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When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption

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Introduction

Electric vehicles (EVs)[1] can dramatically reduce local air pollution and carbon emissions. But relatively little analysis has been done on the broader potential economic benefits as the technology matures and costs decline. In particular, EVs may benefit low-income households for whom car ownership poses a serious financial burden (The Greenlining Institute, 2020). As governments seek to integrate decarbonization policy with environmental justice goals, it will be critical to ensure equal access to clean technology.[2] However, there are still relatively few electric vehicle offerings, many of them marketed as luxury vehicles, such that EV sales have typically gone to relatively affluent households. There are critical unanswered questions about when EVs will provide benefits for lower-income households, and how the magnitude of these benefits will vary between different groups.

The current transportation system dominated by private vehicles contributes to social and economic inequality. Transportation is the second-largest component of household expenditures, after housing costs, and the dominance of fixed costs makes vehicle ownership especially burdensome for low-income households. While the majority of U.S. households own at least two vehicles, over 10 million households do not have access to a car. The vast majority of these households do not have a vehicle due to physical or economic constraints (Brown, 2017), including over 25% of households earning less than $25,000 per year (U.S. Census Bureau, 2020). Over half of families living in poverty do

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1 In this paper, we use "electric vehicle" to include both battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs).

2 The White House, "Fact Sheet: President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government," January 27, 2021 https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government/

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not have access to a vehicle at least some of the time (Klein & Smart, 2017), which limits access to a range of essential services like jobs, health care, and food (Blumenberg & Pierce, 2017; Bullard et al., 2004; Dawkins et al., 2015).

Low-income households that do own cars often must spend larger proportions of their income on vehicle-related expenses. Figure 1 shows the cost of vehicle ownership as a percentage of household income, broken down by the major cost components: net cost of vehicle purchase after accounting for resale value, insurance, maintenance, and fuel costs. The analysis is based on the 2017 National Household Travel Survey (NHTS) (US Federal Highway Administration, 2018) and the 2018 Consumer Expenditure Survey (U.S .Bureau of Labor Statistics, 2020). As shown, due to the dominance of fixed net purchase cost and insurance, average vehicle-owning U.S. households earning less than $25,000 spend 50% of their income on vehicle ownership and operation annually, or about $7,400 (U.S. Bureau of Labor Statistics, 2020). In contrast, median-income vehicle-owning households spend approximately 16% of their income, or about $10,000 annually, on vehicle ownership and operation. While low-income households own fewer vehicles and purchase more of them used, these lower costs are not enough to offset differences in income. This analysis also does not include costs from financing, licensing and registration, or parking, all of which can also disproportionately impact low-income car-owners.

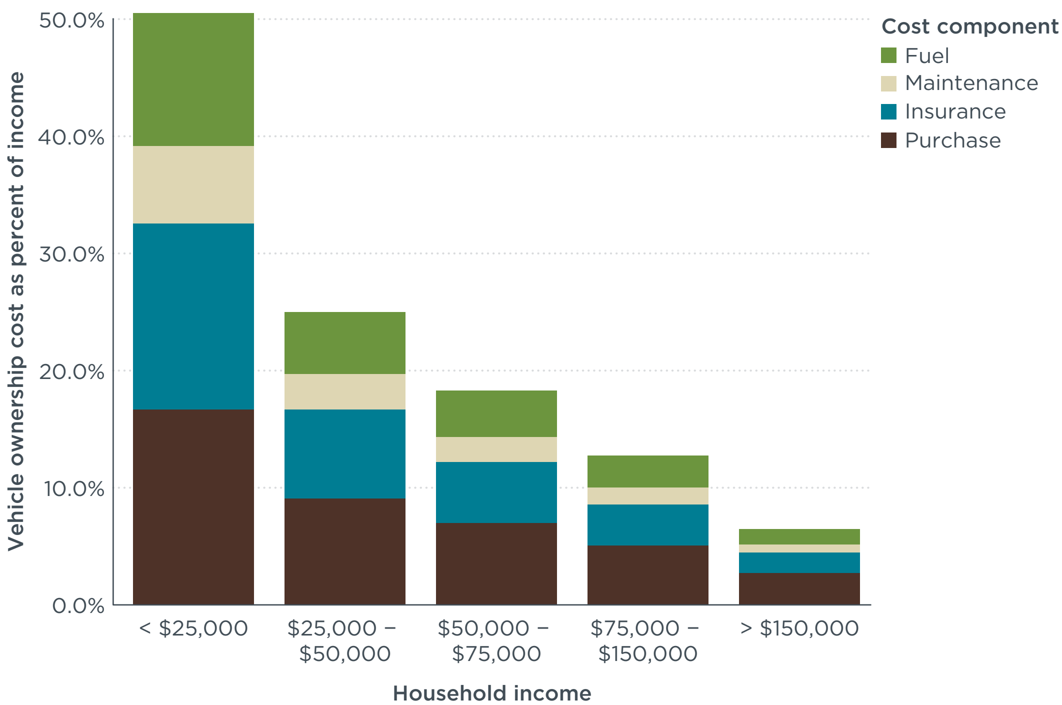

Figure 1. Total cost of vehicle ownership as percent of income, by annual household income.

As EV technology improves, it holds the potential to reduce several of the cost components shown in Figure 1, including vehicle purchase, maintenance, and fueling costs (Kerman, 2019; Lutsey & Nicholas, 2019; Propfe et al., 2012), which together account for over two-thirds of total vehicle ownership costs. Such changes could dramatically change transportation costs relative to household income, especially for low-income households. Research has shown that fuel savings from increased conventional gasoline vehicle efficiency can have positive distributional impacts (Greene & Welch, 2017), and that similar effects may be true of electric vehicles.

Most early electric vehicles have been bought and driven by relatively affluent households. Muehlegger and Rapson (2019) find that counting both new and used vehicle purchases, households earning less than $100,000 per year represent 72% of gasoline vehicle purchases, but only 44% of electric vehicle purchases. Black and Latino car buyers make 41% of gasoline vehicle purchases, but only 12% of EV purchases (Muehlegger & Rapson, 2019). Among used vehicle buyers, the median income of EV buyers in California is $150,000, compared with $90,000 for gasoline vehicle buyers (Turrentine et al., 2018). Previous studies have found similar patterns when comparing EV adoption between census tracts and zip codes (Canepa et al., 2019; Wee et al., 2020).

Some of the disparity in adoption by income is due to the fact that many EV models on the market in 2020 are luxury vehicles. Zip-code level vehicle registration data through 2019 shows that the rate of adoption of Teslas as a proportion of all household vehicles is 15 times higher in the top 20% of zip codes by income than it is in the lowest 20% of zip codes by income (Atlas EV Hub, 2020). Adoption in high-income zip codes is 5.7 times higher than low-income zip codes for the Nissan Leaf, 4.3 times higher for the Chevrolet Bolt, three times higher for the Chevrolet Volt, and roughly twice as high for new gasoline vehicles.

As the U.S. EV market expands over time, especially for used vehicles, EVs will likely become more attractive to lower-income households. There have been roughly 1.6 million cumulative electric vehicle sales in the United States as of September 2020 (U.S. Department of Energy, 2020), and many of these are now entering the used car market. Already, in disadvantaged communities in California, used EVs are purchased at higher rates than new EVs (Canepa et al., 2019). In addition, improving electric vehicle technology, increased electric range, and declining electric vehicle costs will continue making electric vehicles more attractive to a greater swath of consumers. As both purchase price and total cost of ownership for EVs decline in coming years, EV cost savings will become significant, and it will be critical to ensure equal access to disadvantaged groups.

Previous studies on EV equity have focused on existing disparities in EV adoption and consequences of failing to provide equal access, ranging from disparities in local pollution (Holland et al., 2019; Ju et al., 2020), to unfair distribution of public subsidies (Borenstein & Davis, 2016), and disparate changes in neighborhood desirability (Henderson, 2020; Rice et al., 2020; Wells, 2012). Inequitable access to EVs has also provided opponents of climate policy with justification to block policies that accelerate EV adoption (Slowik, 2019).

In this report, we focus on the potential benefits of equitable electrification and the speed at which EVs will become affordable more broadly across different households. Our primary focus is answering the critical question of when EVs will reach cost parity with equivalent gasoline vehicles for different socioeconomic groups. We use data on household vehicle purchases and ownership to estimate how much each household spends on their current vehicles. We combine this analysis with data on resale values of electric vehicles in the market in 2020, as well as bottom-up electric vehicle cost projections following battery cost trends. From this analysis, we quantify how much the potential cost savings of EVs vary by socioeconomic factors, including race, income, and residential location, and how will these savings change between now and 2030.

Approach

To understand the financial equity impacts of EVs, we must assess how much different groups of consumers currently pay for car ownership and compare these to the estimated costs of EVs. We analyze vehicle ownership cost at the household level, using data from the 2017 National Household Travel Survey (NHTS) (U.S. Federal Highway Administration, 2018) and 2018 Consumer Expenditure Survey (CEX) (U.S. Bureau of Labor Statistics, 2020). Household-level analysis allows for more precise insights into potential cost savings from EVs, as there is a wide range in how much households spend on vehicle ownership and operation, even within socioeconomic groups (Desai et al., 2020). In addition, households can only benefit from electrification if there are EV models available that fit their needs—for low-income households, this would require used vehicles of similar age and price to the vehicles they typically purchase.

The sections below summarize each component of analysis, and the overall analysis structure is depicted in Figure 2. As indicated, the primary inputs include specifications and estimated values for each household vehicle, socioeconomic characteristics of each household, and projected costs for EVs and gasoline vehicles to 2030. These inputs allow us to estimate the main cost components that vary between gasoline vehicles and EVs, namely purchase cost (including resale value), fuel, insurance, and maintenance. Comparing these costs for each vehicle allow us to make disaggregated cost parity estimates, including economic impacts by socioeconomic group.

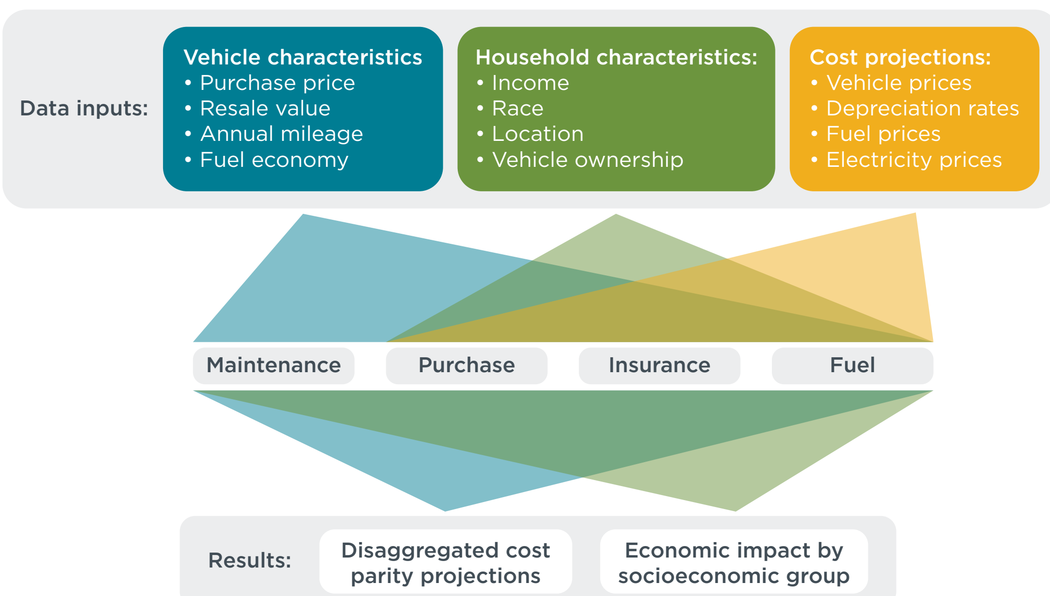

Figure 2. Flowchart depicting data inputs, analysis structure, and outputs.

Vehicle purchase price and depreciation

To estimate the price difference between purchase and sale of each household vehicle, also known as depreciation, we develop estimates for vehicle price by model, mileage, and age. These estimates are based on our review of retail prices from MSN Autos (https://www.msn.com/en-us/autos) and used vehicle sales prices from a variety of online vehicle marketplaces. Using sales data from the 2018 U.S. Consumer Expenditure Survey (CEX) (U.S. Bureau of Labor Statistics, 2020), we develop estimates for how long consumers retain a vehicle. By integrating these analyses with vehicle ownership data from NHTS, we estimate the price at which households purchased their current vehicles and the amount they will receive when they sell them.

To estimate EV prices over time, we combine the 2020 EV price estimates with bottom-up projections of new EV purchase prices based on analysis from Lutsey and Nicholas (2019). As a result, our EV cost modeling through 2030 incorporates how increasing EV volume, technology innovation, and supplier competition are reducing battery prices by approximately 7% per year, thus lowering electric vehicle costs. Projected vehicle prices are scaled from vehicle-class averages based on the manufacturer suggested retail price (MSRP) of household vehicles, assuming households with cheaper gasoline vehicles will look to replace them with cheaper EVs. However, given the current limitation of model availability, we assume EVs can be no cheaper than the vehicle-class average in 2020, decreasing to 50% of the vehicle-class average in 2030 assuming more entry-level EV models are introduced gradually.

Figure 3 shows our estimates for depreciation for the Chevrolet Bolt EV compared with mid-size gasoline cars, the Chevrolet Impala and Chevrolet Cruze. These depreciation estimates are based on a review of historical sales values contained in the Internet Archive from 2016 to 2020. The left-hand figure shows our estimates for depreciation over time since the Bolt was released in 2016 with extrapolations for 2021 and later. The right-hand figure shows the associated depreciation by odometer mileage. The vertical access shows the estimated price of the vehicles over time, and the colors show trends for the different models. As shown, the Bolt depreciates more slowly than the similarly priced Impala by mileage, but historical sales values show the Bolt has depreciated more rapidly over time since its launch in 2016. Price trends for the Tesla Model S and Nissan Leaf also show relatively faster depreciation with time as compared to mileage.

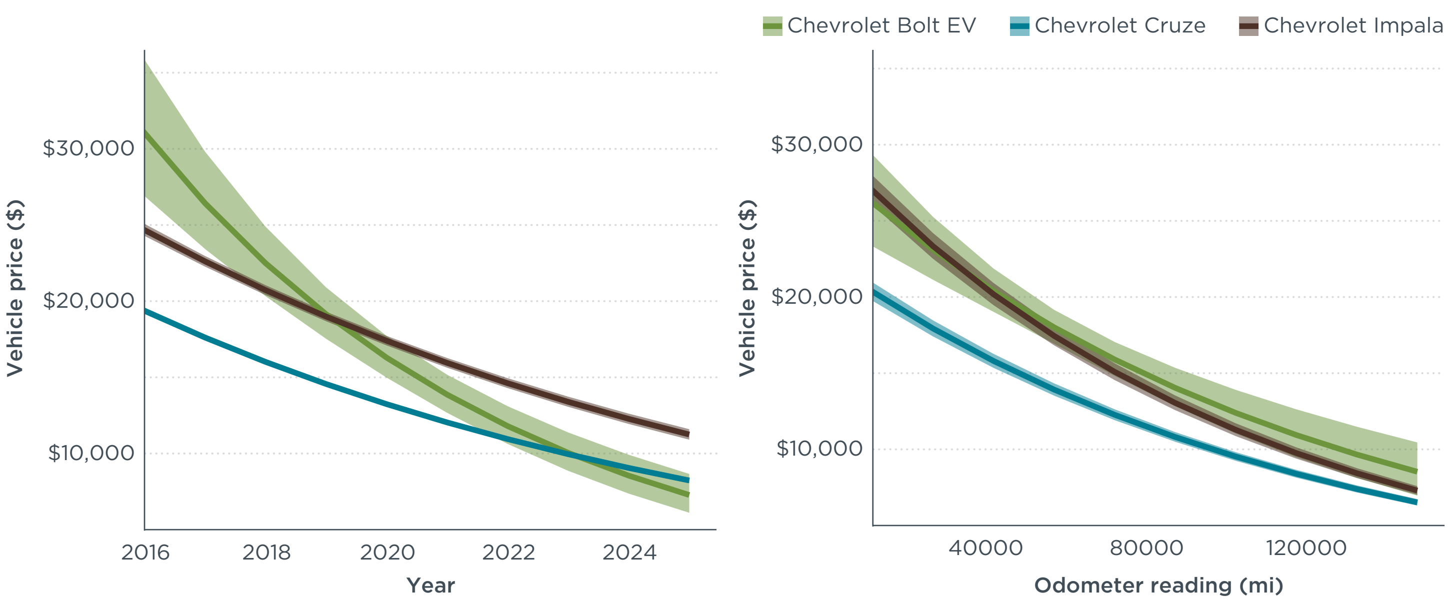

Figure 3. Comparison between vehicle purchase price for Chevrolet Bolt EV and two comparable Chevrolet gasoline vehicles. Left: Estimated value of a 2016 model driven 15,000 miles per year, by year of sale. Right: Estimated value of a used vehicle driven 15,000 miles per year and sold in 2020, by odometer reading. Ribbons show 95%-confidence interval of estimates.

These trends suggest that EVs experience faster depreciation than conventional vehicles, but not because of concerns about battery reliability at higher mileage. Rather, used EVs lose value more quickly because the technology is improving rapidly over time. This finding makes intuitive sense given that used vehicle prices are determined by their value relative to other vehicles; in this case, the declining price of a new EV sets a benchmark for valuing used EVs sold in that year. For example, according to CarGurus, over the past year the average Tesla Model S has lost over 10% of its value, and the average Chevy Bolt has lost over 25% of its value, even as many used gasoline cars have increased in value due to a lack of inventory and higher demand during the 2020 recession (CarGurus, 2020). This isn't surprising given that both companies have significantly cut the prices of their new models in response to increased competition (Beresford, 2020; Berman, 2020).

To incorporate these market dynamics, used EV prices in this analysis are assumed to internalize the change in new EV prices over time. For example, the value of a 2020 model EV sold in 2025 is determined by the price of a new EV sold in 2025, not the original price of the new vehicle sold in 2020. Cost reductions in new EVs are assumed to create downward pressure on the used EV market, such that the benefits of both subsidies and cost reductions on new EVs are passed on to used EV buyers. We also analyzed a scenario where new EV prices had no impact on the used EV market, which would decrease EV cost savings in 2030 by 23%.

Several other factors are included in the modeling of the EV pricing dynamics. When comparing the cost of EVs and gasoline vehicles, we assume consumers would consider EVs of the same age and mileage at which they purchased their current gasoline vehicles and retain them for the same number of years. In cases of older vehicles where EVs of the same age would not be available, we assume consumers would consider the EV with the closest available age. These dynamics will depend in part on how EVs age compared to conventional vehicles. Fewer moving parts could result in longer lifetime for EVs, and commercial opportunities for second-life batteries like in power grid applications give used EVs some potential for increased residual value (Engel et al., 2019). To be conservative, it is assumed that EVs will depreciate at the same rate as gasoline vehicles by mileage, losing about half their value every 50,000 miles.

Fueling and charging

Annual fuel expenditures for each household are calculated based on gasoline prices from NHTS and fuel economy data by model year from U.S. EPA. Average gasoline prices are $2.64 per gallon in 2020, increasing to $2.81 in 2030 (U.S. Energy Information Administration, 2020). For EVs, charging costs are based on average electricity rates for each utility in the United States from Homeland Infrastructure Foundation-Level Data (U.S. Department of Homeland Security, 2020), electricity price projections from the EIA (U.S. Energy Information Administration, 2020), and EPA ratings for EV energy consumption (U.S. Department of Energy & U.S. Environmental Protection Agency, 2018), as well as projections of EV efficiency (Lutsey & Nicholas, 2019). Home charging costs increase from an average of $0.124 per kilowatt-hour (kWh) in 2020 to $0.131 per kWh in 2030. Public charging costs are typically about two to three times the per-kWh prices of home charging, based on average prices by region and charger type from PlugShare (www.plugshare.com), housing type data from the 2018 American Community Survey (U.S. Census Bureau, 2020), outlet access data from the 2015 Residential Energy Consumption Survey (U.S. Energy Information Administration, 2015), and charging behavior data from Tal et al. (2014). Note that we did not analyze the cost of installing charging infrastructure, which is an important area for future research.

Maintenance

Given that electric drivetrains have many fewer moving parts than their fossil fuel counterparts, EVs experience significantly lower maintenance costs. Maintenance costs are estimated by vehicle odometer reading and technology based on Harto (2020). Maintenance costs for new 2020 conventional vehicles are assumed to be $0.028 per mile, compared to $0.012 for EVs, increasing gradually to $0.079 per mile for gasoline cars and $0.043 per mile for EVs with over 100,000 miles. These data show roughly 50% cost savings from EVs, similar to values reported in other studies (American Automobile Association, 2020; Kerman, 2019; Logtenberg et al., 2018; Palmer et al., 2018; Propfe et al., 2012). Note that the maintenance cost estimate for older EVs is based largely on early versions of the Tesla Model S, and so is likely an overestimate of future costs given recent advances in EV reliability. Given trends in battery technology, EVs are assumed to not need a battery replacement and have equivalent residual end-of-life value to gasoline vehicles. Recent reports have found battery failure is rare and capacity will likely decrease by less than 20% over an EV's lifetime (Hanley, 2019; Kane, 2020; Way, 2019).

Insurance

Estimates for how insurance premiums change with the retail price of a vehicle are based on average insurance premiums by make and model from Insure.com. While there have been some anecdotal reports that EVs have higher premiums, this is likely due to the higher purchase price. Low-income buyers of new EVs have reported the premiums were higher than expected, while used EV buyers found them to be only slightly higher or about the same as expected (Center for Sustainable Energy, 2019). We estimate the average premium for a new EV in 2020 will be $170 per month, compared to $153 per month for the average new gasoline car.

Results

Analyzing the vehicle cost factors described above, we compare the cost dynamics of EVs and gasoline vehicles through 2030 in several different ways. First, results are presented for how used EVs manufactured in 2020 compare with similar conventional vehicles from 2020 to 2030. Following this, we analyze the potential impact of electrification on the financial burden of transportation across household income quintiles and racial-ethnic groups. Finally, we show implications with respect to equity screening dimensions in California.

Table 1 shows the average household characteristics relevant for this analysis across income groups, with bins that roughly correspond to household income quintiles based on data from NHTS and CEX (U.S. Bureau of Labor Statistics, 2020; U.S. Federal Highway Administration, 2018). As shown, the relevant household characteristics vary significantly between income groups. For example, lower-income households tend to own fewer vehicles and drive fewer miles each year, which will decrease the potential savings from electrification. On the other hand, the vehicles they purchase tend to be older and less efficient, which could increase the operating savings from electrification, and decrease the difference in upfront price. Based on the estimates of charging behavior and electricity rates by region and charging type described above, we estimate that households in the lowest income quintile will experience higher prices to charge than higher-income households, but these differences are small, roughly $0.01/kWh. While low-income households do more of their charging outside the home, they are also more likely to live in more rural areas with lower electricity rates. This analysis also does not include possible electricity subsidies available to low-income households.

Table 1. Summary of household and vehicle statistics by income group.

	Household income				
	< $25,000	$25,000 - $50,000	$50,000 - $75,000	$75,000 - $150,000	> $150,000
Vehicles owned	1.1	1.7	2.1	2.4	2.5
Average vehicle age	12.6	11.3	10.6	9.4	8.2
Proportion cars vs. light trucks	58%	54%	51%	50%	51%
Average vehicle mileage (miles/year per vehicle)	10,300	10,700	11,100	11,600	11,700
Average price for vehicles when new	$32,800	$33,000	$33,700	$34,600	$38,000
Average vehicle age at purchase	7.2	6.0	5.5	4.7	3.9
Proportion of vehicles purchased new	33%	33%	32%	38%	50%
Duration of vehicle ownership before sale	5.3	5.7	5.9	6.1	6.4
Average vehicle fuel economy (miles/gallon)	21.7	22.0	22.1	22.6	23.0
Average number of household members	2.0	2.2	2.5	2.8	3.0
Proportion of homeowners	35%	56%	69%	79%	87%
Population density (people per square mile)	5490	4711	4721	4842	5973
Proportion single-family homes	55%	62%	70%	77%	77%
Average charging rate ($/kWh)	0.173	0.170	0.165	0.163	0.168

Note: All values represent means of NHTS or CEX respondents, weighted to match total U.S. population.

As shown in Figure 4, cost parity projections are similar for new and used vehicles. The y-axis shows the average purchase price of new vehicles (stars) and used 2020-model-year vehicles (circles), by year on the x-axis, with the color of the lines showing the fuel type. Older vehicles reach cost parity somewhat later than new vehicles due to delays in availability of entry-level models, but these differences are small. We estimate the average purchase price of model-year 2020 BEVs will reach parity with corresponding gasoline cars in 2028, only two years later than new BEV cars. Pickup trucks and SUVs reach cost parity only a couple of years later. By 2030, when the used vehicles are 10 years old, they are projected to cost roughly $10,000 on average regardless of fuel type. This result arises in part from the assumption that reductions in new EV prices as technology improves lead to reduced used EV values. Note that this result does not imply that used EVs will be available to all potential buyers; as used EVs reach cost parity with used gasoline vehicles in later years, used EV supply may become a limiting factor, especially supply of affordable models. While outside the scope of this analysis, this topic deserves further study to determine how used EV prices may be affected by supply constraints, and what policies can help foster equitable access.

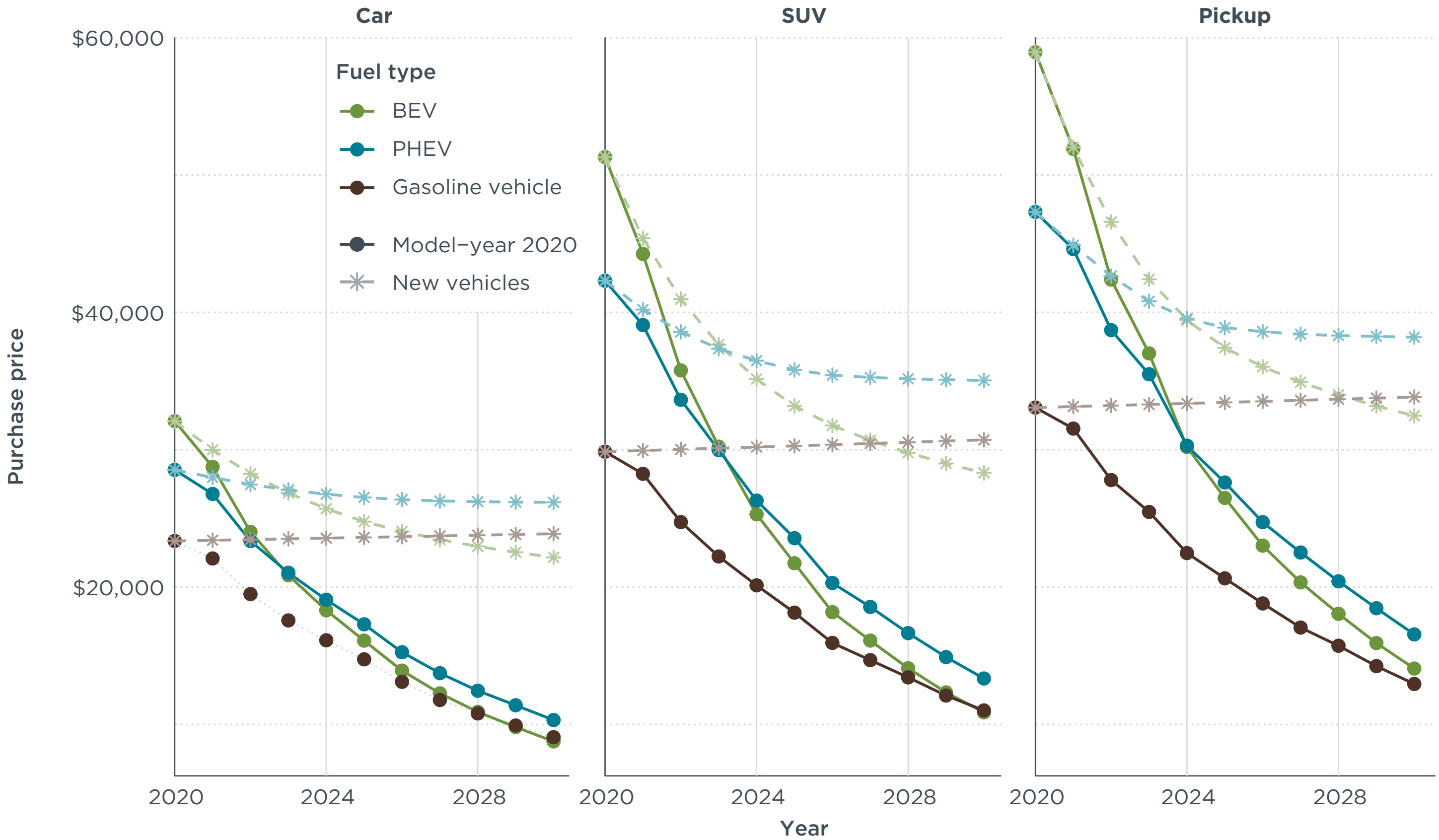

Figure 4. Purchase price of model-year 2020 vehicles (circles) and new vehicles (stars) by vehicle type and fuel type between 2020 and 2030.

Figure 5 shows a similar analysis broken down by household income. The y-axis shows the average difference in purchase price between BEVs and gasoline vehicles, by household income group. Whereas BEVs currently cost over $10,000 more on average to purchase than the equivalent gasoline vehicle for households in each income group, this difference falls to $2,500 by 2025, reaching parity around 2028.

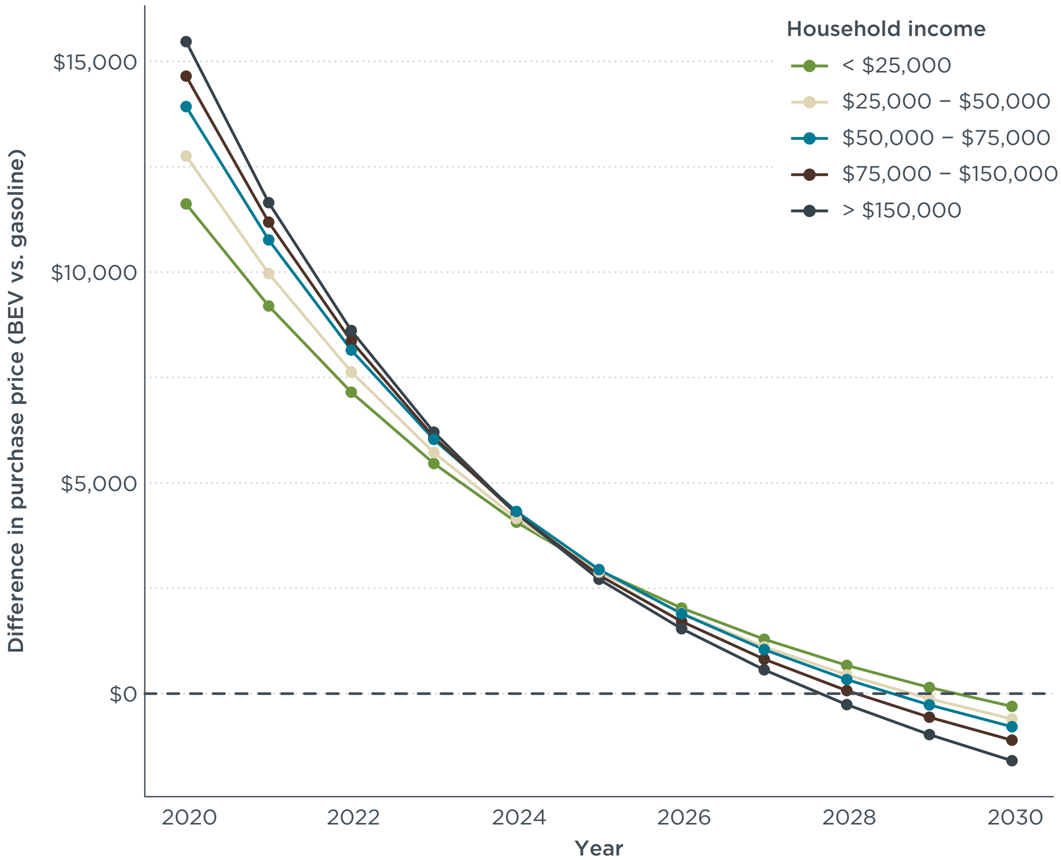

Figure 5. Difference in purchase price between BEVs and gasoline vehicles by household income between 2020 and 2030.

Given our projection that used vehicles will reach cost parity shortly after new vehicles, cost parity does not vary significantly by income: all income groups see average upfront price parity between 2027 and 2029. Lower-income households tend to purchase older vehicles, and EVs of the same age are not yet available in all cases, so electrification would require buying a somewhat newer and more expensive vehicle. However, setting aside the number of vehicles owned, differences in car purchasing behavior between income groups are not as dramatic as often presumed. For example, households earning under $25,000 per year purchase a third of their vehicles new, compared with 38% for households earning between $75,000 and $150,000 per year (US Bureau of Labor Statistics, 2020). Across all income groups, over half of vehicles are purchased when they are less than four years old.

Note that these results show differences between gasoline vehicles and 250-mile BEVs. On average, BEVs with 300-mile range cost $1,100 more to buy than 250-mile BEVs in 2025, and $600 more in 2030. BEVs with 150-mile range cost $1,900 less to buy than 250-mile BEVs in 2025, and $1,000 less in 2030.

Whereas Figure 4 and Figure 5 above reflected conventional and EV purchase price, we also compared vehicles based on total cost of ownership, including purchase, insurance, fuel, and maintenance for each household vehicle. Due to greatly reduced fuel and maintenance expenses, in many cases the total cost of ownership is lower for EVs than gasoline vehicles even with present technology, and all vehicles are projected to reach total cost parity by 2030.

Figure 6 shows the amortized annual total cost of ownership for a 2020 model-year vehicle purchased in the year shown on the x-axis, with the colors showing each of the four main cost components. The black lines show total cost of ownership for new vehicles purchased in the year on the x-axis. As with purchase price, the trends are similar for new and used vehicles, though used EVs decrease in cost more quickly due to the combined forces of depreciation and cost reductions for new EVs. The average 2020 model-year BEV reaches cost parity with the average gasoline vehicle of the same vintage in 2025, one year before cost parity between new vehicles.

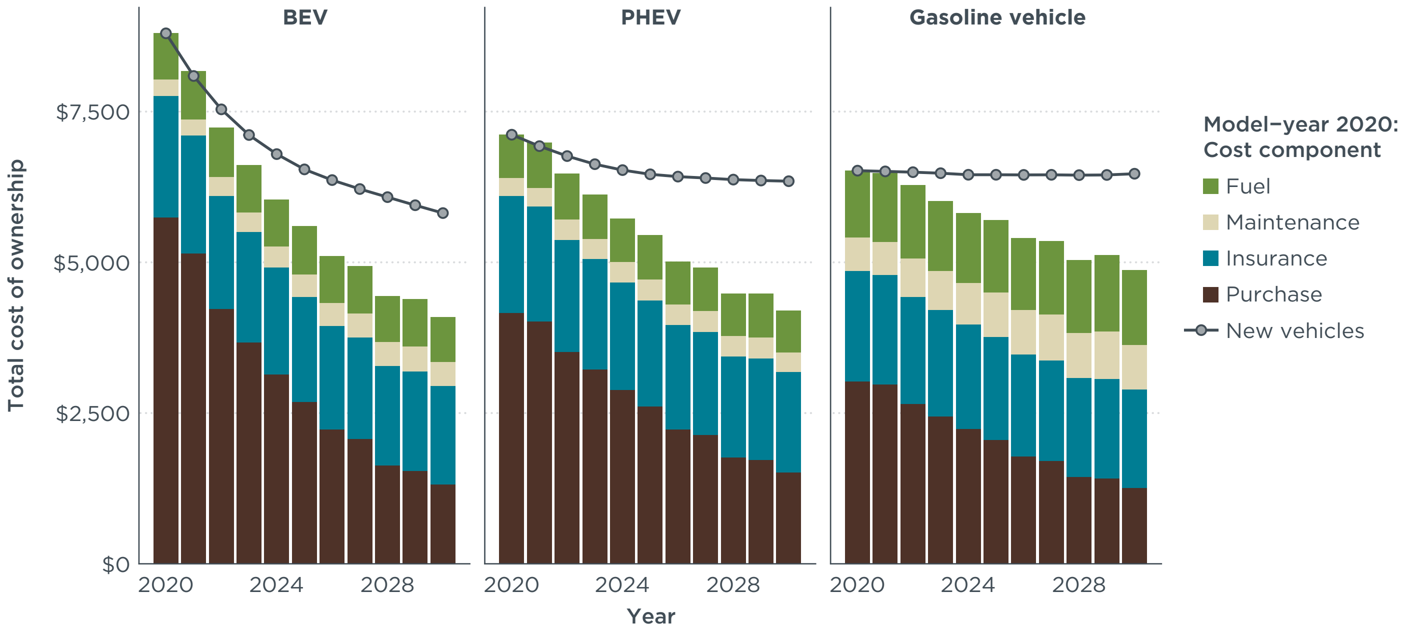

Figure 6. Average amortized total cost of ownership for model-year 2020 vehicles by year of purchase between 2020 and 2030, broken down by cost component and by fuel type. Black lines show total cost of ownership for new vehicles purchased in each year.

As with the purchase price, the trends in total cost of ownership for EVs are very similar across income groups. Figure 7 shows the percent of all vehicles that could be electrified at equal or lower total cost on the y-axis, by year on the x-axis and income group represented by color. Lower-income households see the benefits of electrification slightly later because they tend to buy older vehicles, and so must wait longer for EVs in the right price- and age-range to become available. However, the difference between curves is small – all income groups see parity for 45% of all vehicles in 2025, and for over 90% of vehicles in 2030. If BEVs with 150-mile range are sufficient, total cost parity arrives even sooner, exceeding 60% of households in each income group in 2025.

These results do not include EV purchase incentives or electricity subsidies. In reality, these incentives will increase savings for eligible households, and low-income households in particular. For example, including the $7,500 federal tax rebate for EV purchases increases the percent of vehicles at parity to 20% in 2020, and over 70% in 2025. Other analyses have found that EVs already offer substantial total cost savings to the average household already due to significant discounts offered by manufacturers (Harto, 2020).

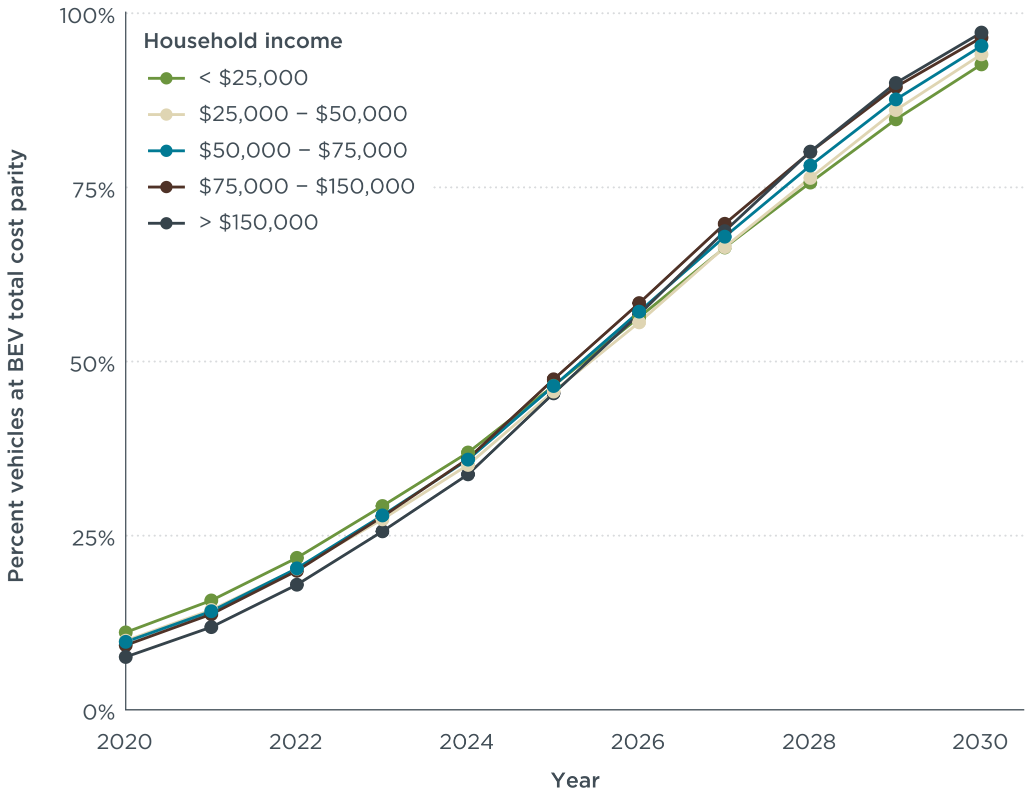

Figure 7. Percent of all vehicles in each income group that could be replaced by a long-range BEV with equal or lower total cost of ownership between 2020 and 2030. We assume BEV cars become available for new purchase in 2017, SUVs in 2020, and pickups in 2021.

As EV prices fall, we project the total cost savings of electrification will become significant. In 2030, the average 250-mile BEV will cost $900 less to buy than the average gasoline vehicle, and the average household could save $1,400 per year by replacing all of their vehicles with EVs, including over $600/year from both maintenance and fuel savings. Battery-electric pickup trucks will still cost a few hundred dollars more than gasoline pickups on average, but net savings will be similar by vehicle type: $800 per year for cars, $700 per year for SUVs, and over $600 per year for pickups. In absolute terms, these savings are higher for wealthier households, but relative to income, we project that electrification will disproportionately benefit disadvantaged groups. As shown in Figure 8, by 2030 the average cost difference between BEVs and gasoline vehicles approaches 7% of income for households earning less than $25,000 per year. The y-axis shows cost difference relative to income, both by individual cost components (solid bars) and the total net difference (black outline), for each socioeconomic group on the x-axis. Each box shows the results for battery electric vehicles (BEVS) or plug-in hybrid electric vehicles (PHEVs) in 2025 or 2030.

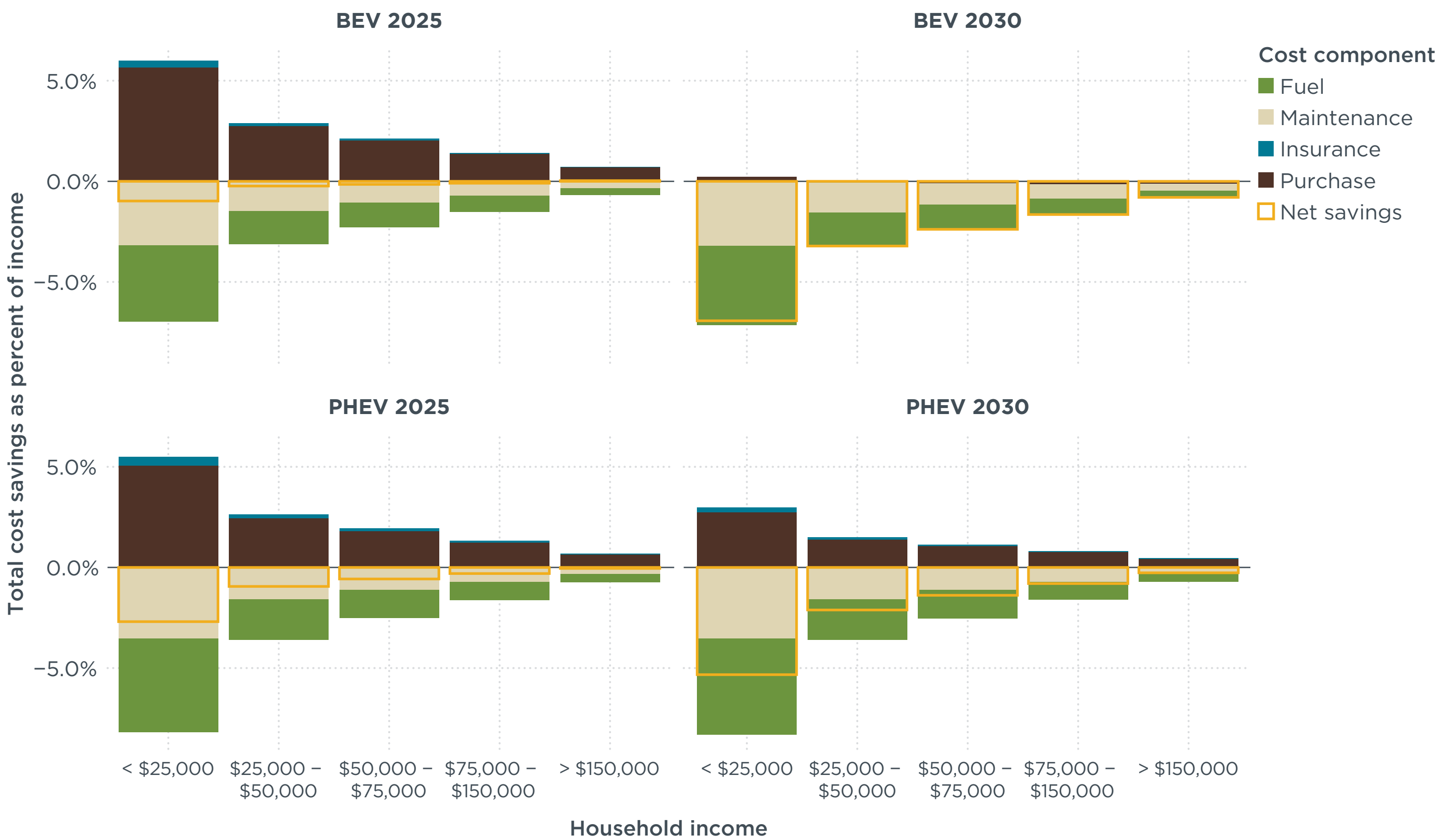

Figure 8. Difference in cost of ownership between gasoline vehicles and BEVs (top row) or PHEVs (bottom row) by income group and cost component, in 2020 (left), 2025 (center), and 2030 (right), expressed as % of income. Cost differences are summed across all household vehicles.

Figure 9 presents vehicle cost of ownership results according to racial-ethnic group rather than the income groups as in Figure 8. As above, results indicate that vehicle ownership savings from electrification relative to income will be higher for Black and Latino households (2.5% of income and 2.2% of income in 2030, respectively) than for White households (1.7% of income).

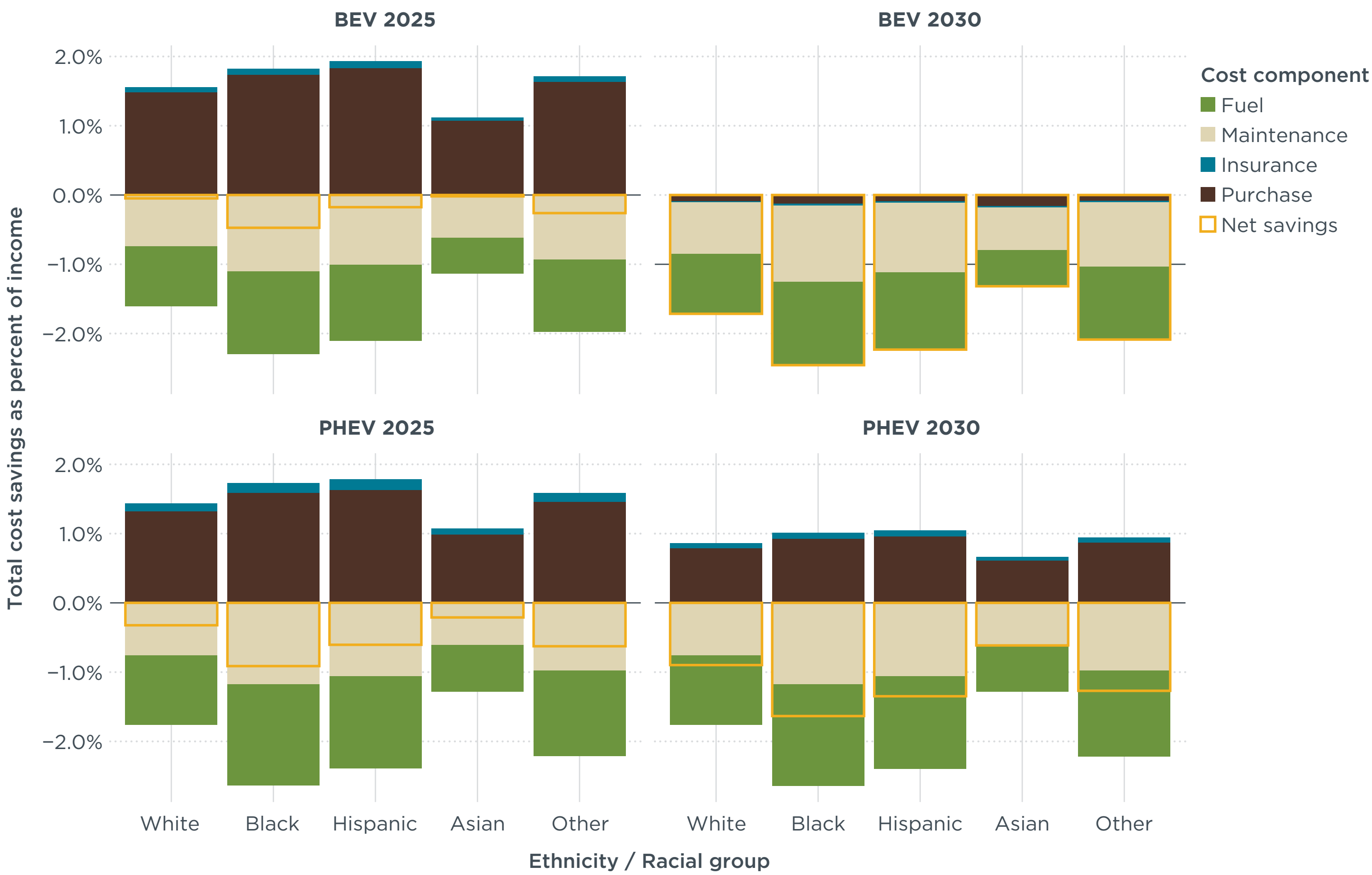

Figure 9. Difference in cost of ownership between gasoline vehicles and BEVs (top row) or PHEVs (bottom row) by racial-ethnic group and cost component, in 2020 (left), 2025 (center), and 2030 (right), expressed as % of income. Cost differences are summed across all household vehicles.

Electric vehicle savings are driven by decreased fuel and maintenance expenditures (green and tan bars, respectively), together providing roughly $1,000 annual savings for the average vehicle-owning Black household starting in 2020. These savings are offset by increased vehicle purchase and insurance costs (brown and blue bars, respectively) in earlier years, for example increasing ownership costs by $900 per year for the average Black household in 2025. But, by 2030 most EVs have lower purchase and insurance costs as well, resulting in large potential cost savings.

Savings relative to income will also be higher for households located in rural areas and small towns than for urban and suburban residents, suggesting that EVs will have positive distributional impacts across geography as well. Based on several household characteristics, we extrapolated estimated EV savings by household in 2030 to average savings by census tract. As shown in Figure 10, savings relative to income are highest (shown by darker green colors) in rural areas where low-income residents are more dependent on automobiles and must travel further to access jobs and essential services. We find that similar to the results described above, households in more vulnerable areas have higher potential cost savings from electrification relative to income. For example, in California, projected EV savings are correlated with CalEnviroScreen scores (correlation coefficient = 0.44), a composite metric that combines pollution levels with economic and health measurements such as rates of poverty and heart disease (California

Environmental Protection Agency, 2016). Reductions in air pollution, not included in this analysis, could also disproportionately benefit vulnerable communities.

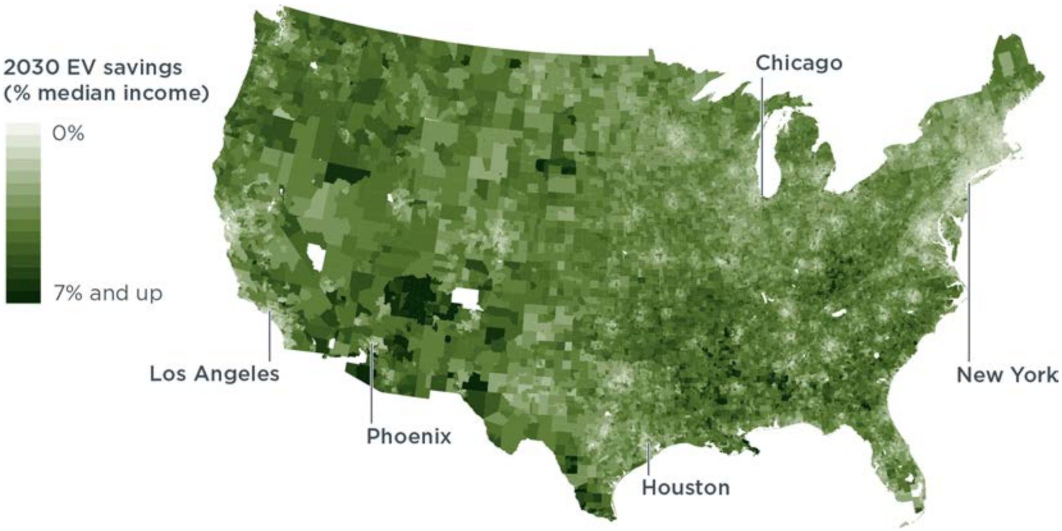

Figure 10. Map showing projected average electrification savings relative to household income by census tract across the continental U.S. in 2030.

This analysis also reveals significant differences in projected savings both within and between metro areas. As shown in Figure 11, savings are lower in large cities in the Northeast and West like New York City and Los Angeles, where low-income residents rely more heavily on mass transit networks. In particular, savings are minimal in Manhattan, as lower-income households typically do not own cars. Savings are higher in more outlying auto-dependent areas of New York and in less wealthy satellite cities like Newark, NJ. In contrast, in Southern and Midwestern cities like Detroit and Houston where low-income residents have less access to transit (Tomer et al., 2011), average savings in low-income neighborhoods in some cases exceed 7% of income. In many cases, these differences in savings correspond to histories of segregation, poverty, and disinvestment. For example, savings are much higher within the city of Detroit, which is 80% Black and has a poverty rate of 36%, than in surrounding suburbs like Grosse Pointe, which is 94% White, with a poverty rate of under 3%. A similar pattern appears in Houston, where savings are highest in neighborhoods east of downtown with majority Black and Latino populations, median household incomes under $30,000, and college graduation rates of less than 10%. Savings are lowest in areas west of downtown like Bellaire, where median income is over $200,000 and 80% of household heads have a four-year degree (U.S. Census Bureau, 2020).

Figure 11. Maps of projected average electrification savings in 2030 relative to household income by census tract for selected metropolitan areas. Clockwise from top left: New York City, NY, Los Angeles, CA, Detroit, MI, and Houston, TX.

By 2030, the average cost of ownership for a new EV is about the same as the cost of ownership for a used gasoline car that is several years old. This finding suggests that consumers may shift away from the used gasoline car market en masse, further accelerating the transition to electric vehicles. This analysis also does not consider shorter-range EVs, which could further increase potential savings by decreasing purchase cost and increasing vehicle efficiency. We also note that we have not considered market dynamics, which could decrease the price of used gasoline vehicles and increase the price of used BEVs as the demand for BEVs exceeds supply. The cost of charging infrastructure was also excluded from this study, as much of the cost may be borne by taxpayers or utility ratepayers. However, these costs could also disproportionately increase costs for vulnerable communities if funds are not distributed equitably (Aguayo, 2020).

Conclusion

This analysis finds that rapid reductions in the cost of used EVs over the next decade will enable lower-income households to access EVs in the near future, with cost savings resulting in substantial equity benefits. As discussed below, these results have several important policy implications.

There is great potential for increasing EV affordability across the used EV market. Cost reductions in new EVs will lead to decreased used EV prices and cost parity for low-income households in the 2025-2030 period. Higher rates of depreciation for first owners will lead to larger benefits for lower-income second owners. By 2029, EVs will reach upfront price parity with the average vehicle purchased by a low-income household, less than two years after the average vehicle purchased by a high-income household. Currently, once accounting for fuel and other operating savings, some households in all income groups could save money by replacing at least one vehicle with an EV; this increases to 45% of households by 2025 and 95% of households by 2030. Limited supply of affordable used EVs may become a major barrier to adoption in the future, and this topic deserves further research.

Cost savings from EVs can enable substantial equity benefits by 2030. Savings from EVs relative to income are significantly higher for low-income households, non-White households, and households in areas with higher levels of pollution. For car owners in the lowest-income quintile, savings from switching to EVs amount to $1,000 per household annually, or 7% of income, by 2030. Given these benefits from EVs are higher in less-dense car-dependent areas that also tend to have lower housing costs, electrification could provide low-income households with more options for affordable housing.

Purchase incentives targeting low-income groups may be most effective. Given that low-income households are likely to benefit most from an EV yet are typically less likely to adopt one, there is a clear justification for targeting purchase incentives towards low-income consumers. Previous studies have shown that low-income EV buyers are more responsive to incentives, and that purchase incentives have become more important over time (Jenn et al., 2020; Muehlegger & Rapson, 2018). Thus, as EVs become a significant part of the mainstream market and governments consider modifying incentives, it may be most effective to implement and gradually increase eligibility requirements by income (Jenn et al., 2020).

Even with widespread EV affordability, additional policy action would ensure equal access to EVs. To date, EV adoption has skewed towards wealthy households, and other barriers beyond EV costs remain. Our results are sensitive to model availability, and broad EV model deployment across all market segments will be critical. Combustion vehicle phase-out regulations can force manufacturers to serve diverse markets (Cui et al., 2020). Broader access to financing for EVs, for example with loan-loss guarantees, will be critical for low-income households (Klein & Smart, 2017; The Greenlining Institute, 2020). Policymakers will also need to ensure targeted deployment of home and public charging deployment to support vulnerable communities and renters with less charging access (Aguayo, 2020; Davis, 2019). As used EVs will be particularly important for lower-income groups, it will also be important to take into account used EV sales when planning charging infrastructure development. To increase EV awareness, policymakers can develop inclusive promotion programs.

It is generally recognized that electric vehicles can dramatically improve air quality in lower-income communities that are most affected by vehicle pollution. This work shows EVs also have the ability to directly benefit all income groups directly in their pocketbooks over the next ten years. Our findings here show there is an opportunity to considerably expand the benefits of EVs. Ensuring equitable EV access will be critical for creating the broad coalition necessary to pass aggressive policies and avoid negative equity impacts (Slowik, 2019). As policymakers seek to integrate equity and environmental policy goals, equitable electrification can serve as a key component that helps pave the way to a just transition.

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