibility to ZEV ownership based on percent POC populations. However, the project team can qualify this observation based on demonstrated trends in California's economy. There may be a discrepancy between ZEV registration data and where non-POC live. Many people that work in southern California commute from outer regions or move closer to high POC populations, which could potentially explain why ZEV ownership slightly increases as the percent POC population increases. As the percent POC population increases, overall median incomes decrease, which may limit affordability and accessibility to ZEVs and their infrastructure. This, along with other complex factors, such as ZEV charging permitting processes across zip codes or EJ factors that limit infrastructure development, may be part of why ZEV ownership varies the way it does when looking at racial and ethnic groups across California.

Michigan

In Michigan, the total passenger vehicle population and the end of 2021 was approximately 8.3 million, 85 percent of which are gasoline vehicles, and ZEVs are just 0.4 percent of the light-duty vehicle population. A summary of the ZEV and non-ZEV population statistics are shown in Table 2.

Table 2. Michigan Light-Duty Vehicle Population, end of 2021*

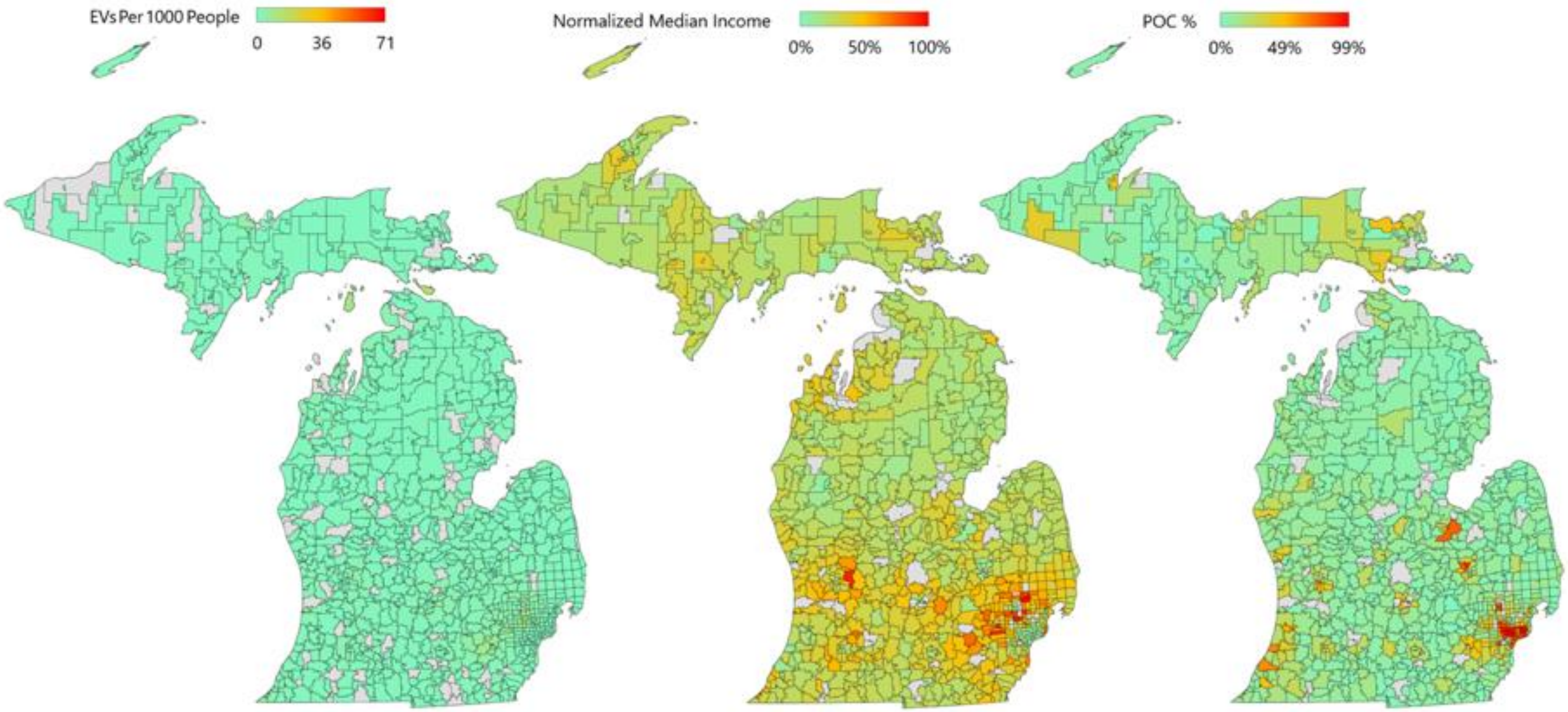
Vehicle	Technology	Population	Total Population
ZEV	BEV	17,500	34,700
	PHEV	17,200	
	FCEV	0	
Non-ZEV	Diesel	173,200	8,259,800
	Flex Fuel	912,200	
	Gasoline	7,067,400	
	Gasoline Hybrid	106,400	
	Natural Gas	500	
	Propane	100	

*Source: U.S. Department of Energy Alternative Fuels Data Center, TransAtlas (https://afdc.energy.gov/transatlas#/)

For Michigan, we calculated the number of ZEVs per 1000 people per zip code for over 950 zip codes. These results, as well as the geographic variation in normalized median income and percent POC populations are shown as geographic heat maps in Figure 6.

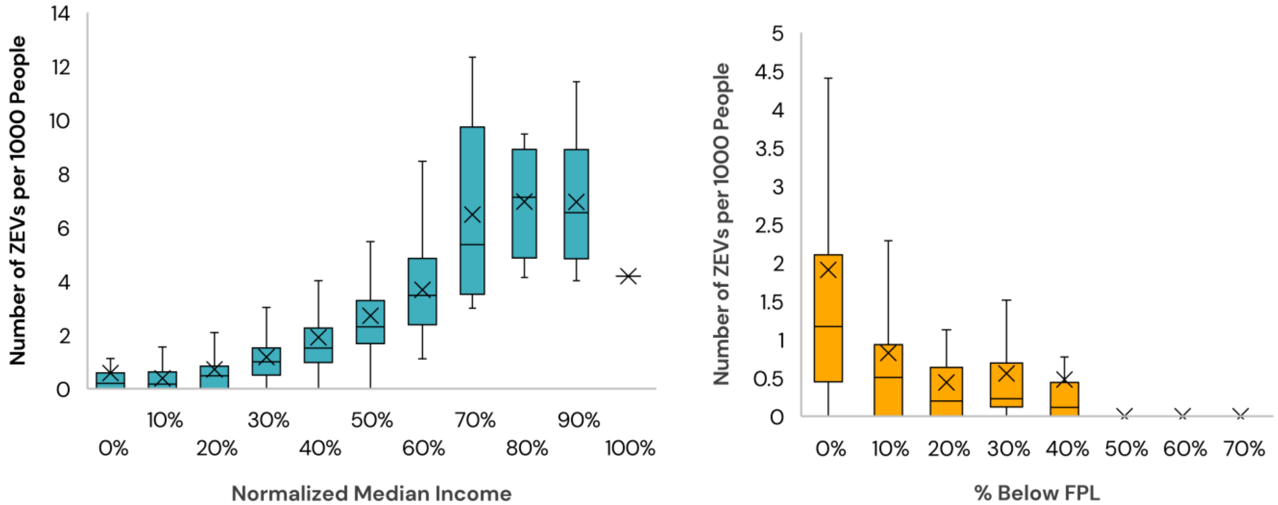
The number of ZEVs per 1000 people varies between 0 through 71. The Detroit metropolitan area in the south-east has the highest ZEV ownership rates compared to the rest of the state; zip codes within Livingston, Oakland, and Wayne counties (all in the Detroit metropolitan area) reflect almost all ZEV ownership rates between 1 through 71 ZEVs per 1000 people. High median incomes relative to the rest of the state of Michigan can be observed near the Detroit metropolitan area, as well as in the western Grand Rapids area of the state. Also illustrated in Figure 6 is Michigan's distribution of people by race or ethnicity. The majority of Michigan's POC population take residence near the Detroit metropolitan area. Statewide, the ACS estimates a total population of 9,975,900 people, where POC represent 25 percent of the total population.

Figure 6. Number of ZEVs per 1000 people in Michigan, Normalized Median Income, and Percent POC Population (From Left to Right)



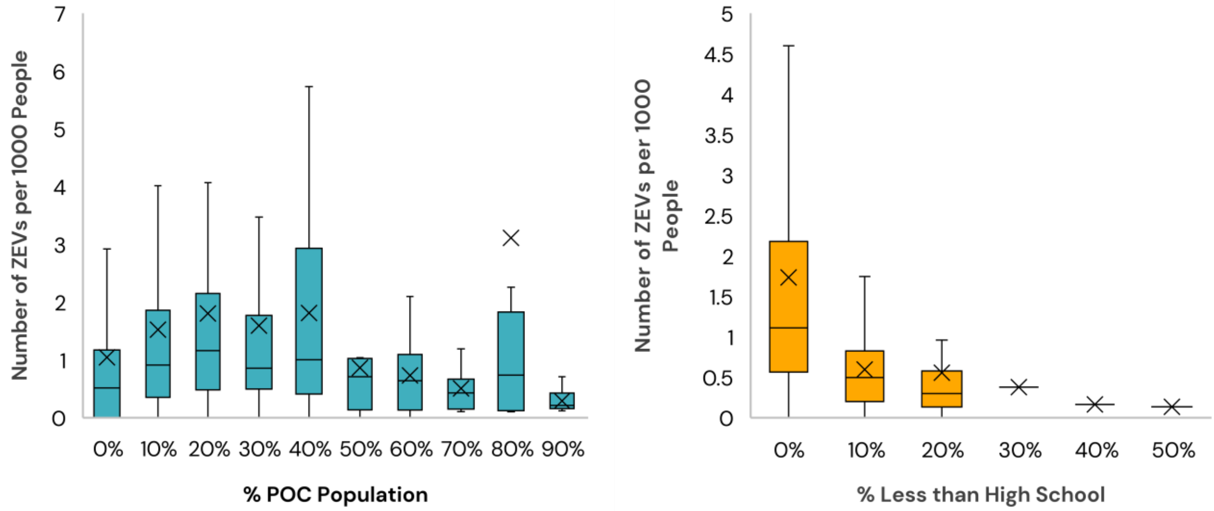
For Michigan, the results for the number of ZEVs per 1000 people per zip code compared to the normalized median income and percent population below FPL per zip code are shown in Figure 7. The results suggest that ZEV ownership in Michigan is influenced by overall economic position. At high median income levels (e.g., 80 to 100 percent), average ZEV ownership is approximately 7 ZEVs per 1000 people, whereas at low median income levels (e.g., below 20 percent), average ZEV ownership is approximately 1 ZEV per 1000 people. Similar ZEV ownership rates can be observed when compared to percent populations below the FPL. At low percent populations in poverty (e.g., below 10 percent), the average ZEV ownership is approximately 2 ZEVs per 1000 people. At high percent populations in poverty (e.g., 50 to 70 percent), there is no observable ZEV ownership. These results highlight a significant disparity in ZEV ownership for people in Michigan.

Figure 7. ZEV Ownership Compared to Income Statistics by Zip Code in Michigan



EV ownership rates, as they relate to the percent POC population and educational attainment, are shown in Figure 8. The results between ZEV ownership and percent POC populations are less indicative than those of California. At low percent POC populations (e.g., below 20 percent), ZEV ownership is observed to grow incrementally up until mid-percent POC populations (e.g., 30 to 60 percent), and decreases at high percent POC populations (e.g., between 70 and 90 percent). In terms of educational attainment, the results suggest that ZEV ownership is significantly influenced by the percent population with less than a high school education. At low percent populations with less than a high school degree (e.g., below 10 percent), the average ZEV ownership is approximately 2 ZEVs per 1000 people and can be as high as 5 ZEVs per 1000 people. At high percent populations with less than a high school education (e.g., 40 to 50 percent), there are nearly 0 ZEVs per 1000 people.

Figure 8. ZEV Ownership Compared to Percent POC Population by Zip Code in Michigan



The assessment of Michigan's ZEV market provides some evidence of gaps in the ZEV market across the U.S. and North America. In Michigan's case, the overarching barrier to entry into electrified transportation and infrastructure is tied to socioeconomics – at lower median income levels or high poverty levels, ZEV ownership rates do not surpass 2 ZEVs per 1000 people. Although overall ZEV ownership rates in Michigan are several times lower than California, it can still be observed that low-income and less-educated people are much less likely to own ZEVs than even the higher-earning or higher-educated populations. Michigan's ZEV ownership rates are uncorrelated to percent POC populations, especially when considering Detroit metropolitan demographics – for reference, the distribution of percent POC populations as shown in Figure 6. Not only is 75 percent of Michigan's overall population white, the majority of Michigan's POC population can be found within just the Detroit metropolitan area. Cross examining the percent POC population with the distribution of ZEV ownership, it can be inferred that certain sociodemographic metrics, such as urbanization, job markets, and possibly even seasonally inclement weather play complicated roles in the overall ZEV market. Another important consideration for Michigan's market is that overall ZEVs have not experienced widespread adoption, meaning that any uptick in the number of ZEVs per zip code, regardless of racial or ethnic diversity, will present initially askew data resulting from early adopters, as seen with the Detroit metropolitan area. Similar to California, there may be discrepancies between where ZEVs are registered and where people live relative to the state's most major urban area.

England

For England, the total passenger vehicle population (i.e., vehicle stock) at the end of first quarter of 2022 was approximately 27 million, 94 percent of which are gasoline (petrol) and diesel vehicles, and ZEVs represent just 2.6 percent of the population. A summary of the ZEV and non-ZEV statistics by technology type are shown in Table 3.

Table 3. England Light-Duty Vehicle Population, Q1 2022

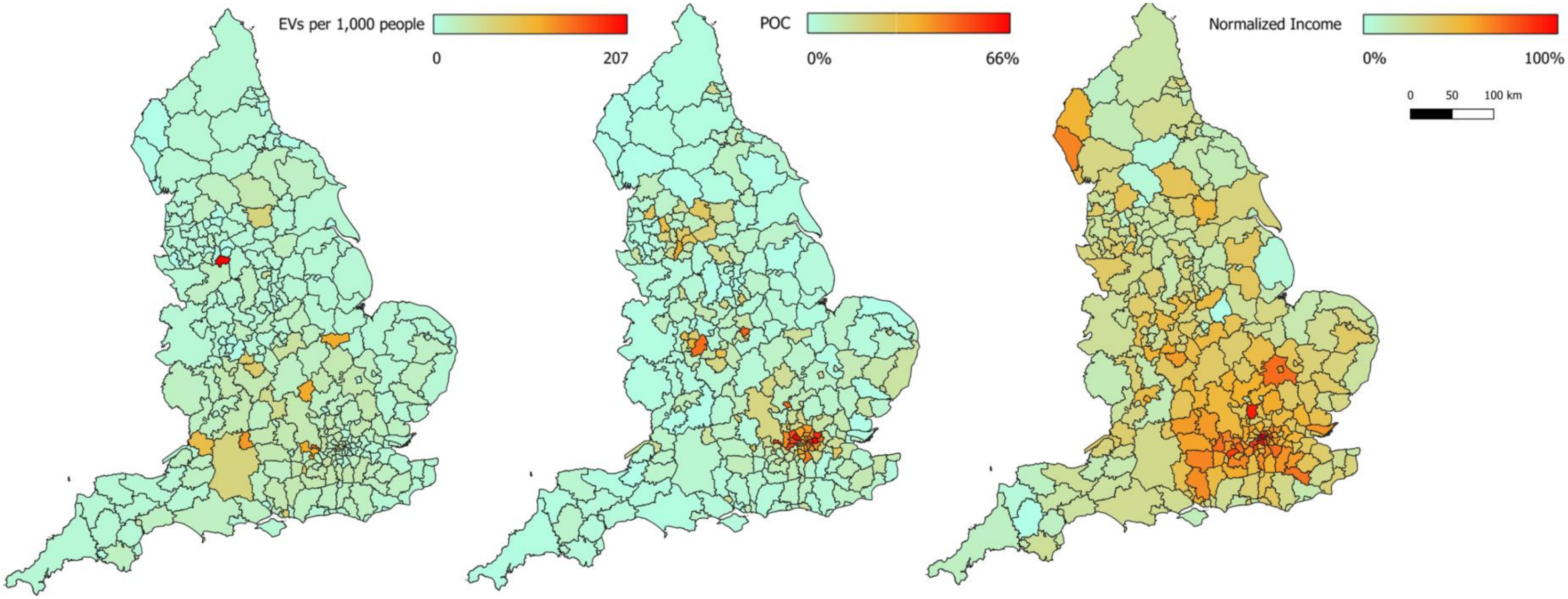
Vehicle	Technology	Population
ZEV	Battery Electric	394,333
	Plug-in hybrid electric (petrol)	9,275
	Plug-in hybrid electric (diesel)	294,840
	Range extended electric	8,734
Non-ZEV	Gasoline	16,019,998
	Diesel	9,582,932
	Other Fuel	905,935

*Source: Vehicle Statistics from U.K. Department of Transport (https://www.gov.uk/government/collections/vehicles-statistics)

For England, we calculated the number of ZEVs per 1000 people for over 330 ONS. These results, as well as the geographic variation in normalized median income and the percent POC populations are shown as geographic heat maps in Figure 9Figure 6.

The number of ZEVs per 1000 people varies between 1 through 105. On average, there are approximately 13 ZEVs per 1000 people in England (700,000 ZEVs for a total population of more than 56 million in England). Generally, the southern part of the country has the highest ZEV ownership with almost 19 ZEVs per 1000 people. For example, the South Gloucestershire region near Bristol and Swindon have ZEV ownerships of 84 and 142 per 1000 people, respectively. High ZEV ownership rates can also be observed running along the center column of England, where regions like Milton Keynes in Buckinghamshire or Peterborough have a ZEV ownership rate of approximately 110 per 1000 people. Located in Greater Manchester, the city of Stockport has the highest ZEV ownership rate at 207 ZEVs per 1000 people. Lower- to medium-level median incomes relative to the rest of England can be observed within the same center column, and higher median incomes are seemingly dispersed in the south-east, within counties such as Berkshire, Hertfordshire, and London. Also illustrated in Figure 9 is England's distribution of POC by percent of the population. Different boroughs within London, such as Newham, Brent, and Redbridge, have POC populations that reflect more than 60 percent of the total population in each. In other cities, such as Luton and Birmingham, POC represents nearly half of the total population.

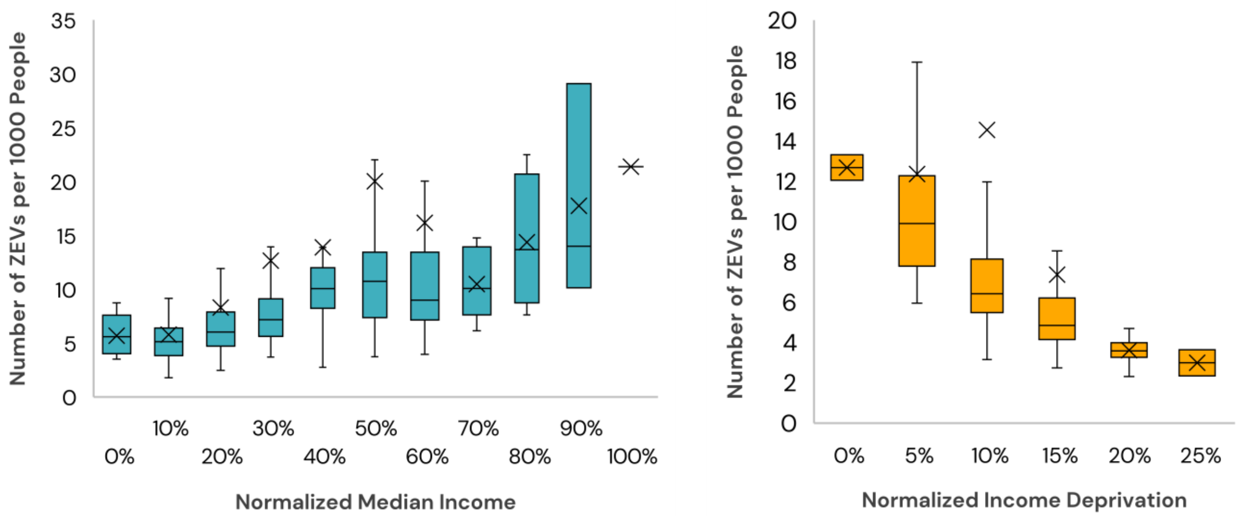
Figure 9. Number of ZEVs per 1000 people in England, Percent POC Population, Normalized Median Income[14] (From Left to Right)



[14] People of color for the England market are defined as the population that are not white (regardless of whether it is white British or all other whites).

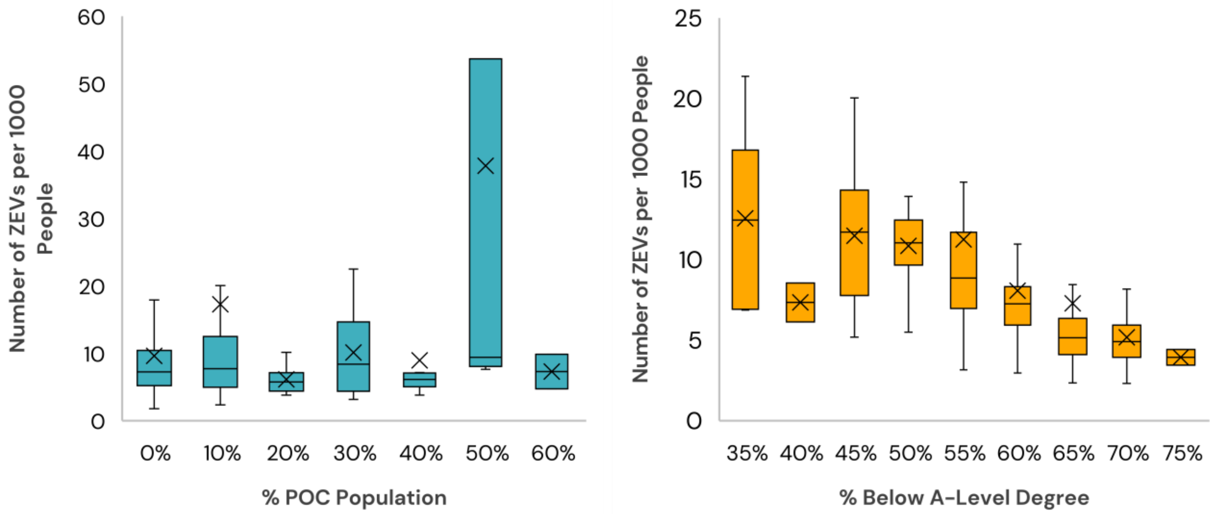
For England, the results for the number of ZEVs per 1000 people per ONS compared to the normalized median income and normalized income deprivation per ONS are shown in Figure 10. The results suggest that like Michigan and California, ZEV ownership in England is influenced by overall economic position. At high median income levels (e.g., 80 to 100 percent), average ZEV ownership is approximately 16.5 ZEVs per 1000 people, whereas at low median income levels (e.g., below 20 percent), average ZEV ownership is approximately 6 ZEVs per 1000 people. Similar ZEV ownership rates can be observed when compared to normalized income deprivation. At low percent populations in poverty (e.g., below 5 percent), the average ZEV ownership is approximately 12 ZEVs per 1000 people. At high percent populations in poverty (e.g., between 20 to 25 percent), the ZEV ownership drops to less than 3 ZEVs per 1000 people. These results highlight how lower income regions are the ones that have the least ZEV ownership. To ensure that the correlation of ZEV ownership versus income is not solely due to the lower vehicle ownership in low-income communities, we also compared the overall vehicle ownership (ZEV and Non-ZEVs) versus income. We did not find a strong relationship between car ownership and income level, and in fact, our analysis demonstrated that regions with higher income levels tend to have lower car ownership rates. Of course, when compared to income deprivation, we did observe lower vehicle ownership in regions with higher income deprivation, however, the correlation is not as strong as for ZEVs. For example, in regions with more than 20 percent income deprivation, vehicle ownership is approximately 400 vehicles per 1000 people, whereas in regions with less than 5 percent income deprivation the vehicle ownership is around 600 per 1000 people.

Figure 10. ZEV Ownership Compared to Income Statistics by ONS in England



ZEV ownership rates as they relate to the percent POC population and educational attainment are shown in Figure 11Figure 8. The results between ZEV ownership and percent POC populations are less indicative than those in North America. As shown, the ZEV ownership does not seem to have any direct correlation to percent POC at the ONS geographic index level. In terms of educational attainment, the results suggest that ZEV ownership is significantly influenced by the percent population with less than an A-Level education[15]. At low percentages (e.g., below 35 percent), the average ZEV ownership is approximately 13 ZEVs per 1000 people. At high percent populations with less than an A-level degree (e.g., above 70 percent), there are less than 5 ZEVs per 1000 people.

Figure 11. ZEV Ownership Compared to Percent POC Population and Education Level by ONS in England



The assessment of England's ZEV market provides some evidence of gaps in the ZEV market across the country. According to our assessment, income and education seem to be the overarching barriers to entry into electrified transportation – at lower median income levels or high poverty levels, ZEV ownership rates do not surpass 5 ZEVs per 1000 people. Despite England's relatively high ZEV ownership compared to individual states in the U.S. (except for California), there is a significant gap in ZEV ownership between lower and higher income regions. Similar to Michigan, ZEV ownership rates in England are seemingly uncorrelated to percent POC populations. Not only is 86 percent of England's overall population white, but most of the non-white population reside around the London and Birmingham metropolitan regions, leaving the white population to reflect the rest of the country. Cross examining the percent POC population with the distribution of ZEV ownership, it can be inferred that certain sociodemographic indicators, such as urbanization, job markets, and possibly even alternative transit systems may play complicated roles in the overall ZEV ownership.

It is also noteworthy to mention that the public transportation system in England, and the U.K. overall, is much more developed than U.S. According to U.K. Transportation Statistics, of the 953

[15] It is noteworthy to mention that while A-level could be considered as an equivalent degree to U.S. high school diploma, typically those who pursue the A-level degree are the ones that plan to join Universities and obtain a college degree. This is why compared to U.S., there is higher fraction of population in U.K. regions with educations less than A-level.

All three markets are showing similar relationships between the ZEV ownership and socio-economic factors.

The disparity in ZEV ownership rates can be explained by immediate obstacles, such as high upfront costs of new ZEVs, lack of pre-owned ZEVs, and lack of access to charging or fueling infrastructure.

trips that each person made in 2019, more than 10 percent of those were using public transport[l] while in the U.S., only 2.5 percent of the trips are made using public transportation. The availability of transit system in England certainly impacts overall vehicle ownership rates. For example, data for England shows that in urban areas with dense transit system, the vehicle ownership is much lower than rural areas with less transit system availability. Specifically, while on average there are 482 vehicles operating in England for every 1000 people, in Greater London the vehicle ownership is 40 percent lower than the national average. This clearly shows that there might be a sizable fraction of households in the England, especially in urban areas, who may not own any vehicle let alone ZEVs which could certainly be one of the factors influencing the ZEV ownership analysis conducted in this report.

Environmental Justice Impacts of ZEVs

Increased adoption of ZEVs can offer a suite of benefits to regions globally, including improved air quality, health benefit, and economic prosperity through increased job opportunities, as well as cost savings resulting from the lower operational cost of ZEVs. In this section of the research report, the project team focused on the public health benefits due to increased ZEV operation within the California and Michigan markets. The project team also quantified the potential emissions and monetary public health benefits in the U.K., the details of which are available in Appendix B – Emission and Health Benefits of Increased ZEV Adoption in the U.K. To achieve this, we leveraged previous work conducted by ICF on behalf of the American Lung Association[m] (ALA) where the project team quantified the health benefits of widespread adoption of ZEVs across the United States. This comprehensive analysis quantified the health benefits, in terms of both number of health incidents, as well as monetized health benefits, based on electrification of light-duty and heavy-duty vehicles at U.S. County level.

Adapting the results from previous work to this research report, we considered a scenario under which ZEV sales in both California and Michigan grows to 100 percent over the next 10 to 15 years. The ALA analysis includes increased adoption of ZEVs in medium- and heavy-duty vehicles as well, and quantifies both *downstream* (tailpipe exhaust, evaporative, brake and tire wear) and *upstream* (reduced fuel production, transport, and refining activities for internal combustion vehicles and increased electricity generation for electric vehicles) emissions. The primary pollutants considered as the basis for health modeling are PM2.5 (exhaust, brake wear, tire wear), NOx and VOC. When accounting for emissions from electricity or fuel production, a baseline energy portfolio is maintained across the business-as-usual and increased ZEV operation scenarios. For example, the project team used an electricity generation mix as projected by the U.S. Energy Information Administration's 2021 Annual Energy Outlook. This is certainly a conservative scenario, considering recent greenhouse gas reductions commitments made by the federal administration as well as various states setting ambitious goals to achieve carbon free electricity over the next two decades.

Utilizing the ZEV adoption scenario as well as the assumed energy portfolio, the prospective emissions benefits resulting from increased ZEV operation are projected between 2020 through 2050. These emissions benefits are utilized to quantify the health outcomes (e.g., reduced mortality, reduced hospital admissions, reduced emergency room visits, work loss days) at the county level. Avoided health incidents and monetized health benefits are based on the U.S. EPA

COBRA model. For additional details on the scenario leveraged in this report, see Appendix A – More on National Health Benefits from ZEVs.

ZEVs bring significant public health benefits especially in low-income and disadvnataged comunities

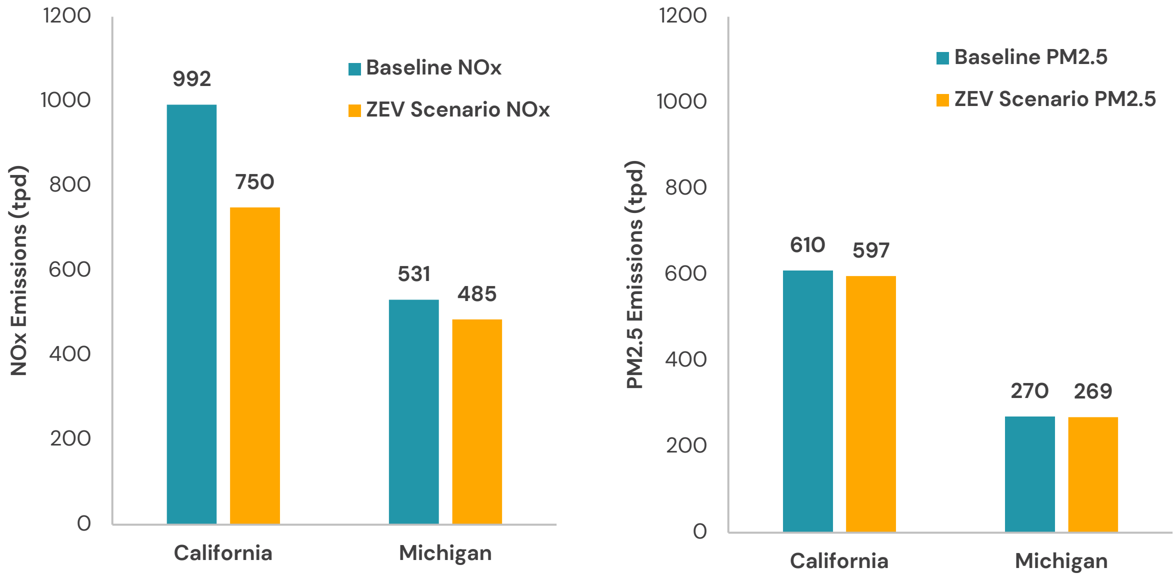
Adoption of ZEVs in counties with higher levels of air pollution will lead to higher monetized health benefits per capita as compared to those with better air quality

In the sections that follow, we describe the emission benefits at the state level, the avoided health incidents at the state level, and the cumulative monetized health benefits at the county level. While we understand that quantifying the environmental justice impacts of ZEVs requires an analysis at much higher spatial resolution than the county level, such analysis will require spatially resolved air quality (e.g., at census tract level), and emissions data which are currently not available. Despite this shortcoming, the project team used the county level health benefits to demonstrate the correlation between air pollution burden and cumulative monetized health benefits. This analysis helps illustrate the relationship between the monetized health benefits from increased adoption of ZEVs with air pollution burden and demonstrate how disadvantaged communities will benefit from policies that result in ZEV uptake within their regions.

State Level Benefits

Emission benefits in calendar year 2050 for the states of California and Michigan are determined by taking the difference between baseline conditions (e.g., no planned increase in ZEV operation) and the increased ZEV adoption scenario. Note that the baseline scenario does reflect the various criteria vehicle emissions standards adopted in the U.S. and therefore, criteria tailpipe emissions are modeled to decrease over time. The emissions inventory considers all emission sources, including on- and off-highway vehicles, industrial sources (e.g., refineries), electric utilities, etc. In this report, emphasis is placed on assessing potential NOx and PM2.5 emission benefits, the results of which are shown in Figure 12. In a scenario where ZEV sales increase to 100 percent by 2035 for light-duty vehicles and 2040 for heavy-duty vehicles, both California and Michigan see significant reduction in NOx and PM2.5 emissions. California's NOx emissions are expected to decrease by 25 percent from baseline conditions, whereas PM2.5 emissions are expected to decrease by 2 percent from baseline conditions. Michigan's NOx emissions are expected to decrease by 9 percent from baseline conditions, whereas PM2.5 emissions are expected to decrease by 1 percent from baseline conditions. It should be noted that in California, on-highway vehicles contribute to almost 23 percent of NOX and 2.5 percent of PM2.5 emissions, whereas in Michigan, the contribution of on-highway vehicles is limited to 11 percent for NOx and 1.2 percent of PM2.5.

Figure 12. Total NOx Emissions, Total PM2.5 Emissions in short tons per day (tpd) (From Left to Right)



Avoided health incidents between the years 2020 through 2050 for the states of California and Michigan are determined for mortalities, hospital admissions, emergency room visits, and work loss days. State level monetary health benefits are also determined using 3 percent and 7 percent discount rates to express future economic values in present terms. A summary of the state-level monetized health benefits for California and Michigan are shown in Table 4. A more detailed breakdown of monetized health benefits by avoided health incident for California and Michigan are available as Table A-2 and Table A-3 (respectively) in Appendix A – More on National Health Benefits from ZEVs.

Table 4. Summary of State Level Monetized Health Benefits Between 2020 through 2050

	Monetary Health Benefits (Million 2017$, 3% Discount Rate)	
Health Incident	**California**	**Michigan**
Mortality, low estimate	94,700	8,010
Hospital Admits, All Respiratory	95.2	6.12
Emergency Room Visits, Asthma	2.1	0.2
Work Loss Days	262	16.5
Total, low estimate (in Millions)	**$95,100**	**$8,030**

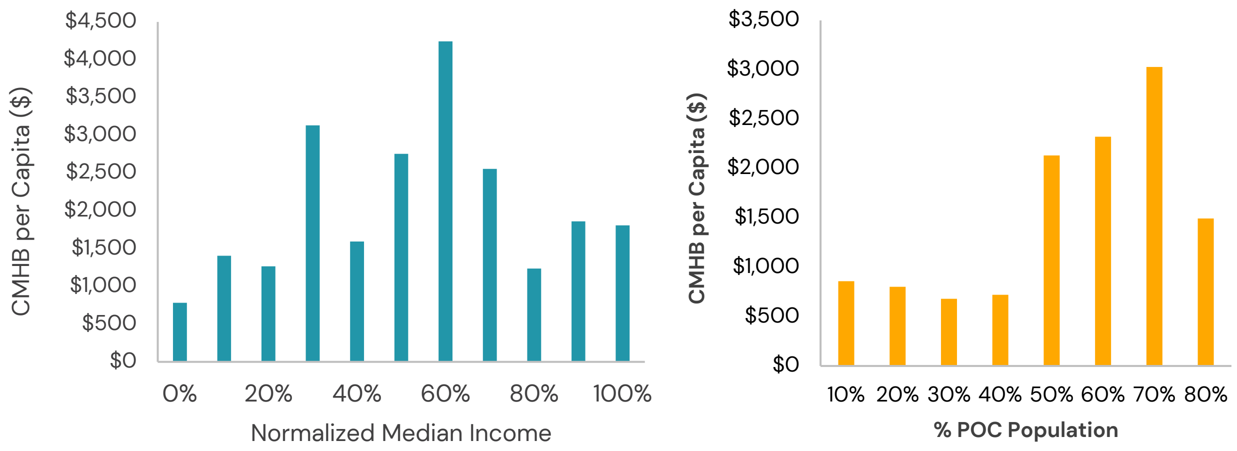
County Level Monetized Health Benefits

The project team also looked at prospective health benefits per county for California and Michigan. We calculated cumulative monetized health benefits between 2020 through 2050 for California's 58 counties and Michigan's 83 counties, then normalize by each county's 2020 population to determine the cumulative monetized health benefits (CMHB) per capita.

California

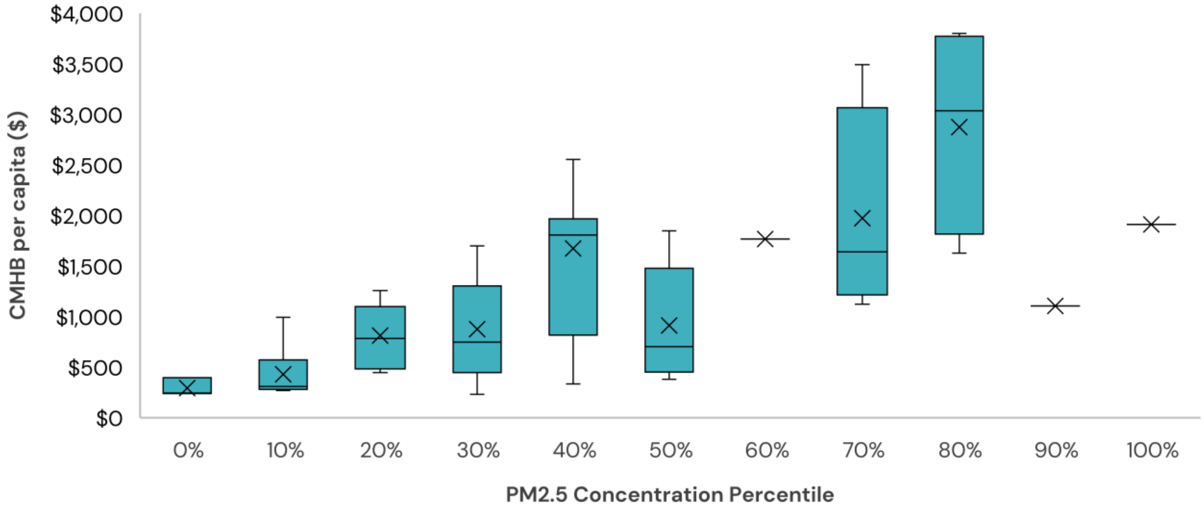
Cumulative monetized health benefits per capita are compared to California's normalized median income and percent POC populations, shown in Figure 13. At this resolution, the results do not indicate a strong correlation between prospective health benefits or metrics such as income, race or ethnicity. However, regions with percent POC populations greater than 50 percent do experience at least two times greater monetized health benefits per capita than regions with percent POC populations less than 50 percent. It should be noted that regions with greater POC populations are also the regions that tend to have worse air quality now which could explain the higher CMHB per capita values in those regions.

Figure 13. County Level Cumulative Monetized Health Benefits (CHMB) per capita



Note that aside from emission reductions, health benefits are highly correlated with population density and the existing air quality of the county. So, while a county such as Los Angeles County might on average have higher level of income, the regional air quality issues (i.e., high levels of ozone and PM2.5 concentrations) combined with high population density results in the county to have much higher monetized health benefits per capita than a low-income county such as Fresno. That is why we believe the impact of increased ZEV operation may be better qualified by other EJ indices, such as PM2.5 concentrations. Figure 14 shows the correlation of CMHB per capita and PM2.5 concentrations.

Figure 14. CA Cumulative Monetized Health Benefits Per capita Compared to PM2.5 Concentration



Although the results do not indicate that cumulative monetized health benefits are greatest for lower income populations at the county level, we qualitatively recognize some correlation between potentially realized health benefits and poor air quality. As illustrated in Figure 14, regions with higher levels of air pollution are often the ones that gain the greatest monetary health benefits from the increase adoption of ZEVs. This stands true whether the region is considered disadvantaged or not, although many studies have shown that regions with higher levels of air pollution are more likely to be comprised of lower income regions and disadvantaged communities.

Michigan

Cumulative monetized health benefits per capita are compared to Michigan's normalized median income and percent POC populations, shown in Figure 15. Similar to the issue with county level resolution in California, the results do not indicate a strong correlation between cumulative monetized health benefits and income or race or ethnicity. Although cumulative monetized health benefits are greatest when POC populations are largest in Michigan, the project team looked to air quality as a qualitative measure of how increased ZEV operation will impact regions with higher levels of air pollution burden. Figure 16 shows the correlation of CMHB per capita and PM2.5 concentrations.

Figure 15. County Level Cumulative Monetized Health Benefits

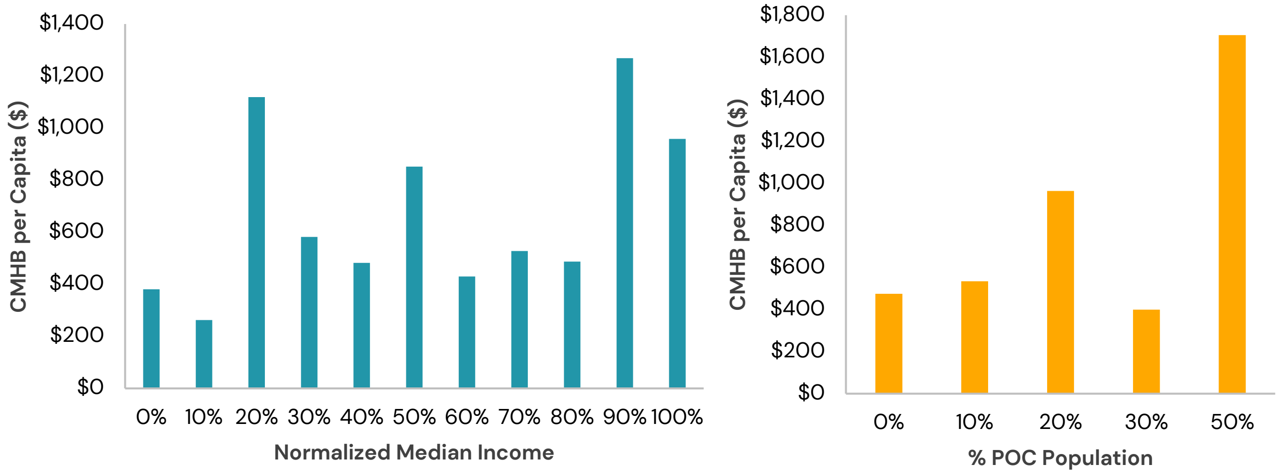
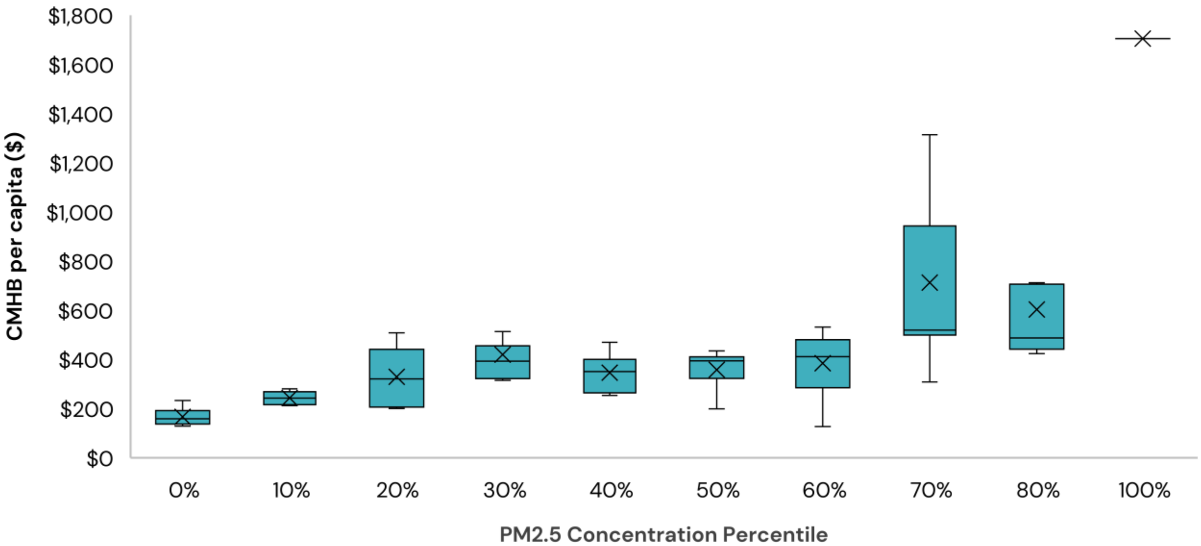


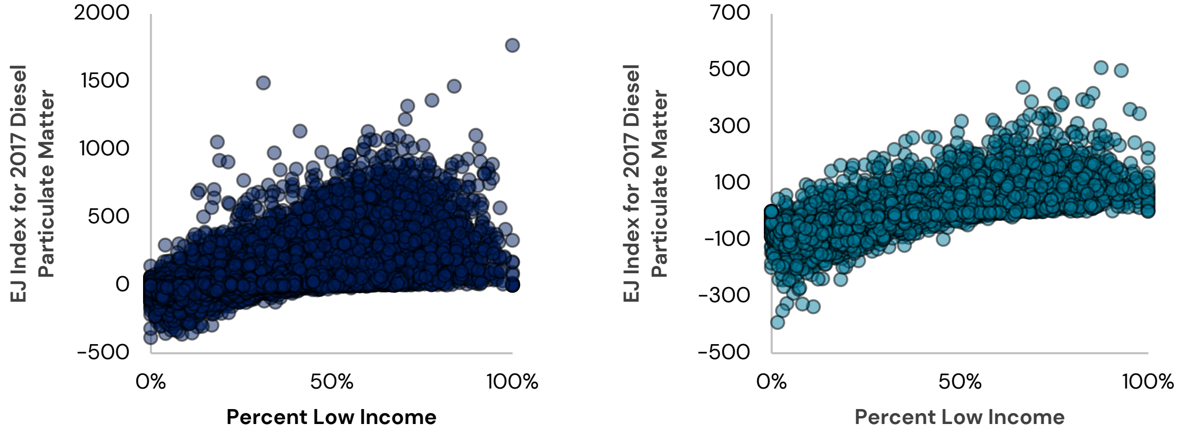
Figure 16. MI Cumulative Monetized Health Benefits Per capita Compared to PM2.5 Concentration



Similar to what we observed for California, the results suggest that regions with higher levels of air pollution in Michigan achieve higher monetary health benefits per capita than regions with cleaner air.

To further elaborate on this correlation, Figure 17 shows the EJ index for diesel particulate matters (diesel PM) from the EPA EJScreen as a function of percent low-income population in both California and Michigan. Each dot represents one census tract. As shown, census tracts with higher fractions of low-income populations are often the ones that have higher levels of exposure to diesel PM emissions. For this analysis, we selected diesel PM as a surrogate for transportation related air pollution. This is again to confirm that lower income regions are often disproportionately impacted by higher levels of air pollution, and increased ZEV adoption in these regions provides higher monetized health benefits than communities with lower levels of air pollution. This result lends itself to say that clean transportation investments within lower income regions could result in higher return-on-investments when one accounts for health benefits in addition to other economic impact (e.g., cost saving, workforce development).

Figure 17. EJ Index for 2017 Diesel Particulate Matter as a function of percent low-income census tract population (Left is California, Right is Michigan)



Role of Policies in Enhancing Environmental Justice

As discussed, ZEVs offer great potential to mitigate long-standing public health and economic burdens that lower income regions and POC have historically endured. However, our quantitative analysis in Section 2 illustrated that while there has been significant progress made in adoption of ZEVs, most of those vehicles belong to higher income and educated regions. Accordingly, ZEV policies will play a key role in improving equitable access to ZEV ownership and operation in the future. In this section, we described some of the barriers to ZEV adoption in these regions and provide examples of policies adopted in various regions of the world that have demonstrated to be successful in integrating EJ within ZEV programs.

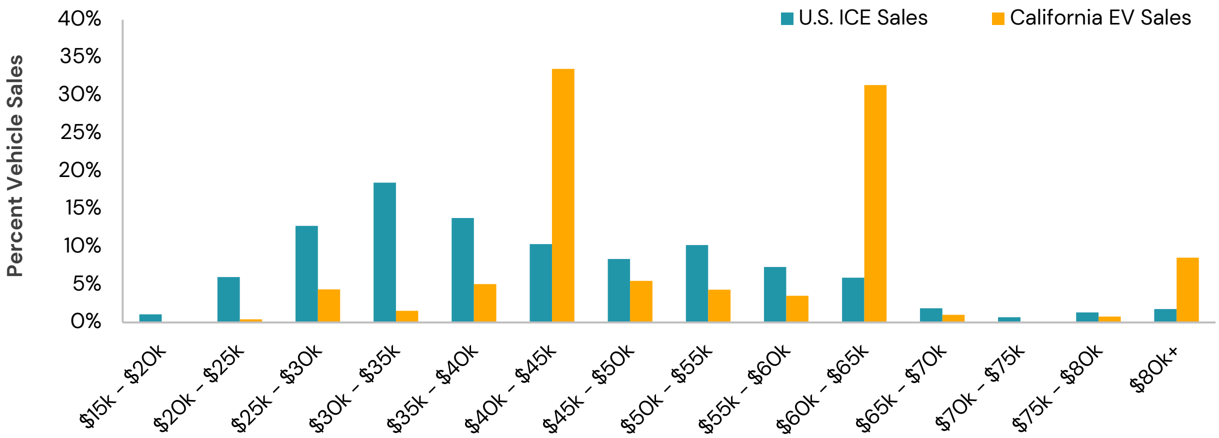
To better understand the barriers to ZEV adoption, especially within disadvantaged communities, the project team conducted interviews with EJ experts and stakeholders. The purpose of this engagement was to solicit input from both regions as well as EJ experts to articulate policy recommendations that various government agencies can deploy to overcome those disparities. We conducted semi-structured interviews and online workshops with 15 EJ experts and engaged with 24 organizations dedicated to EJ. Through each workshop, we discussed various policy scenarios (e.g., financial incentives, mandates for manufacturers, ZEV infrastructure policies, etc.) and allowed EJ stakeholders to provide their feedback based on general thoughts around policy, economic, access, and indirect impacts of ZEVs. In the following section, we highlight some of the key concerns expressed by stakeholders on the gaps and barriers with adoptions of ZEVs in disadvantaged communities and explore policies that look to address these issues.

Barriers

Affordability

North American EJ stakeholders expressed that ZEVs remain unaffordable for many low-income households. According to ZEV new vehicle sales data from the CEC and ICF's proprietary ZEV library, the sales weighted average MSRP for ZEVs sold in California was approximately $56,000, or $13,000 more than the average gasoline vehicle sold in the United States. To better illustrate this point, we took the sales data both at the California and U.S. level and combined them with the price data from various sources, including ICF's ZEV library to show the sales distribution as a function of vehicle price. Through this analysis, we were able to show a comparison of vehicle sales as a function of MSRP for new ZEVs sold in California in Q1 2022 versus new ICE vehicles sold in the U.S. in 2021. As shown in Figure 18, prior to applying federal, state, and local incentives, ZEVs are generally more expensive than their counterpart ICE vehicles.

Figure 18. Percent of passenger vehicle sales by MSRP range

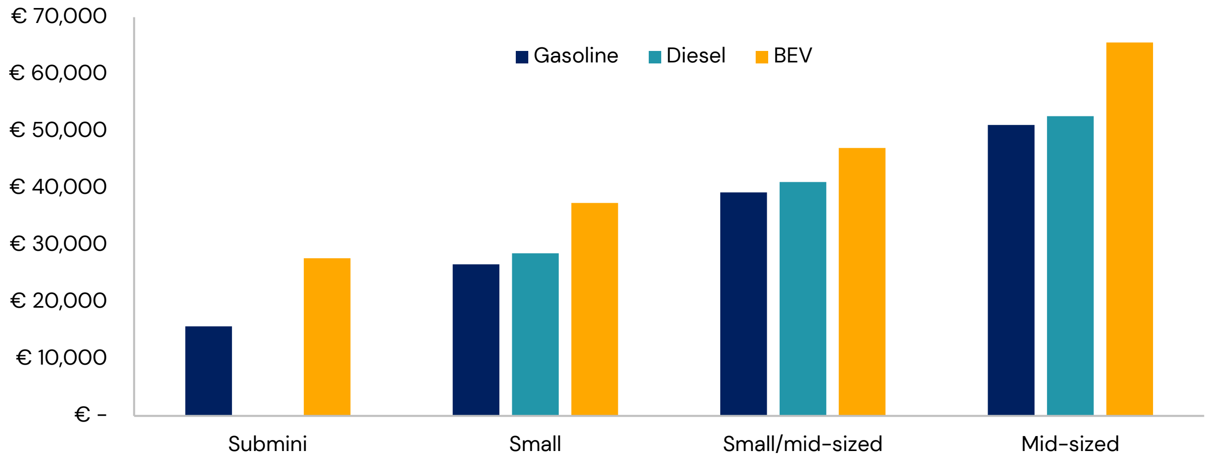


Adding to high upfront vehicle costs are high insurance costs that can make ZEVs unaffordable in certain regions. Michigan stakeholders noted that insurance costs for ZEVs are expensive, adding that Detroit has one of the highest auto insurance rates in the country. In addition to high auto insurance rates, participants shared that auto ownership itself is financially prohibitive for many low-income households.

North American EJ stakeholders also shared that the existing incentive portfolio has not made ZEVs sufficiently affordable. In some past instances, financial incentives have benefited affluent groups more than disadvantaged groups. In example, ZEV charging grants benefit homeowners with off-street parking, while in low-income areas homes without off-street parking are more prevalent. There have been some measures to reduce benefit disparity between affluent and disadvantaged communities, such as the Inflation Reduction Act (IRA) of 2022, which puts income cap eligibility criteria ($150,000 for an individual, or up to $300,000 for a household) for federal ZEV tax credit. However, the incentive is not yet enough for low-income households to afford ZEVs. Both the newly proposed as well as the existing federal ZEV tax credits are non-refundable which means that purchasers should owe at least $7,500 in taxes to qualify for the full benefit – low-income households often do not owe this much, so they lose out on incentives intended to make ZEVs more affordable.

European EJ experts shared that financial incentives are needed to make ZEVs more affordable through loans and financing options for qualified individuals, rather than grants for all. Whilst it is a concern that there is a potential risk of putting more debt on those that cannot afford ZEVs, there is an expectation that the running cost of a ZEV helps to negate the impact of unaffordable debt. However, in-life benefits can only be accessed if one can afford the vehicle in the first place. Similar to the analysis conducted in the U.S., comparing the average purchase prices of new ICE and ZEV private cars in the Netherlands clearly shows the higher purchase costs for ZEVs. Especially there is a significant price difference of 76% for sub-minis and 36% for small vehicles compared to ICE equivalents. This relative price difference becomes smaller with an increase in vehicle size. The average price of large ZEVs (not depicted in graph) is even 10% lower compared to gasoline vehicles.

Figure 19. Average purchase price of new private cars in the Netherlands by car size[n]



Access to Charging Infrastructure

Lack of access to charging infrastructure is also one of the key barriers to increased ZEV adoption in low-income and disadvantaged communities. Lower income regions, especially those living in multi-family housing or those who rent their places, often do not have access to home charging, and instead have to rely on either workplace or public charging infrastructure if they decide to transition to ZEVs. A recent study conducted by Hsu and Fingerman (2021)[o] which demonstrated that public charger access is lower in block groups with below-median household incomes and in those with a Black and Hispanic majority populations. These public charger access disparities are more pronounced in areas with a higher proportion of multi-family housing, where they are critical for ZEV operation due to a lower likelihood of residential charger access.

While lack of access to charging infrastructure is a significant barrier, EJ experts shared that there are also concerns with charging infrastructure being a factor that causes gentrification and displacement in disadvantaged communities. This is especially important when considering that disadvantaged communities are challenged by increasing rent and basic needs costs. Indeed, discourse on electrified transportation can sometimes fail to consider indirect impacts on regions meant to benefit from expansion in the first place. EJ groups also advise to be wary in how we approach the prospect of investing in electric mobility with people who may not have the privilege to “care” about ZEVs. Thus, policy options for ZEV uptake and charging infrastructure deployment cannot be viewed as separate from the everyday struggles of

EJ communities face multi-issue struggles, and transportation electrification may not be a community priority for various reasons.

Participants stressed that EJ communities are rent burdened and struggle for basic needs, including food, transportation, and shelter. In this context, a participant shared that "How do we think of clean mobility if there is not even equitable access to transportation?"

community members; any policy considerations for ZEVs should consider the realities that impacted residents face.

Availability of Mobility Options

EJ experts in California and Michigan expressed that community members need a suite of mobility options from which they can choose. Participants noted that access to single occupancy ZEVs in itself would not address public health, air quality or climate crises; they suggested that policies should also focus on expanding access to micro-mobility, transit, and ZEV carshare. Many stakeholders shared that the regions they serve do not have basic access to public transit and that rural regions face additional barriers to different modes of transportation. In this context, a participant posed the issue in this way: "…how do we think of clean mobility if there's not even equitable access to transportation?" Another concern is that even with options such as bikeshare or scooter share, many regions do not have the infrastructure to safely use these modes. It is often the case that bike, and scooter share require people to ride on the road alongside cars, however community feedback surveys suggest that people would rather ride on the sidewalk (if there is one) than share the road with high-speed traffic.

In the workshop with European EJ experts, they collectively agreed that EJ in this context is about improving access to zero-emission mobility, rather than increasing ZEV ownership. It involves electrification of the wider transportation system and access to new and shared mobility (e.g., EV sharing, micro-mobility). Lower income groups and marginalized communities are more likely to travel by public transport or to use low-cost shared mobility alternatives (e.g., scooters). Indirect incentives for ZEVs, such as allowing ZEV drivers to use bus lanes, can have a negative impact on public transport and its users. At the same time, large investments on ZEV subsidies may askew investment away from improving public transport.

Scotland, for example, integrates the country's ZEV strategy in the sustainable transport system, prioritizing active modes, public transport and shared transport, in that order, before private cars. Scotland's goal is a 20 percent reduction in car kilometers by 2030 as they find that widening private vehicles would increase the negative external impacts of cars. These negative effects fall disproportionately on the most vulnerable communities without access to private cars (e.g., lower income households, disabled people and certain minority ethnic groups). By increasing mobility options and reducing car use Scotland aims to invest in streets and public spaces so they can be accessed safely and easily by everyone, thereby helping to address transport poverty and deliver a fairer Scotland[p].

Role of Policies and Programs

With representative concerns expressed by engaged EJ experts and groups in mind, we evaluated the role of policies and mechanisms that will be most effective to enhance EJ outcomes of ZEV policies. We offered our overview of equity and EJ programs hosted by utilities, local and state governments supporting efforts to make transportation and ZEVs more accessible. Many of these equity and EJ ZEV programs offer grant or incentive structures to provide immediate cash assistance towards the purchase of passenger ZEVs, such as NV Energy's proposed low-income ZEV rebates in Nevada. Some broader efforts are in the form of regulations that seek to ensure grid infrastructure is adequately fortified for more ZEVs on the roads, such as New York's Climate Leadership and Community Protection Act. Local efforts also play a key role in the accessibility to ZEVs by providing e-mobility options, such as the Twin Cities' HOURCAR or Rancho San Pedro's Electric Car Share ZEV programs, which offer access to ZEVs on a rate basis. More on proposed and current programs promoting equitable access to ZEVs and their infrastructure are described below.

Incentives

In Nevada, the NV Energy utility offers the Economic Recovery Transportation Electrification Plan (ERTEP) program. The plan approved a $100 million investment in transportation electrification and has reportedly reserved 51 percent of the funding for historically underserved regions. ERTEP intends to advance economic recovery and accelerate transportation electrification by strategically expanding charging station access across the NV Energy service territory. Namely, ERTEP will result in the deployment of more than 1,000 charging ports at highway stops, urban areas, public buildings, transit bus depots, and recreation and tourism destinations. Charging will be deployed to service a large vehicle portfolio, including light- through heavy-duty vehicles, electric water vessels, and even e-bikes and e-scooters. Additionally, an electric school bus vehicle-to-grid (V2G) trial will assess the benefits of utilizing bus batteries as grid resources for school districts and qualified customers. The benefit of V2G is that it has the potential to reduce electricity rates and increase grid reliability for customers[q].

ERTEP will prioritize the needs of disadvantaged communities by focusing on three areas: 1) providing low-cost energy for publicly available charging infrastructure through the NV Energy Electric Vehicle Charging Network Rate (as low as $0.05 per kWh during summer in Northern Nevada), 2) strengthening strategic outreach and partnerships to increase participation in the clean energy economy and workforce, and 3) prioritizing historically underserved regions where feasible. Reportedly, charging capabilities for early generation electric vehicles that are incapable of using DC fast chargers will be prioritized to benefit those who may have purchased used, older generation ZEVs.

There have been other incentive programs hosted by local government agencies that provide ease of cost burden for ZEVs. In California, the Beneficial State Foundation in partnership with California Air Resources Board (CARB) supported the Clean Vehicle Assistance Program, providing grants and affordable financing to help low-income Californians purchase or lease a new or used hybrid or electric vehicle. The Clean Vehicle Assistance Program is funded by

California Climate Investments, a statewide initiative that puts billions of Cap-and-Trade dollars to work reducing GHG emissions and improving public health, especially in disadvantaged communities. Qualified residents of California's disadvantaged communities are eligible for up to $5,000 in grants for a new or used battery-electric or plug-in hybrid EV, up to $2,500 in grants for hybrid ZEVs, and up to $2,000 in grants for at home charging station and installation support. This type of incentive structure took advantage of the broader ZEV market in California, where first-time ZEV buyers may be more inclined to peruse the used-car market to gain familiarity with ZEVs at more approachable prices. The Clean Vehicle Assistance Program also closely examined applicants based on their income and the CalEnviroScreen to ensure that residents of disadvantaged communities are the ones who benefit the most from electrified transportation opportunities. Applications to this program are now closed and is expected to serve the current waitlist of applicants over an undefined timeframe.

Clean Cars 4 All (CC4A) is another example of an incentive program in California that aims to enhance equitable access to ZEVs. The program provides incentives to help lower-income consumers living in and near disadvantaged communities replace their old higher-polluting vehicles with newer and cleaner transportation by reducing the purchase price. Options include the purchase of new or used hybrid, plug-in hybrid, or ZEV replacement vehicles. Furthermore, participants can choose an alternative mobility option such as an electric bike, a voucher for public transit, or a combination of clean transportation options allowed under the program in lieu of purchasing a replacement vehicle. In addition, buyers of plug-in hybrid and battery electric vehicles are also eligible for home charger incentives or prepaid charge cards if home charger installation is not an option. Participants must have a household income of less than 400 percent of the federal poverty limit and live in a zip code containing a disadvantaged community census tract. While in nature the program is similar to the Clean Vehicle Assistance Program, the scrappage requirement of the CC4A ensures that the program achieve surplus emissions reductions, and the high polluting vehicles are being taken off the road.

In addition to programs within U.S., ICCT's *Annual Update on the Global Transition to Electric Vehicles: 2021* briefing highlights other notable efforts to support ZEVs and charging infrastructure[r]. In a few countries across Europe (e.g., Norway, Sweden, Netherlands, Switzerland), much has already been done to achieve record-setting ZEV penetration levels within the single passenger and transit vehicle sectors. As a result, incentive structures have begun to prioritize different goals reflecting progress made to date. For instance, the U.K.'s ZEV purchase subsidy, originally £3,000, has been phased out for most standard passenger vehicles. Perhaps unintuitively, the reason for this decrease is because the U.K. had seen increased sales of plug-in cars, vans, and motorcycles through December 2021, which was when the government announced that the grant scheme for ZEVs was updated to target less expensive models to stretch the funding further and to help more people make the switch to a ZEV. The U.K. government states that the grant scheme has successfully provided the ZEV market enough momentum that ZEVs are now more affordable, and that £1,500 can be used to help more consumers choose from over 20 models under £32,500.

Similarly, the new government of Germany announced changes to their ZEV purchase subsidies due to the ZEV market's steady success. Under the plan, the incentives for ZEVs priced below €40,000 will fall from €6,000 to €4,500 by next year, and then fall again to €3,000 in the following year. For cars priced over €40,000, incentives will drop to €3,000 at the start of next year. Germany's Economy Minister justifies these changes to the country's ZEV incentives by citing that ZEVs are becoming increasingly popular and will not need government subsidies in the foreseeable future. The Economy Minister also maintains that the next funding phase is intended to go "all-in" on BEVs for the greatest climate protections.

The Netherlands also decreased their ZEV purchase subsidies in 2023, from €3,350 to €2,950 for new purchases, while subsidies for secondhand ZEVs remained at €2,000. These incentives are for ZEVs priced below €45,000. Looking back at Figure 19 it is clear that the purchase subsidy does not make up the price difference between ZEV and ICE vehicles (e.g., small cars have an average price difference of almost €10,000)[s].

Regulations

The policy landscape also features regulations that are directed to address ZEV accessibility more systematically. In California, CARB adopted the Advanced Clean Cars (ACC) II, which would take the state's already growing ZEV market and robust motor vehicle emission control rules and augment them to meet more aggressive tailpipe emissions standards and ramp up to 100 percent ZEVs. The proposed regulation supports Governor Newsom's 2020 Executive Order N-79-20 that requires all new passenger vehicles sold in California to be ZE by 2035. As early as 2026, 35 percent of new vehicle sales must be ZEV and PHEV, and the sales requirement increases by an average of 8 percentage points per year between 2026 through 2035, at which point 100 percent of new vehicle sales would be ZEVs. The ACC II regulation is one of the first regulatory ZEV actions that includes specific EJ strategies embedded in it. As part of the ACC II, car manufacturers could receive EJ credits for increasing affordability of ZEVs for California low-income and disadvantaged communities. To earn EJ credits, manufacturers would have to provide a discount for use of ZEVs in a community-based clean mobility program. In addition to the clean mobility option, the ACC II program also offer manufacturers the chance to earn EJ credits for retaining pre-owned ZEVs in California. According to the regulation, ZEVs and PHEVs originally leased in California with an MSRP of less than or equal to $40,000 when new, adjusted for inflation, can earn additional EJ credits, if the vehicle is subsequently sold to a dealership participating in a financial assistance program for pre-owned ZEVs, including Clean Cars 4 All and the Clean Vehicle Assistance Program.

California Advanced Clean Cars II is one of the first regulatory actions that includes explicit policy mechanisms for increasing affordability of ZEVs for California undeserved communities.

The EJ credits could be used to meet the ZEV mandates in model years 2026-2031, with a 5% cap on the number of EJ credits allowed to fulfill a manufacturer's obligation in any year. To earn EJ credits, manufacturers would have to provide a discount for use in a community program.

The European Union (EU) also boasts strengthened ZEV regulations and infrastructure strategies that seek to systematically accelerate ZEV adoption and deployment of charging equipment. In July 2021, the EU released multiple proposals as a part of the "Fit for 55" package. In one proposal, the EU revises its CO_2 emissions for new passenger cars and vans where fleet-wide CO_2 emissions would need to be cut by 55 percent and 50 percent by 2030, respectively, from 2021 levels. Although still under discussion, the proposal also seeks to reduce light-duty fleet CO_2 emissions to 0 g CO_2/km by requiring 100 percent new ZEV (only BEVs and FCEVs) sales by 2035. In another proposal, EU lays out a plan to implement an Alternative Fuel Infrastructure Regulation, which would require that each EU Member State to have at least 1 kW of publicly accessible charging potential for each BEV and 0.66 kW for each PHEV registered. The proposal also sets minimum requirements for the rollout of charging stations and hydrogen refueling stations serving HDVs across the Trans-European Network for Transport (TEN-T) and related urban nodes in addition to overnight truck parking areas. Such requirements could significantly increase access to zero-emission infrastructure across Europe which could, to some extent, address one of the most critical barriers to equitable EV adoption in low-income and disadvantaged communities. However, it should be noted that the proposal does not provide any incentive for such infrastructure to be placed in underserved regions, and it is possible that the wealthy regions may benefit more from such a network. Additionally, the European Commission has also claimed that the proposed stringent CO2 emission performance standards will trigger manufacturers to increase the supply of ZEVs, and with that increased supply, consumers can benefit from more affordable zero-emission vehicle models and significant energy savings from the use of zero-emission vehicles, hence decreasing the total cost of ownership of such vehicles.

A notable development within the U.K. is the government's recent decision to expand electric charging infrastructure for people without at-home charging. The U.K. government recently proposed £1.6 billion in funding to develop as many as 300,000 public charging stations by 2030[t]. The expansion will follow the Electric Vehicle Infrastructure Strategy, which would make it so that there are almost 5 times as many EV chargers as there are fuel pumps[u]. Reportedly, the strategy aims to expand the U.K.'s charging network so that it is fair and covers the entire country, with special emphasis on supporting consumers without access to off-street parking. To this end, £450 million is committed to establish the Local Electric Vehicle Infrastructure (LEVI) fund to initiate public on-street charging projects, which must demonstrate innovation and that the project would benefit regions without at-home charging solutions. Announced earlier this year, the LEVI scheme allowed local authorities and partnerships in England to apply for a share of the funding. As of August 2022, 9 local authorities, including North Yorkshire, will share about £30 million in funding to create new, commercial EV charging infrastructure for residents - project plans vary in style, from faster on-street charging stations to large petrol station-style charging hubs[v]. These projects are expected to create over 1,000 public charging stations and have a marked impact on residents without private driveways to have better access to EV chargers.

In New York, the CCPA focuses on reaching net zero GHG emissions by 2050, intending to achieve this through significant transportation electrification. The CCPA includes a requirement that at least 35 percent of the benefits are realized by historically disadvantaged communities. Additionally, New York is a signatory to the Multi-State ZEV Memorandum of Understanding, which commits it to have 850,000 ZEVs on the roads by 2025. Pursuant to these goals, the Public Service Commission directed its staff to develop a report on New York's infrastructure needs over the long term to support widespread transportation electrification. This ultimately led to an order requiring New York's regulated utilities to establish ambitious make-ready programs, collectively totaling more than $700 million. The commission also recognized the importance of equitable access to charging infrastructure and authorized higher incentives for investments in low- to moderate-income (LMI) and disadvantaged communities. In addition, it established specific prizes to reduce air pollution and increase mobility in disadvantaged and EJ areas. Transit and medium- and heavy-duty specific programs were also authorized and must support a direct reduction in emissions in disadvantaged communities in addition to funding for DCFC sites in rural regions.

These are just a few examples of the type of policies being implemented in the North American and European markets, with the goal of enhancing equitable access to ZEV and e-mobility. Of course, most of these programs have been recently developed and implemented, although there are some, such as CC4A that started back in 2014. Therefore, it remains to be seen how successful these programs could be in enhancing ZEV adoption in low-income and underserved regions. As illustrated in Section 2, in all three markets that we studied, there remains a significant disparity when it comes to ZEV ownership.

Recommendations

Through our EJ stakeholder engagement, it became evident that EJ is about centering justice, addressing the disparities in air quality, and ensuring community access to green investments. EJ stakeholders emphasized that EJ is a response to environmental racism; environmental health disparities are linked to discriminatory practices such as redlining and the citing of major pollutant sources near communities of color and lower income regions. Additionally, EJ stakeholders shared that EJ is not only about preventing environmental harms but also ensuring that green investments benefit disadvantaged communities is an equally important aspect of EJ. Here in this section, we will summarize some of the recommendations from the EJ stakeholders as well as those of ours based on the quantitative and qualitative analysis conducted in this study on how governments could enhance the EJ outcomes of ZEV policies.

Leverage the Expanding Pre-Owned ZEV Market

The pre-owned vehicle market provides a great opportunity for more affordable ZEVs. Inclusive programs to offer not just new but also pre-owned ZEVs would be beneficial to disadvantaged communities. As referenced previously, California's Advanced Clean Cars II has developed a new concept to give credits to pre-owned ZEVs coming off a lease. The IRA calls out a package of incentives for clean vehicles including pre-owned ones. As it stands now, the IRA is planning to offer a new credit of $4,000 or 30% of the vehicle sale price (whichever is lower) for pre-owned ZEVs for purchasers with income less than $75,000 (or $150,000 for a joint return). Additionally, potential first-time buyers should be assured of the quality and safety of pre-owned ZEVs. In example, the United Nations Economic Commission for Europe (UNECE) has proposed regulations regarding minimum threshold requirements for battery durability and performance. Notably, one of UNECE's proposals would require that electric vehicles retain at least 70 percent of their rated usable energy after either an 8-year period or 161,000 km[w]. This is similar to Advanced Clean Cars II warranty and durability requirements to ensure a stable supply of higher quality pre-owned ZEVs. This sort of standardized requirement would enable greater numbers of second-hand ZEV owners and increase transparency overall on ZEV reliability and capability. These efforts are certainly steps in the right direction to expanding the used market of ZEVs and making them affordable for lower income households.

Public Charging and Fueling Infrastructure

As discussed earlier, lack of access to charging and fueling infrastructure is one of the key barriers for lower income regions to transition to ZEV. Often these regions should rely on publicly accessible fast charging and fueling stations to meet their day-to-day needs. When deploying public charging and fueling infrastructure, governments need to ensure that the deployment of these infrastructures will have direct benefits in low-income and disadvantaged communities. Prioritizing equity does not always translate to placing chargers within disadvantaged communities, but the focus should be on how to maximize zero-emission operation within these regions. Governments can leverage data analytics and travel data in determining strategic placement of charging and fueling infrastructure to attract a higher fraction of ZEVs within the underserved regions. For example, in California, Senate Bill (SB) 1000[x] (Lara, Statutes of 2018, Chapter 368) requires the CEC to assess whether EV charging station infrastructure, including DCFC, is disproportionately deployed by population density, geographical area, or population income level. In its most recent report[y], CEC conducted an analysis using the average drive time to public DCFC stations as a measure to identify fast charging network gaps that discourage EV travel within California communities and travel to and from those communities. Using these type of travel analyses, CEC is evaluating whether its investments are closing the gap on EV charging accessibility within disadvantaged communities.

EJ experts also recommended that governments should work directly with regions on identifying charging locations, considering multi-benefits such as possible economic opportunities for local businesses, and prioritizing affordable housing. In Europe, EJ stakeholders recommended ensuring legal right to be able to install a charge-point in a rented or leasehold home with off street parking so that landlords cannot stop a tenant with an ZEV installing a home charger. Similarly, the United States has several S1777s with "right-to-charge" legislation intended to broaden access to at-home charging.

Targeted Incentives toward Lower Income Regions

Supporting transportation electrification will continue to require direct aid and systemic adoption pathways, especially in disadvantaged communities, where barriers to entry are demonstrably high and poor air quality persists. Incentives are critical to move the fated transition to ZEVs along, but it is not reasonable to assume that they will be able to offset the cost of every single ZEV and charging station. Improving accessibility to incentives has undoubtedly accelerated initial commercialization of ZEVs, but the onus is on federal, state, and local governments to have programs directed at disadvantaged communities. It needs to be emphasized that such policy changes should come with more streamlined processes to ensure that funds can be expended as effectively and expeditiously as possible. Complex processes to verify eligibility could inhibit the successful implementation of incentive programs and thus reduce their effectiveness. More streamlined processes, such as Oregon's income eligibility calculator that enables users to instantly determine their eligibility for low-income adder rebates, may inspire future incentive acquisition processes. Top-down approaches that are well-informed and backed by community-driven decisions will offer the best strategy to make the transition to ZEVs most equitable.

> **Incentives are critical to move the fated transition to ZEVs along, but it is not reasonable to assume that they will be able to offset the cost of every single ZEV and charging station.**

Supporting transportation electrification will continue to require direct aid and systemic adoption pathways, especially in disadvantaged communities, where barriers to entry are demonstrably high.

As federal, state, and local government agencies examine options to offer greater funding opportunities for ZEV adoption, current and proposed programs have room for improvement by being made more user friendly. At the same time, regions may not be aware of available grants or incentive programs if information is kept online. Many community members rely on local news channels for their understanding of the economy or changes in infrastructure that would affect their day-to-day life. One strategy ZEV governments may consider streamlining the use of incentives by low-income people is to continue using EJ mapping tools to determine which regions qualify for programs, and then send informational packets in the mail to inform regions about applications they can submit then, or about events they can attend in the near future to learn more. These resources should also be made available in a variety of languages, similar to how ballots are commonly available in a region's top 10-12 languages. The idea is to eliminate doubts people have about their eligibility for resources while also making grants and incentives easy enough to apply to that community members follow through the entire process.

Community-Driven Decision-Making

Community driven decisions are key to building more inclusive and equitable policies. During the EJ stakeholder engagement, experts shared that community members need to be engaged early and be part of the decision-making process in order to have equitable outcomes. Equitable outcomes can include implementing policies and programs that regions actually want, providing multiple co-benefits such as local job creation, and mitigating further harm such as reduced parking and rent increases. The participants also emphasized the timing of policies. As ZEV uptake increases and becomes market-led, policies will need to be reshaped to target those left behind.

Support Regions' Mobility Alternatives

Although the major foci of this research report are ZEVs and the potential air quality and public health benefits that can result from introducing more of them to regions, it is obvious that light-duty vehicles are not the only mobility option that people advocate for. Many stakeholders shared that the regions they serve do not have basic access to public transit and that rural regions face additional barriers to different modes of transportation. Simply put, not every community member is interested in owning a car if there are alternative mobility options that

are preferable. Depending on the proximity to city centers or maturity of network, public transit can be one of the most effective transportation modes available to low-income and urban-bound people. When powered by zero emission technology, this mode of transportation accomplishes one of the same goals as advocacy for ZEVs in EJ policies, which is to mitigate tailpipe emissions from ICE vehicles. In recent years, e-bikes and e-scooters have also gained public acceptance as a micro-mobility option.

The Role of Electrifying Medium- and Heavy-Duty Trucks

Despite broad efforts to improve air quality and public health, large metropolitan areas that are home to people of all income bands and racial/ethnic backgrounds, such as Los Angeles and Detroit, still suffer from high levels of air pollution. It is often the case that the marginalized and low-income shoulder the greatest air pollution and health burdens due to their proximity to industrial complexes and congested traffic zones. Within the nexus of disadvantaged communities and the transportation sector, medium- and heavy-duty diesel trucks are some of the worst offenders. At the same time, these vehicles are responsible for much of the goods movement that empowers local economies. The solution to mitigating EJ issues that current medium- and heavy-duty truck fleets present is to transition this sector to zero-emission technologies. Much of the overall approach taken to introduce more zero-emission light-duty vehicles onto the roads can be applied for medium- and heavy-duty vehicles, where grants and incentives can address immediate needs of drivers and zero-emission oriented policies can direct zero-emission truck supply and expectations.

In recent years, California has made several strides to transition its medium- and heavy-duty vehicle sector to zero emission through both regulatory as well as incentive programs. For example, the state has recently adopted (or is in process of adoption) several regulations which require both the supplier of the medium- and heavy-duty vehicles (i.e., manufacturers) to sell zero emission vehicles in California and Californian consumers (i.e., fleets operating in California) to purchase those trucks. On the supply side, the Advanced Clean Trucks (ACT) regulation is a manufacturers ZEV sales requirement which applies to vehicles with a GWVR greater than 8,500 lbs. and manufacturers with greater than 500 annual California sales. The regulation requires manufacturers to produce and deliver zero emission trucks in California. By 2035, the regulations will require 55 percent of Class 2b-3[16], 75 percent of Class 4-8[17] vocational (i.e., any

[16] Class 2b-3 refers to vehicles with GVWR between 8,501 - 14,000 lbs.
[17] Class 4-8 refers to vehicles with GVWR greater than 14,000 lbs.

class 4-8 trucks excluding class 7-8[18] tractors), and 40 percent of Class 7-8 tractors sold in California to be zero emission. CARB adopted the ACT regulation in June 2020 with the first sales requirement kicking in 2024. Upon the adoption of the ACT regulation in California, 15 states and the District of Columbia announced a joint memorandum of understanding (MOU), committing to working collaboratively to advance and accelerate the market, with the goal of reaching 100 percent of all new medium- and heavy-duty vehicle sales to be zero emission vehicles by 2050, and with an interim target of 30 percent zero-emission vehicle sales by 2030.

In the meantime, CARB is working on a complementary regulation to create consumer demand for zero emission trucks in California. The Advanced Clean Fleet (ACF) regulation, planned for board consideration in early 2023, seeks transition of fleets to zero emission vehicles and will focus on setting two major ZE truck requirements. The first is a ZE vehicle purchase schedule for public fleets. The second is 100% ZE requirements for drayage[19] and high priority[20]/federal fleets. Specific to drayage trucks, these are the trucks that operate in low income and disadvantaged communities near ports and railyards. By requiring all drayage trucks in California to transition to zero emission by 2035, the state is intending to accelerate the emissions and public health benefits of the ACF regulation in its low income and disadvantaged communities.

While policy actions such as ACT and ACF are key in accelerating the adoption of zero emission trucks, the full transition of medium- and heavy-duty vehicles to zero emission technology will not be possible without financial incentives. As described, current regulations, such as ACF, are primarily targeting public, drayage, federal, and high priority fleets, while smaller fleets that do not fall into any of these categories may be left unregulated. Additionally, California's regulations are only focusing on vehicle adoption, while there is an imminent need to prepare and build charging and fueling infrastructure needed to support these vehicles. This is where incentive programs could play a significant role in facilitating this transition. Notably, California has already established several incentive programs that have been instrumental in facilitating the adoption of zero-emission vehicles. For example, the Hybrid and Zero-Emission Truck and Bus Voucher Project (HVIP) is a point-of-sale incentive program that provides a voucher up to $120,000 for zero-emission trucks. At the time of writing this report, the program has supported the purchase of 1,800 battery-electric trucks since 2010 (redeemed vouchers), and over half of all

[18] Class 7-8 refers to vehicles with GVWR greater than 26,000 lbs.
[19] Drayage refers to trucks operating at ports and intermodal railyards in California
[20] California heavy-duty truck fleets are high priority if: 1) the fleet has 50 or more vehicles, or 2) the fleet earns $50 million in gross annual revenue

voucher requests have come from disadvantaged communities. Although HVIP has provided much needed resources for adopting clean technologies, it is one of California's most oversubscribed programs, a key issue especially for smaller fleets that do not have the resources to quickly apply for these grants and use them to transition their trucks to clean technologies. In response to these limitations, in 2021, CARB proposed amendments to the HVIP program by introducing fleet size limits. Beginning on January 1, 2023, private fleets with more than a total of 100 trucks and buses will no longer be eligible for HVIP incentives. This limit would be reduced to 50 trucks and buses beginning on January 1, 2024.

On the infrastructure side, the CEC's Clean Transportation Program[z] (CTP) is one of the key incentive programs in California intended to provide incentive for buildout of charging and fueling infrastructure for medium- and heavy-duty vehicles. Most recently, to facilitate distribution of the CTP funds allocated to medium and heavy-duty vehicles, the agency launched the EnergIIZE Commercial Vehicles block grant which will provide exclusive zero emission infrastructure funding to support the transition of medium- and heavy-duty vehicles to battery electric and hydrogen fuel cell vehicles. EnergIIZE also establishes four "Funding Lanes" each with differing qualifications and incentive structures. These funding lanes include:

- **EV Fast-Track**: Targeting zero emissions medium and heavy-duty fleets registered in California or have been purchased, funded or otherwise incentivized through state/federal projects.
- **EV Jump Start:** Targeting small businesses[21], certified Minority Business Enterprise, Woman-Owned Small Business, Veteran-Owned Small Business, or LGBT-owned small business. This funding lane is also available for transit agencies, school districts, or commercial fleet whose infrastructure will be located in a designated disadvantaged community. Additionally, the funding is available to California Federally Recognized Tribes and California Tribal Organizations, or commercial fleets that is a 501(c)(3) non-profit organization.
- **Public Charging Station**: Available to public charging station developers, who can show documentation providing adequate utilization and throughput for the proposed public charging stations. The funding shall be used to install DC fast chargers at capacities of 150 kW or higher (level 2 chargers are not eligible).
- **Hydrogen Fueling**: Available for medium and heavy-duty hydrogen fueling infrastructure projects only.

HVIP and EnergIIZE are only two examples of incentive programs advancing adoption of zero emission medium- and heavy-duty vehicles in California. There are multiple other examples across the U.S. as well as in other parts of the world that could be used as policy models for accelerating the transition of this sector to zero emission technologies.

[21] As recognized by the California State Legislative Code, Section 14837(d)

Resilience and Ability to Manage Change

The phase out of the incentive programs was one of the major concerns that was raised by EJ stakeholders. They noted that sooner or later the subsidy schemes will be removed, and this will cause a "shock of removal". Marginalized communities are not the typical early ZEV adopters and will be at risk in the long term. The phasing-out of incentives needs to be gradual and to take into account besides the environmental performance of technology, the usage, and miles driven by the ZEVs (road pricing tax example). The participants also brought up concerns regarding the operational costs of ZEVs. Potential rises in electricity prices and/or further cuts to fuel tax, in addition to road pricing and the introduction of tax on ZEVs, all of which will make ZEVs more expensive to own.

Job Transition

EJ stakeholders also explained that the transition to ZEVs presents challenges for truck drivers. There are several small independent truck drivers contracted by large truck companies. Without strong support for a smooth and just transition, policies that require fleet transition, with the goal of increased zero emission medium and heavy-duty operations in low-income and disadvantaged communities, can create harmful consequences for small truck drivers; the burden and cost of that transition could fall on individual workers. Given this risk, participants shared the need for allocating specific funding to support job transition. Similarly, there was a concern about small and local automobile repair shops that may not have the expertise to work on electric vehicles.

Stakeholders also shared that there may be opportunities to increase job options with the uptake of ZEVs. In order to take advantage of these types of job opportunities, there needs to be different types of workforce development training. A trained workforce is needed to manufacture, service and repair ZEVs, but Government schemes for capacity building are not well established. The maintenance and service requirements for ZEVs are significantly lower and this will result in more small garages closing. Professional drivers can often resist ZEV transition and training can help to overcome range anxiety or other related fears.

Appendix A: More on National Health Benefits from ZEVs

In this report's Environmental Justice Impacts of ZEVs section, ICF leverages *Evaluation of National Health Benefits from the Transition to Zero Emission Transportation Technologies*, an analysis conducted for the American Lung Association (ALA) of the potential health and climate benefits of a scenario for increasing on-road vehicle electrification across the United States. The electrification scenario analyzed in that report included both light- and heavy-duty vehicles and both *downstream* (tailpipe exhaust, evaporative, brake and tire wear) and *upstream* (reduced fuel production, transport, and refining activities for internal combustion vehicles and increased electricity generation for electric vehicles) emissions components along with two potential Cases for the nation's future electricity production. It presented results for both short-term (2030) and long-term (2050) projection years including the emissions that could be avoided and resulting public health and climate benefits from these reduced emissions. For the purposes of this report, ICF considers just the results from the ALA Report's Base Electricity Generation Case Scenario, a more business-as-usual projection for the electric grid, for all light- and heavy-duty vehicles.

The ALA report determines the vehicle categories considered, the sales fractions for ZEVs under the Scenario for each vehicle category, and the resulting penetration of ZEVs into the total national vehicle fleet. This is needed for comparison of ZEVs and for establishing baseline emissions by vehicle type, model year, and calendar year and their associated vehicle miles traveled. The study models years 2020, 2030, 2040, and 2050, and considers passenger vehicles, light heavy-duty trucks, medium- and heavy-trucks, and school buses. All national fleet and activity data for the baseline and business-as-usual Scenarios are based on data in US EPA's MOVES3 model.

From this, the ALA Report formulates an objective to achieve 100% ZEV sales by 2035 for passenger vehicles (less than 8,500 lbs. GVWR) and by 2040 for the rest of the fleet (i.e., above 8,500 lbs. GVWR). This study continues to use BEVs as a marker for zero emission technologies, anticipating that the market for most ZEVs will be addressed through BEVs. Also, for simplicity it substitutes ZEVs for traditional ICE vehicles one-to- one, excluding any replacement of existing ZEVs. The ZEV sales projections for light-duty vehicles modeled for the ALA Report are shown in Figure A-1; the ZEV sales projections for medium- and heavy-duty vehicles modeled for the ALA Report are shown in Figure A-2. For school buses California's Innovative Clean Transit (ICT) regulation[aa] requires large transit agencies to have 25 percent, 50 percent, and 100 percent of their new purchases to be zero emission starting from 2023, 2026, and 2029, respectively.

The ALA Report uses the ZEV sales projections to determine the penetration of electric vehicles into the national vehicle fleet by vehicle category, fuel type, and model year for its increased ZEV Scenario. The business-as-usual and ZEV Scenario are used as the basis for modeling emissions nationally, including PM2.5, NOx, VOC, and GHGs. Emission reductions and emission benefits are subsequently quantified and further processed in tools such as US EPA COBRA model to estimate public health benefits on a county basis. Tables A-1 through A-6 describing the total cumulative health impacts for California and Michigan, broken down by light-duty and heavy-duty vehicles, using 3% and 7% discount rates, are available for reference in Supplementary Data and Charts.

Figure A-1. Light-Duty Zero Emission Vehicle Sales Trajectories

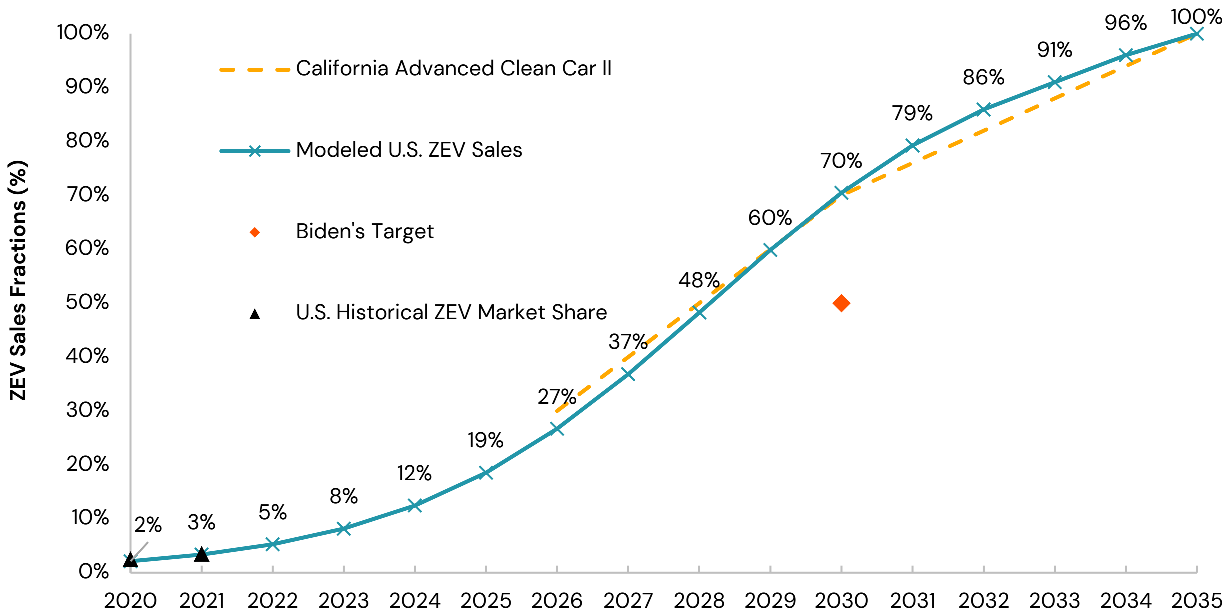
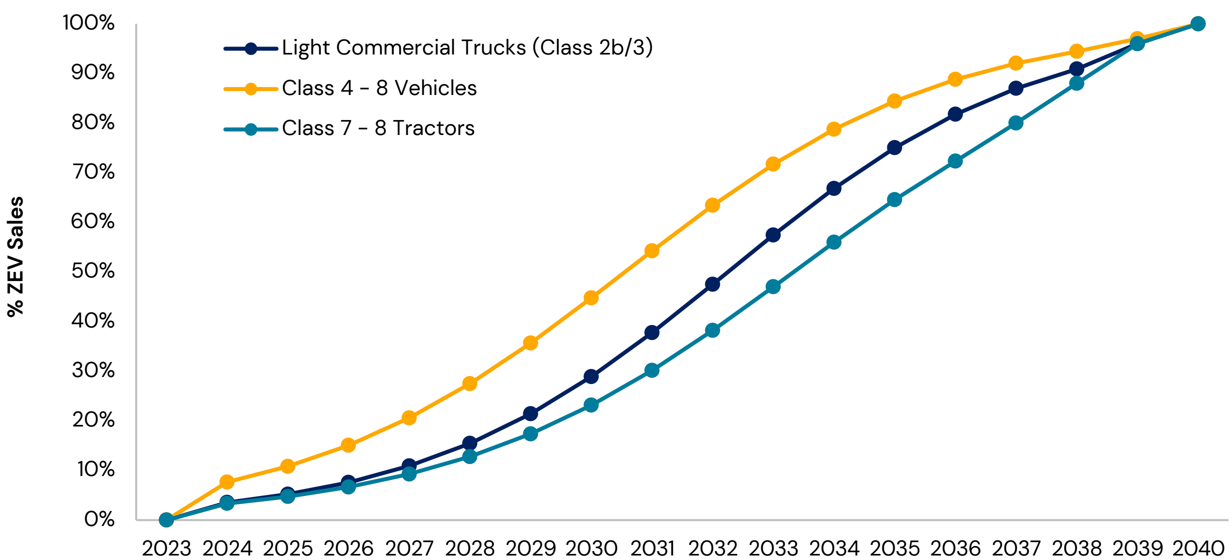


Figure A-2. Medium- and Heavy-Duty Vehicle Sales Trajectories



Supplementary Data and Charts

Table A-1. California State-Level Cumulative Health Impact Summary for 2020-2050 Under the Total Vehicle Scenario (Light-Duty and Heavy-Duty Combined) and the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$) 3% Discount	2020-2050 Monetary Health Benefits (Million 2017$) 7% Discount
Mortality, low estimate	8,690	$94,700	$85,300
Mortality, high estimate	9,280	$101,000	$91,200
Hospital Admits, All Respiratory	2,420	$95.2	$95.2
Emergency Room Visits, Asthma	3,680	$2.07	$2.07
Work Loss Days	1,310,000	$262	$262
Total, low estimate (in Millions)		$95,100	**$85,700**
Total, high estimate (in Millions)		$101,000	**$91,600**

Table A-2. California State-Level Cumulative Health Impact Summary for 2020-2050 for Light-Duty Vehicles in the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$) 3% Discount	2020-2050 Monetary Health Benefits (Million 2017$) 7% Discount
Mortality, low estimate	4,760	$51,700	$46,600
Mortality, high estimate	5,090	$55,200	$49,800
Hospital Admits, All Respiratory	1,310	$51.8	$51.8
Emergency Room Visits, Asthma	1,990	$1.12	$1.12
Work Loss Days	717,000	$144	$144
Total, low estimate (in Millions)		$51,896	**$46,796**
Total, high estimate (in Millions)		$55,396	**$49,996**

Table A-3. California State-Level Cumulative Health Impact Summary for 2020-2050 for Heavy-Duty Vehicles in the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$)	
		3% Discount	7% Discount
Mortality, low estimate	3,930	$43,000	$38,700
Mortality, high estimate	4,200	$46,000	$41,500
Hospital Admits, All Respiratory	1,100	$43.4	$43.4
Emergency Room Visits, Asthma	1,700	$0.95	$0.95
Work Loss Days	593,000	$119	$119
Total, low estimate (in Millions)		**$43,163**	**$38,863**
Total, high estimate (in Millions)		**$46,163**	**$41,663**

Table A-4. Michigan State-Level Cumulative Health Impact Summary for 2020-2050 Under the Total Vehicle Scenario (Light-Duty and Heavy-Duty Combined) and the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$)	
		3% Discount	7% Discount
Mortality, low estimate	728	$8,010	$7,210
Mortality, high estimate	764	$8,400	$7,570
Hospital Admits, All Respiratory	166	$6.190	$6.190
Emergency Room Visits, Asthma	375	$0.211	$0.211
Work Loss Days	82,500	$16.5	$16.5
Total, low estimate		**$8,030**	**$7,230**
Total, high estimate		**$8,420**	**$7,590**

Table A-5. Michigan State-Level Cumulative Health Impact Summary for 2020-2050 for Light-Duty Vehicles in the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$)	
		3% Discount	7% Discount
Mortality, low estimate	245	$2,710	$2,450
Mortality, high estimate	253	$2,810	$2,530
Hospital Admits, All Respiratory	54	$1.99	$1.99
Emergency Room Visits, Asthma	131	$0.073	$0.073
Work Loss Days	28,800	$5.76	$5.76
Total, low estimate		**$2,717**	**$2,457**
Total, high estimate		**$2,817**	**$2,537**

Table A-6. Michigan State-Level Cumulative Health Impact Summary for 2020-2050 for Heavy-Duty Vehicles in the Base Case

Health Endpoint	Number of Cases	2020-2050 Monetary Health Benefits (Million 2017$)	
		3% Discount	7% Discount
Mortality, low estimate	483	$5,290	$4,770
Mortality, high estimate	511	$5,600	$5,040
Hospital Admits, All Respiratory	112	$4.21	$4.21
Emergency Room Visits, Asthma	245	$0.138	$0.138
Work Loss Days	53,700	$10.7	$10.7
Total, low estimate		**$5,305**	**$4,785**
Total, high estimate		**$5,615**	**$5,055**

Figure A-3. Cumulative Monetized Health Benefits (CHMB) per capita, PM2.5 Concentration (From Left to Right)

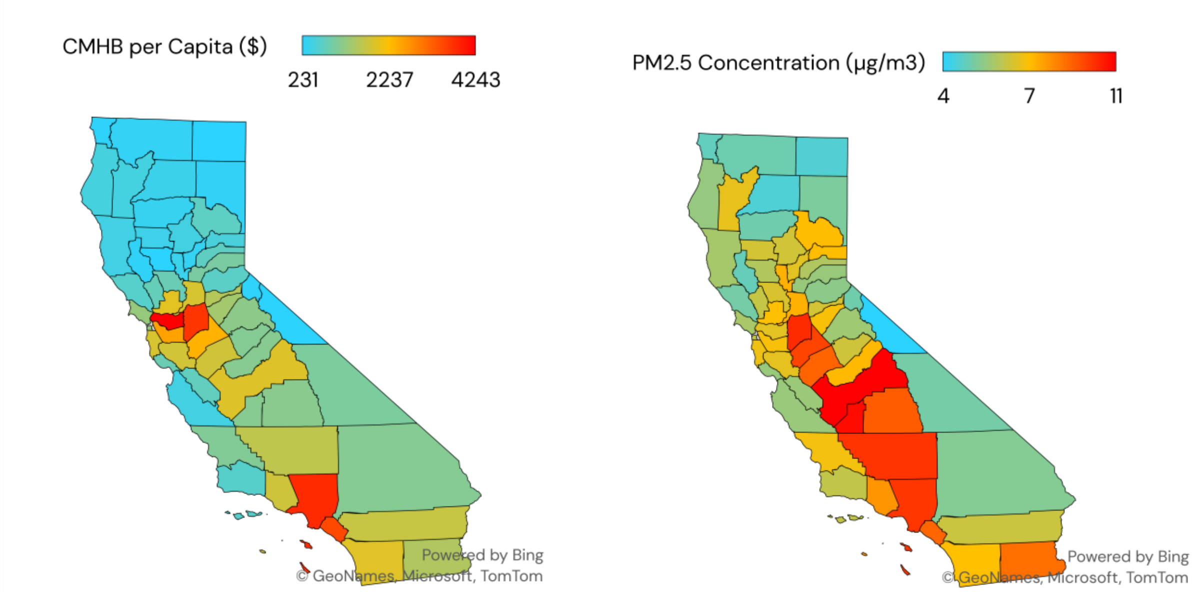
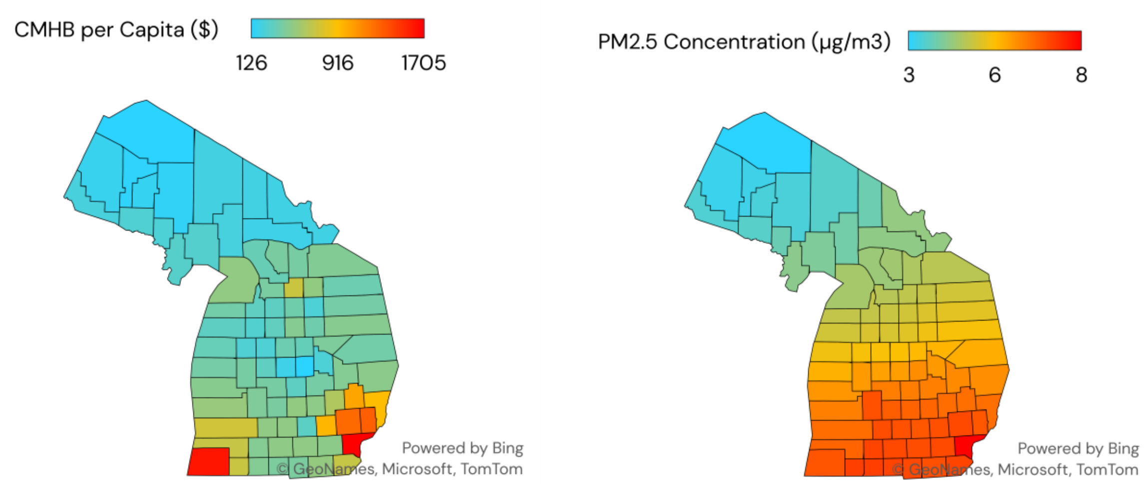


Figure A-4. Cumulative Monetized Health Benefits per capita, PM2.5 Concentration (From Left to Right)

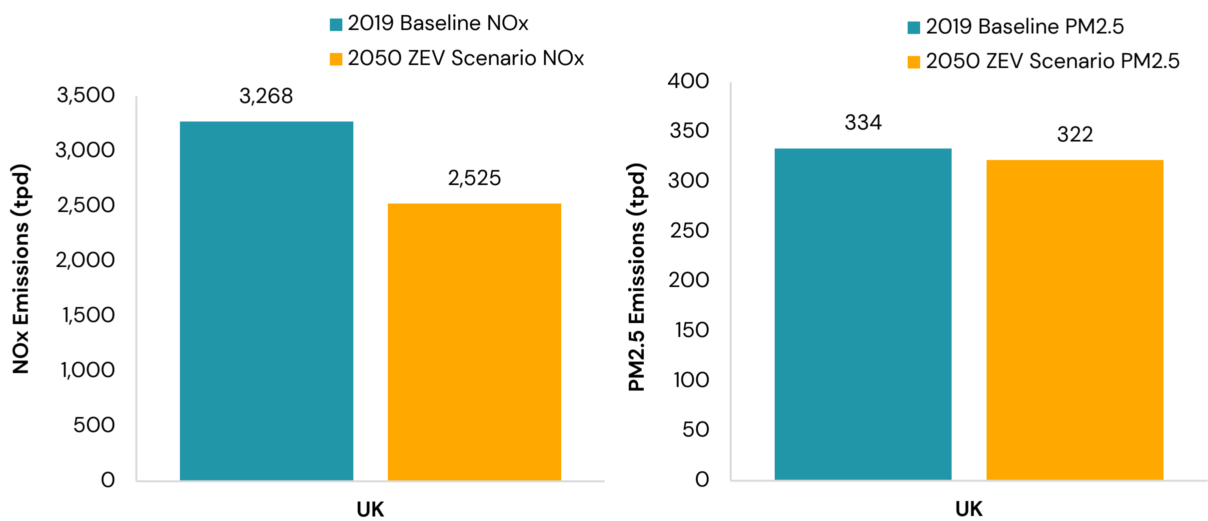


Appendix B: Emission and Health Benefits of Increased ZEV Adoption in the U.K.

In addition to California and Michigan, the project team also quantified the potential emissions and health benefits associated with the increase adoption of ZEVs in the U.K. To do that, the team leveraged the national emissions data produced by the U.K. Department for Transport which shows that on-road transportation is responsible for 23 percent of national level NOx and 3.5 percent of national level PM2.5 emissions.

To assess the impact of ZEV adoption on the overall emissions, the project team developed a ZEV uptake scenario with the assumption that sales of various categories of on-road vehicles (e.g., light duty, heavy duty, and buses) will fully transition to zero emission technologies by 2035. Under such scenario, the project team estimated that by 2050, NOx and PM2.5 emissions from on-road vehicles will be reduced by more than 98 percent which translates to approximately 743 tpd of NOx and 11.6 tpd of PM2.5 emissions reductions. The impact of such reductions on the overall national emission of NOx and PM2.5 is illustrated in Figure B-1.

Figure B-1. U.K. total emissions of NOx and PM2.5 (all sources) under Baseline and ZEV Scenarios



Following the emissions reductions assessment, the project team also quantified the potential health benefits resulting from such reductions. Utilizing the Damage Costs Appraisal Toolkit[bb] from the U.K. Department of Transport Green Book, the project team was able to translate the cumulative NOx and PM2.5 emissions benefits (2020 through 2050) to monetary health benefits using the £/ton transport damage cost for NOx and PM2.5. The benefits are shown in Table B-1. As shown, our analysis has demonstrated that the mass adoption of ZEVs in the U.K., could results in cumulative monetary health benefits of £38 - £42 billion from 2020 through 2050.

Table B-1. Monetary Health Benefits of Mass Adoption of ZEVs in the U.K.

Pollutant	Cumulative Emissions Reductions 2020 - 2050 (1000 tons)	Public Health Benefits (£ million)	
		3% discount	7% discount
NOx Road Transport	4,067.4	£36,875	£33,217
PM2.5 Road Transport	63.4	£5,168	£4,655
	Total	**£42,043**	**£37,872**

Appendix C: Engagement with EJ Experts

EJ Experts

In California, we interviewed 5 EJ experts and engaged with 8 experts in the workshop. These experts represented administrators of ZEV programs and community-based organizations working on public health, transportation policy, EJ, and housing. These organizations are listed below:

- Community Environmental Council
- Central Coast Alliance United for a Sustainable Economy (CAUSE)
- Clean Cars For All
- Grid Alternatives
- Regeneración
- Physicians for Social Responsibility Los Angeles
- Transform
- Adrian Gomez, Forth and formerly with Beneficial State Foundation

For Michigan, we interviewed 5 EJ experts and engaged with 6 EJ groups for the focus group discussion. These experts represented community-based organizations working on transit, racial equity, EJ, and policy. These organizations included:

- Eastside Community Network Detroit
- Southwest Detroit Environmental Vision
- NAACP Grand Rapids Chapter
- Transportation Riders United
- Greenlining Institute
- Equiterre (Canada)

For the U.K. and EU, we interviewed 5 EJ experts and stakeholders and engaged with 7 EJ experts and stakeholders for the focus group discussion. The engaged experts and stakeholders range from academic experts to local governments. These organizations included:

- Generation Climate Europe
- RoadPeace
- Local Government Association
- REA (Renewable Energy Association)
- Urban Transport Group
- TIER Mobility
- IPPR (Institute for Public Policy Research)
- Sustainability West Midlands
- UCL (University College London)
- Delft University of Technology, Transport Policy Department

Interview Questions

1. Please tell us about your organization and your role within it.
2. What is your understanding of the term EJ? What work do you do that relates to EJ?
3. Please give some background on some of the communities you work with.
4. Regarding the communities, you know of/work with how this work is related to climate change, air quality and/or electric vehicles (if at all).
5. What is the communities' level of engagement in climate change, air quality, and electric mobility? Please tell us about their level of understanding and interest in the subjects.
6. What barriers and challenges do the communities you work with face when considering clean mobility options?
   - Prompt/Clarification: In general, and then particularly for transportation and ZEVs, economic.
7. How does the adoption of ZEVs in your community compare to other nearby communities or even the country?
8. What are the economic and environmental impacts that disadvantaged communities may face in the transition to clean transportation and uptake of ZEVs?
9. What are the economic opportunities & barriers for disadvantaged communities associated with transitioning to transportation electrification?
   - How can we ensure that disadvantaged communities understand and receive economic opportunities from electric transportation?
10. Do you have any data on car ownership, travel, transport, or EV-related topics that you may be able to share to aid in the analysis?

Workshop Policy Scenarios and Questions

For the online workshop, the project team presented the group with a selection of EV policy scenarios that represent different approaches taken across the world and/or could be taken. These scenarios are developed through previous work exploring consumer impacts of EV uptake and in partnership with the project consortium. The workshop participants were asked to provide inputs into the different scenarios and explore how they may impact disadvantaged communities in the three studied markets. The group were then asked to give their examples or ideas for EV policies. Below is a list of policy scenarios and questions that were discussed during the workshops:

1. Incentives for used and new electric vehicles
   a. Context: Incentives for accessible used and new electric vehicles are available at the point of purchase. There is a decrease in the upfront costs for an electric vehicle.
   b. Questions for working group: For each policy scenario, we asked the following set of questions:
      - What are your thoughts on this policy scenario?
      - What are the economic impacts?

  - What are the access impacts?
  - What are the indirect impacts?

2. Financing programs for used and new electric vehicles
   a. Context: Financing programs for electric vehicles are accessible to low-income consumers. Borrowers can easily access non-predatory auto loans to purchase electric vehicles.
   b. Questions for working group: Same as above

3. Funding availability for increased access to charging infrastructure
   a. Context: State and local governments are able to apply for funding for local charging projects.
   b. Questions for working group: Same as above

4. Charging infrastructure at apartment complexes/MUDs, Affordable Housing
   a. Context: Charging infrastructure is prioritized at Apartment Complex/MUDs,
   b. The role of building codes
   c. Questions for working group: Same as above

5. Sustainable shared mobility is prioritized
   a. Context: Funding for electrifying transit, micromobility, electric carsharing & ridesharing, and creating mobility hubs with micromobility (electric bikes, e-scooters, etc.) is prioritized (/affordable). Mobility Wallet
   b. Questions for working group: Same as above

6. Policies are enacted that making it more difficult to access an electric vehicle
   a. Context: Financial incentives such as rebates, grants, and tax credits are reduced or eliminated. Registration fees are increased for electric vehicles. Insurance rates increase for electric vehicles
   b. Questions for working group: Same as above

7. Standards on Electrifying Medium- Heavy Duty Vehicle
   a. Context: Requires entities to electrify Medium- Heavy Duty vehicles within a certain time frame.
   b. Focus on sectors with highest impact in low income and disadvantaged communities (DAC)
   c. What policies can increase EV operation of MD/HD vehicles in DACs?
   d. Questions for working group: Same as above

References

[a] http://www.zevalliance.org/wp-content/uploads/2019/12/ZEV_access_workshop_report-_fv.pdf

[b] Zeroing in on Healthy Air, American Lung Association (2022). Link: https://www.lung.org/getmedia/13248145-06f0-4e35-b79b-6dfacfd29a71/zeroing-in-on-healthy-air-report-2022.pdf

[c] Hsu, C. W., & Fingerman, K. (2021). Public electric vehicle charger access disparities across race and income in California. Transport Policy, 100, 59-67.

[d] U.S. EPA, Clean School Bus Program, https://www.epa.gov/cleanschoolbus/school-bus-rebates-clean-school-bus-program

[e] U.S. EPA https://www.epa.gov/environmentaljustice

[f] California Energy Commission (2022). Light-Duty Vehicle Population in California. Data last updated April 29, 2022. Retrieved June 29, 2022, from https://www.energy.ca.gov/zevstats

[g] https://www.atlasevhub.com/materials/state-ev-registration-data/

[h] https://www.gov.uk/government/collections/vehicles-statistics

[i] https://oehha.ca.gov/calenviroscreen/about-calenviroscreen

[j] https://www.epa.gov/ejscreen

[k] https://census.gov.uk/

[l] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/945829/tsgb-2020.pdf

[m] Zeroing in on Healthy Air, American Lung Association (2022). Link: https://www.lung.org/getmedia/13248145-06f0-4e35-b79b-6dfacfd29a71/zeroing-in-on-healthy-air-report-2022.pdf

[n] https://www.raivereniging.nl/binaries/content/assets/downloads/mic-auto-2021-2022.pdf

[o] Hsu, C. W., & Fingerman, K. (2021). Public electric vehicle charger access disparities across race and income in California. Transport Policy, 100, 59-67.

[p] https://www.transport.gov.scot/media/51271/a-network-fit-for-the-future-draft-vision-for-scotland-s-public-electric-vehicle-charging-network-revised-march-2022.pdf

[q] Cenex (2021). Commercial Viability of V2G: Project Sciurus [White paper]

[r] https://theicct.org/wp-content/uploads/2022/06/global-ev-update-2021-jun22.pdf

[s] https://www.rvo.nl/subsidies-financiering/sepp

[t] https://www.gov.uk/government/news/tenfold-expansion-in-chargepoints-by-2030-as-government-drives-ev-revolution

[u] https://www.gov.uk/government/publications/uk-electric-vehicle-infrastructure-strategy

[v] https://www.gov.uk/government/news/drivers-to-benefit-from-20-million-ev-chargepoint-boost

[w] https://zevalliance.org/wp-content/uploads/2021/12/ZEVA-used-EVs-white-paper-v2.pdf

[x] https://openstates.org/ca/bills/20172018/SB1000/

[y] https://efiling.energy.ca.gov/GetDocument.aspx?tn=244067-1

[z] https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program

[aa] https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/ict2018/ictfro.pdf

[bb] https://www.gov.uk/government/publications/assess-the-impact-of-air-quality/air-quality-appraisal-damage-cost-guidance