Assessing the Potential Impacts of Toll Discounts on Zero-Emission Vehicle Adoption

January 2023

A Research Report from the National Center for Sustainable Transportation

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16. Abstract
Zero-emission vehicles are a central component of plans to eliminate greenhouse gas emissions from California's transportation sector. Because these vehicles generally have higher purchase prices than conventional vehicles and represent a new technology that many households are hesitant to adopt, it is important to find ways to incentivize the adoption of these vehicles. A range of methods have been tested globally, including monetary incentives and stickers that allow these vehicles to access high-occupancy vehicle lanes. This report assesses the potential use of express lane discounts as a driver of ZEV adoption by testing the effectiveness of a range of discount scenarios. These scenarios are built upon a baseline scenario that incorporates adoption drivers from existing policies and market growth trajectories. This analysis treats the express lane discount as a monetary incentive. The researchers find that providing even very large discounts for express lane usage to zero-emission vehicles would only slightly increase vehicle sales but would make these lanes much less capable of serving their other purposes. As part of this project, an Excel tool was developed that allows users to test their own scenarios. As an alternative to providing toll discounts to owners of new zero-emission vehicles, the authors recommend developing targeted incentives that focus on low-income and disadvantaged communities and are available to households that purchased pre-owned vehicles.

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Disclaimer

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NCST

Assessing the Potential Impacts of Toll Discounts on Zero-Emission Vehicle Adoption

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EXECUTIVE SUMMARY

Light duty vehicles are responsible for 17% of U.S. carbon emissions and roughly 58% of emissions from transportation. Eliminating these emissions is a key component of any effort to reach climate targets, and zero-emission vehicles (ZEVs) are central to this strategy. Because ZEVs generally have higher purchase prices than conventional vehicles and represent a new technology that many households are hesitant to adopt, it is important to find ways to support the adoption of these vehicles. A range of incentives have been tested globally, and monetary incentives and stickers that allow ZEVs to access high-occupancy vehicle (HOV) lanes have been shown to be major drivers of adoption.

Because of the usefulness of financial incentives and HOV lane access, it is reasonable to expect that similar benefits could be achieved by giving ZEVs discounted access to express lanes. Express lanes allow free travel for HOVs and charge other users for access, so policies that provide ZEVs discounted access to these lanes can be understood as either a monetary incentive or something akin to HOV lane access. There are currently express lanes on parts of six freeways in California, and more of these lanes may open in coming years, so this sort of incentive has potential to play a significant role in expanding ZEV adoption in the state.

This report assesses the potential use of express lane discounts as a driver of ZEV adoption by testing the effectiveness of a range of discount scenarios. These scenarios are built upon a baseline scenario that incorporates adoption drivers from existing policies and market growth trajectories. Because express lanes are most useful during peak-hour commute traffic and policies that affect regular commute travel are more likely to have an actual effect on ZEV adoption, this analysis focuses on peak-hour traffic only. During peak hours, roads with express lanes currently account for 5% of all trips in California, and these trips are disproportionately likely to be made by ZEVs, since middle- and high-income suburban commuters make up a large share of travelers on these routes as well as being the bulk of existing ZEV owners. Even without a discount policy, roughly half of all trips on these roads will be made by ZEVs by 2035.

To understand the impact of express lane discounts on ZEV adoption, we cast express lane discounts as a monetary benefit, since they essentially offer a discount on a time savings that was already available for any road user to purchase. We test a range of discount scenarios and found uniformly modest impacts on ZEV adoption. Under the most extreme scenario, ZEV ownership would increase by roughly 10% among potential users of express lanes, but less than a 1% increase in ZEV sales statewide. The cost of achieving this sales increase would be allowing up to 1/3 of all peak-hour traffic on these roads to access express lanes at a 75% discount, likely preventing the lanes from serving their intended purpose.

In addition to the specific scenarios described in this report, we developed an Excel tool[1] that allows users to test other scenarios, including scenarios which combine multiple traffic conditions. This tool provides results both at the statewide level and disaggregated by income level. It also allows users to see the potential increase in express lane usage by ZEVs under each scenario.

As an alternative to providing discounted access to express lanes for new ZEVs, we recommend designing target incentives to support ZEV adoption among households and communities that are otherwise struggling to adopt the expensive new technologies. Commute travel time benefits may be particularly valuable to low-income households and residents of disadvantaged communities, since these groups often have particularly long commutes. Additionally, attaching the benefit to used vehicles rather than new vehicles may help expand ZEV adoption while also making ZEV ownership more equitable statewide.

[1] https://ncst.ucdavis.edu/research-product/ev-express-lane-excel-tool

Introduction

Light duty vehicles are responsible for 17% of U.S. carbon emissions and roughly 58% of emissions from transportation (*1*), and eliminating these emissions is a key component of any effort to reach climate targets. Eliminating these emissions will require replacing light-duty internal combustion engine vehicles (ICEV) with zero-emission vehicles (ZEVs), particularly plug-in electric vehicles like battery electric vehicles and plug-in hybrid electric vehicles. ZEVs have been available in small numbers since the late 2000s, but the adoption of EVs has accelerated in recent years, spurred by government incentives, charging infrastructure investments, and declining battery costs (*2*–*7*). Today, EVs make up nearly 10% of new vehicle sales in California and 2% in the U.S. overall. While many countries in Europe have reached higher rates of ZEV ownership than California, California has the most aggressive EV adoption plan in North America, with a goal of eliminating sales of new ICEVs by 2035 (*8*) and achieving carbon neutrality by 2045. A primary mechanism for accelerating ZEV adoption is the California Air Resources Board's proposed Advanced Clean Cars 2 rule, which would mandate that zero-emission vehicles make up 26% light-duty vehicle sales in California by 2026, 61% by 2030, and 100% by 2035 (*9*). While the sales mandate provides the beginnings of a path to electrification, completing this process will require determining how these vehicles will be charged.

Programs granting carpool decals to electric and fuel cell vehicles have been important drivers of ZEV adoption in California, and studies have attributed as much as 40% of ZEV adoptions to these programs (*10*). In this report, we assess the impacts of discounted express lane tolls on ZEV adoption statewide and specifically in disadvantaged communities and areas where these discounts may have a large impact. We analyze a set of general scenarios of the potential impacts of toll discounts on ZEV adoption and express lane usage for ZEV fleet sizes through 2032. We provide an interactive Excel tool[2] allowing users to explore multiple pricing schemes: discounts from 0% to 100%; and discount durations of the first 3-10 years of a vehicle's life. The results of this analysis are used to propose a discount system that will encourage ZEV adoption but not overly burden express lane infrastructure.

The discounts analyzed in this report have limited potential to increase ZEV adoption. The benefit is limited to a relatively narrow range of households, most of which are in the categories that are already considering purchasing a ZEV and is generally smaller in scale than HOV lane stickers. The most extreme traffic and discount scenario included in this report provided less than a 1% increase in ZEV sales per year by 2032 while potentially providing large discounts to up to a third of vehicles traveling on roads with express lanes. As a result, it may be worthwhile to consider a narrower policy targeted at providing express lane discounts to ZEVs purchased in disadvantaged communities, by low-income households, and on the secondary vehicle market. Providing a targeted incentive would support ZEV adoption in an area where it is currently struggling rather than reinforcing its growth in areas where it is already strong.

[2] https://ncst.ucdavis.edu/research-product/ev-express-lane-excel-tool

The rest of this report is organized as follows:

- The Policy Background section outlines how express lanes operate and discusses the federal, state, and regional regulations around their use.
- The Baseline ZEV Adoption Scenario discusses the underlying ZEV adoption model, which tracks the conversion of household fleets from ICEVs to ZEVs by households of different incomes, housing types, and fleet sizes in California through 2035.
- The ZEV Usage of Express Lanes Under Existing Adoption Scenario section describes the process of matching households with ZEVs to potential express lane trips and demonstrates the importance of focusing on peak-hour travel.
- The Impact of Discounts on ZEV Adoption scenario section shows how we link potential express lane usage to adoption, outlines three potential discount scenarios, and provides instructions for using the Excel Tool.
- The Equity Impacts section shows how the potential benefits of these policies are distributed in space and investigates the proportion of the benefits that will go to low-income households and disadvantaged communities.
- Finally, the Policy Options section assesses the usefulness of express lane discounts for supporting ZEV sales and proposes an alternative design targeting used vehicles and disadvantaged communities.

Policy Background

Regulatory Overview of ZEV Sticker Policies

According to the California Department of Transportation (Caltrans), "managed lanes" is defined as, "an operational practice utilized to address congestion by controlling traffic movement on the highway." Managed lanes include high occupancy vehicle (HOV), high occupancy toll (HOT, or Express Lanes), and bus-only lanes. Since 1999, California has additionally used the control of traffic in managed lanes to encourage the purchase and use of relatively lower polluting single-occupancy vehicles.

High occupancy vehicle lanes were first built in California in 1970, and modern road pricing arrived in 1993, amid much debate, with the opening of the Foothill Tollway in Orange County (*11*). But apart from Orange County and bridge tolling, road pricing had not expanded throughout the rest of the state until much more recent times.

Currently, a variety of federal, state, and local/regional laws govern the construction and management of managed lanes, including regulations around the use of stickers to exempt single-occupancy vehicles.

Federal Laws Regulating Managed Lanes (HOV/HOT)

Framing all other regulations, federal laws for HOV/HOT and sticker exemptions can be found in Title 23 of the United States Code, section 166. Federal regulations state that states may allow single-occupancy vehicles meeting certain emissions standards to use both HOV and HOT lanes, and either toll them or allow them without tolls, after meeting certain requirements. In particular, the State agency must provide a report that acknowledges and describes the following:

1. The facility is not, "degraded" (defined as, "vehicles operating on the facility are failing to maintain a minimum average operating speed 90 percent of the time over a consecutive 180-day period during morning or evening weekday peak hour period (or both.).");
2. The exempt vehicles will not cause the facility to become degraded;
3. The State shall establish a program monitoring the impact of the exempted vehicles on the facility;
4. The State shall establish an enforcement program for use of the facility;
5. If the facility becomes degraded, the State shall operate the facility in such a way that will bring traffic back up to a minimum average operating speed, by
    a. Increasing the occupancy of the vehicles;
    b. "Varying the toll charged on non-HOV vehicles…";
    c. "Discontinuing allowing non-HOV vehicles…"; and/or,
    d. Increasing the capacity of the facility.

It is Important to note that federal authorization of vehicles based on emissions standards in HOV/HOT lanes is scheduled to expire in 2025. Enacting language for the emissions standards and the sunset is the FAST (Fixing America's Surface Transportation) Act (*12*).

State Regulations

The first set of vehicle HOV exemptions on the basis of air quality were passed as AB 71, in 1999 (*13*), which created a sticker program for certain lower emitting vehicles. Since that time, a variety of bills concerning exemption have been passed, affecting the time period for sticker validity and the type of vehicle allowed exemption.

AB 2628 (2004) authorized the first 85,000 hybrid vehicles to be allowed stickers valid until 2008, extended by AB 2600 to 2011. AB 2628 also allowed for 40,000 of other certain types of plug-in hybrid vehicles, and which was extended and expanded by AB 266 (2013), SB 853 (2014), AB 2013 (2014), and SB 838 (2016) (*14*).

California currently operates the, "Clean Air Vehicle" (CAV) program through the California Air Resources Board and the California Department of Motor Vehicles (*15*). Enacted by AB 544 (2017), the program provides exemptions for 100% electric or hydrogen fuel cell vehicles, certain plug-in hybrid vehicles, and certain compressed natural gas vehicles. These stickers are issued per year, with staggered expiration dates. As noted in federal law, all stickers are set to expire by September 30, 2025.

Further, the CAV program now manages an income-based program (IB CAV), enacted by SB 957 (2018). This program allows owners meeting income requirements (at or below 80% of the state median income for their household) to be issued a CAV sticker for a used vehicle. Additionally, owners meeting certain lax income levels (beginning at $150,000 for single filers) can obtain a sticker for a used vehicle as well as purchase assistance through the Clean Vehicle Rebate Program (CVRP) (*16*).

CAV sticker regulations and management of HOV/HOT facilities at the state level, including requirements for addressing degradation and income limits, can be found in California Vehicle Code sections 5205.5 and 21655.9. Section 21655.9 also required Caltrans to provide a report on HOV facility degradation in 2017 (*17*).

Regional Regulations

Caltrans currently maintains a comprehensive website (*18*) dedicated to managed lanes throughout the state. Regional regulations vary across the state for vehicles displaying CAV stickers, which are also subject to management changes due to degradation of facilities.

The CAV sticker program allows, within the specified time parameters, for access to HOV throughout California, and allows for regional authorities to provide discounted tolls where applicable. No regional entity currently offers any CAV sticker discount based on owner income.

San Francisco Bay Area authorities manage an extensive network of FasTrak and HOV lanes. Currently, the network offers 50-100% discounts (*19*) on tolls for single-occupancy vehicles displaying a CAV sticker as well as a FasTrak CAV toll tag.

Neither the Toll Roads of Orange County, nor the Orange County Transportation Authority currently offer a discount for CAV stickered vehicles.

The Los Angeles Metropolitan Transportation Authority currently offers a 15% discount on CAV stickered vehicles (*20*).

Baseline ZEV Adoption Scenario

To study the impact of an express lane discount on ZEV adoption, we will use an established ZEV adoption trajectory as the baseline scenario for today through 2030, when there will be roughly 5 million privately owned light duty ZEVs in California. This trajectory was developed as part of a study on the necessary steps to decarbonize California's transportation system (*21*) and expanded on in a study of the charging infrastructure needed to reach 100% ZEV sales by 2035 (*22*). This adoption trajectory is particularly useful because it tracks adoption separately for households of different incomes and housing types, since these are known to be the two largest controls on ZEV adoption (*4*) and are likely to have a strong impact on drivers' willingness to use express lanes. The rest of this section describes the adoption model and the baseline adoption scenario for 2022-2030, with extensions to 2035 where relevant.

The adoption model this report uses is designed to cover the purchase and use of ZEVs by California households from 2021 to 2045, but because the analysis in this report has an end date of 2030, we only consider the first decade of the ZEV adoption trajectory. The first decade of this adoption model is designed to closely reflect existing adoption patterns, with high income households in single family homes accounting for most of the ZEV adoption and most purchases being the first ZEV in a household. In later years, as ZEV sales increase, adoption will expand more into middle-income households and multi-unit dwellings, and multi-EV households become more common. The scenario allocates ZEVs to California households using a two-part adoption model, with adoptions modeled separately based on housing type and income, the two strongest factors affecting ZEV adoption. The purchase of a household's first ZEV is treated as the product of the diffusion of innovations through their market segment, with adoption starting relatively slowly but accelerating rapidly once a many similar households own ZEVs. Once a household has purchased its first ZEV, it begins to be assigned additional ZEVs, up to the total number of vehicles owned by the household. This section covers the key assumptions for building the model, the main inputs used in the model, the adoption model for a household's first ZEV, and the method for assigning additional ZEVs to households that already have one. The output of this model is the total number of households in each group with 1, 2, 3, 4, or 5 ZEVs in their household fleet each year, which we use as the basis to determine how many additional ZEVs would be sold under various express lane discount scenarios.

Key Assumptions

The adoption model is designed around the goal of understanding the amount of charging infrastructure needed to support the electrification of all light duty vehicles in California, in line with goals set by the state government. The first few years emphasize early household segments where ZEV adoption has begun to accelerate under existing conditions. In later years, the adoption model expands ZEV ownership to a wider range of households, under the assumption that vehicle purchase costs will have fallen enough for all households in the state to own ZEVs. Our analysis assumes that decreases in battery costs, purchase incentives, and regulatory pressure like California Air Resources Board's ZEV sales mandate (*9*, *23*) will be sufficient to ensure that fleet electrification meets the state's targets. In addition, we make the following key assumptions:

- Electric vehicle adoption will be generally unidirectional. While roughly 20% of early ZEV owners switched back to ICEVs (*24*), converting all light duty vehicles in California to ZEVs will require all households to replace their ICEVs with ZEVs.
- The specific mix of BEVs, PHEVs, and fuel cell vehicles sold each year is adapted from a previous analysis of the steps needed to decarbonize California's economy by 2045 (*21*), with totals adjusted upward to meet the more aggressive target of 100% ZEV sales by 2035, as well as CARB's proposal for the Advanced Clean Cars II rule (*9*). While different types of ZEVs are likely to be best suited to different uses, we assign BEVs and PHEVs in constant proportion across ZEV-owning households.

- For simplicity, we explore the electrification process for privately owned light-duty vehicles assuming they are used in a similar fashion during the study time frame as they are presently. Households retain the same number of vehicles and have the same annual vehicle miles traveled (VMT) over the study period.
- We assume that the primary barrier to adoption takes the form of hesitancy to acquire the first ZEV, since it requires an investment in charging infrastructure and for household members to adapt their behavior to a new technology. Households that do so will be willing to gradually replace the rest of their ICEVs with ZEVs as these vehicles become available.

Model Inputs

The ZEV adoption model uses American Community Survey (ACS) 2015-2019 Five-Year Public Use Microdata Samples as its main input. This data source is available in consistent format throughout the United States and provides a combination of detail and sample size not available in any similar dataset. Because the ACS does not provide cross tabulations for the specific combination of variables we used, we produced estimates directly by summing the average household weights for all households in California with each combination of income, housing type, and number of household vehicles.

The ZEV adoption model tracks households in six groups according to income and housing type; the categories are based on Lee et al. (2019) but have been simplified to make it possible to generalize the model to the whole population. This grouping uses three levels for annual household income (under $75,000, $75,000–$200,000, and above $200,000) and two levels for housing type (single-family and multi-unit). For simplicity, we assume that the relative sizes of the various population segments modeled do not change over the study period and that vehicle ownership remains constant. The number of households in each group, the adoption model parameters for the first ZEV purchased by households of each group is shown in Table 1. Each group is subdivided by number of household vehicles (1, 2, 3, 4, or 5+); higher-income households generally have more vehicles than lower-income households, and households in single-family homes generally have more vehicles than households in multi-unit dwellings. Only the five most-used vehicles in each household are considered.

Table 1. Number of households and vehicles by category, totals rounded to the nearest thousand

Housing Type	Household Income	Total Households	Total Vehicles	Percent of Households	Percent of Vehicles
Single-family	Under $75,000	3,466,000	6,739,000	28.6%	26.9%
Single-family	$75,000 - $200,000	3,571,000	9,048,000	29.5%	36.0%
Single-family	Above $200,000	1,204,000	3,225,000	9.9%	12.8%
Multi-unit	Under $75,000	2,577,000	3,779,000	21.3%	15.1%
Multi-unit	$75,000 - $200,000	1,097,000	1,963,000	9.1%	7.8%
Multi-unit	Above $200,000	198,000	346,000	1.6%	1.4%

First Vehicle Adoption

The number of households in each group buying their first ZEV each year is determined by a diffusion of innovations model adapted from Lee et al. (*25*). The diffusion of innovations model describes the adoption of new technologies as a sigmoidal pattern where sales begin slowly among households willing to experiment with a new technology, and sales gradually increase as the bulk of the group sees that the technology can meet their needs (*26*). Using this framework, we target household type and income as the main factors driving hesitancy to adopt—wealthier households that can afford new vehicles and charging infrastructure will adopt ZEVs sooner than households that cannot. Subgroups with more total vehicles start with a higher overall rate of ZEV ownership, which reflects the lower risks faced by households with multiple vehicles to adopt a single electric vehicle than those faced by households with one or two vehicles (*2*, *7*). The total number of households with an ZEV in each group each year is shown in Figure 1. High-income households in single-family homes are the largest group of ZEV households in the first few years of the study, but by 2030, middle-income households in single-family homes are the largest group and significant numbers of households in all categories have at least one ZEV.

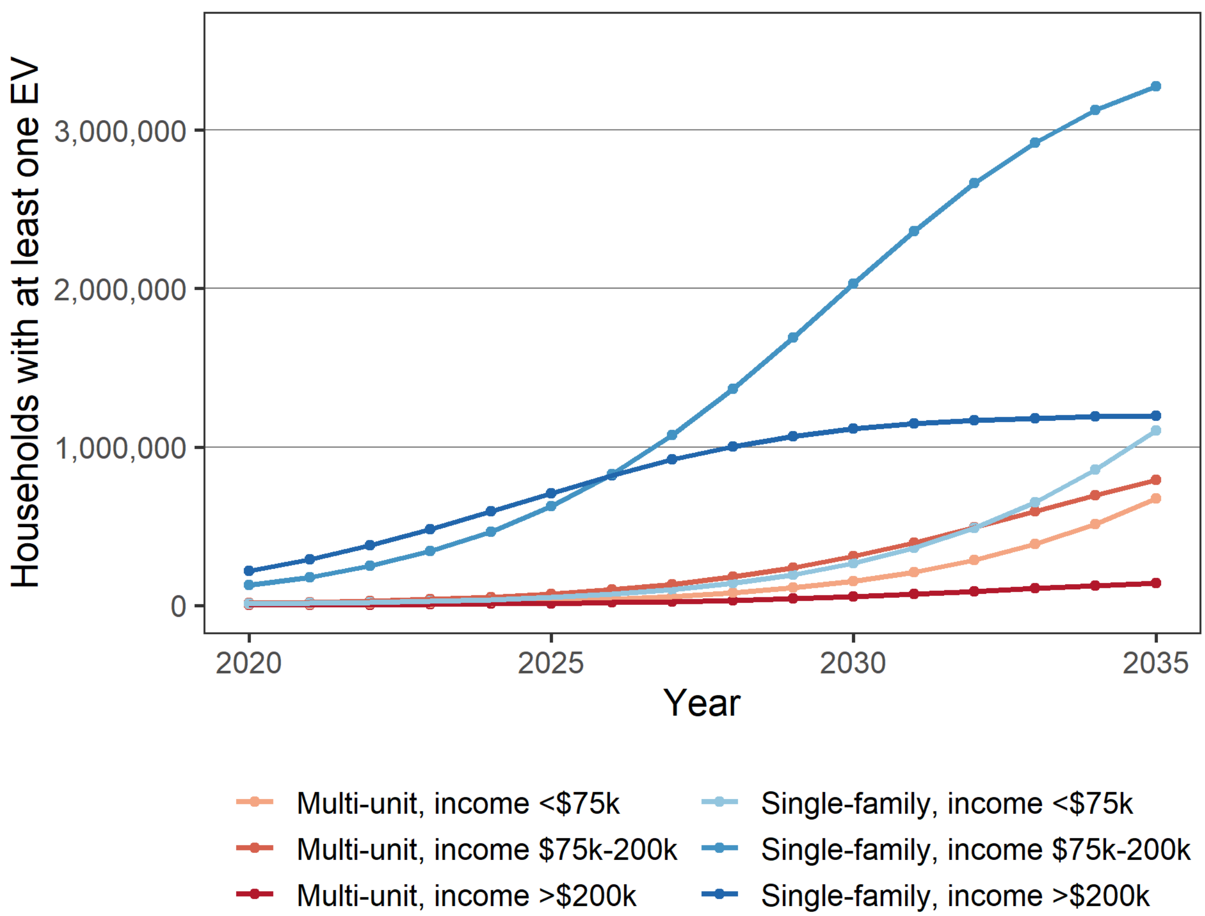

Figure 1. Total households with at least one ZEV grouped by income and housing type

Total ZEV Sales, Additional Vehicle Adoption, and Vehicle Retirement

While first ZEVs provide the bulk of ZEV sales early on, most households in California own multiple vehicles. We address the adoption of additional ZEVs by each household by matching the sales of these vehicles to the gap between the sales attributed to the adoption of new ZEVs or the replacement of retired ZEVs and the annual ZEV sales target set by the state. The expansion of ZEV sales in California so far has been driven in part by the California Air Resources Board's ZEV Mandate (*27*, *28*), which has required an increasing share of vehicles sold in the state to be ZEVs each year. While the current version of the ZEV mandate does not continue past 2025, when 22% of vehicles sold in the state must meet the criteria (*23*), the proposed Advanced Clean Cars 2 rule would mandate that zero-emission vehicles make up 26% light-duty vehicle sales in California by 2026, 61% by 2030, and 100% by 2035 (*9*). The adoption of first ZEVs is discussed in section 3.3, and our model accounts for multiple ZEV households by allocating some sales to replacing ZEVs that have been retired, which is assumed to happen after 14 years. Mandated sales remaining after first ZEV adoptions and ZEV replacements will be assigned to households that already have an ZEV and have at least one remaining ICEV in their household fleet.

The total allocation of vehicle sales to adoption of a first household ZEV, adoption of additional household ZEVs, and ZEV replacement is shown in Figure 2. From 2021 to 2035, 48.4% of new vehicles sold will be ICEVs, 25.4% will be ZEVs sold to households that do yet have any, 22.7% will be ZEVs sold to households with at least one ZEV already (mostly after 2026), and 3.6% will be ZEVs sold to replace existing ZEVs (almost all after 2030).

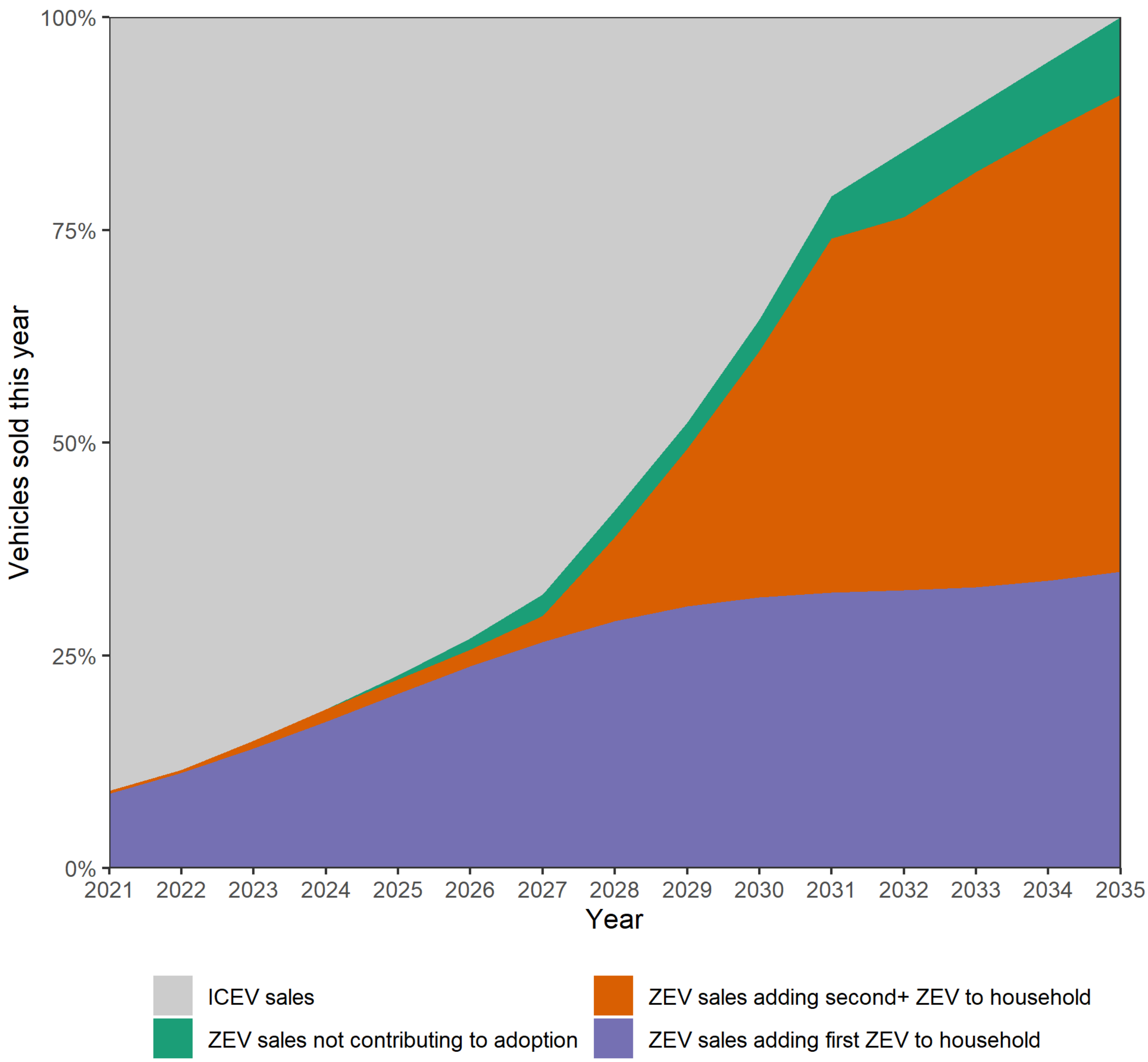

Figure 2. Allocation of new vehicle sales by year

This model separates the adoption of the first ZEV in the household from adoption of additional ZEVs to account for the significant barrier to adoption posed by adopting new technology and installing charging equipment. Once households have converted one vehicle to a ZEV, they are able to convert their other vehicles at a rate of up to one new ZEV per household each year. Because much less is known about the characteristics of multi-EV households, additional vehicles after the first are electrified in proportion to the total number of ICEVs owned by households with at least one ZEV in each group, such that if a household category has 20% of the remaining ICEVs in households with at least one ZEV, they will be assigned 20% of the additional ZEVs. The result of this is that while all households will eventually convert their entire household fleet to ZEVs, households that have more total vehicles and adopt ZEVs sooner will do so much more quickly than households with fewer vehicles and that adopt ZEVs later.

Electric Vehicle Adoption Results

The output of this adoption model is the total number of households in each group with 1, 2, 3, 4, or 5+ ZEVs in their household fleet each year. Figure 3 shows the total number of ZEVs owned by households in the six income and housing type categories in California from 2020 to 2035. Over the first few years, most vehicles will go to middle- and high-income households in single family homes, but ZEV sales increase and these types run out of vehicles to electrify, an increasing number of vehicles will be purchased by other types of households.

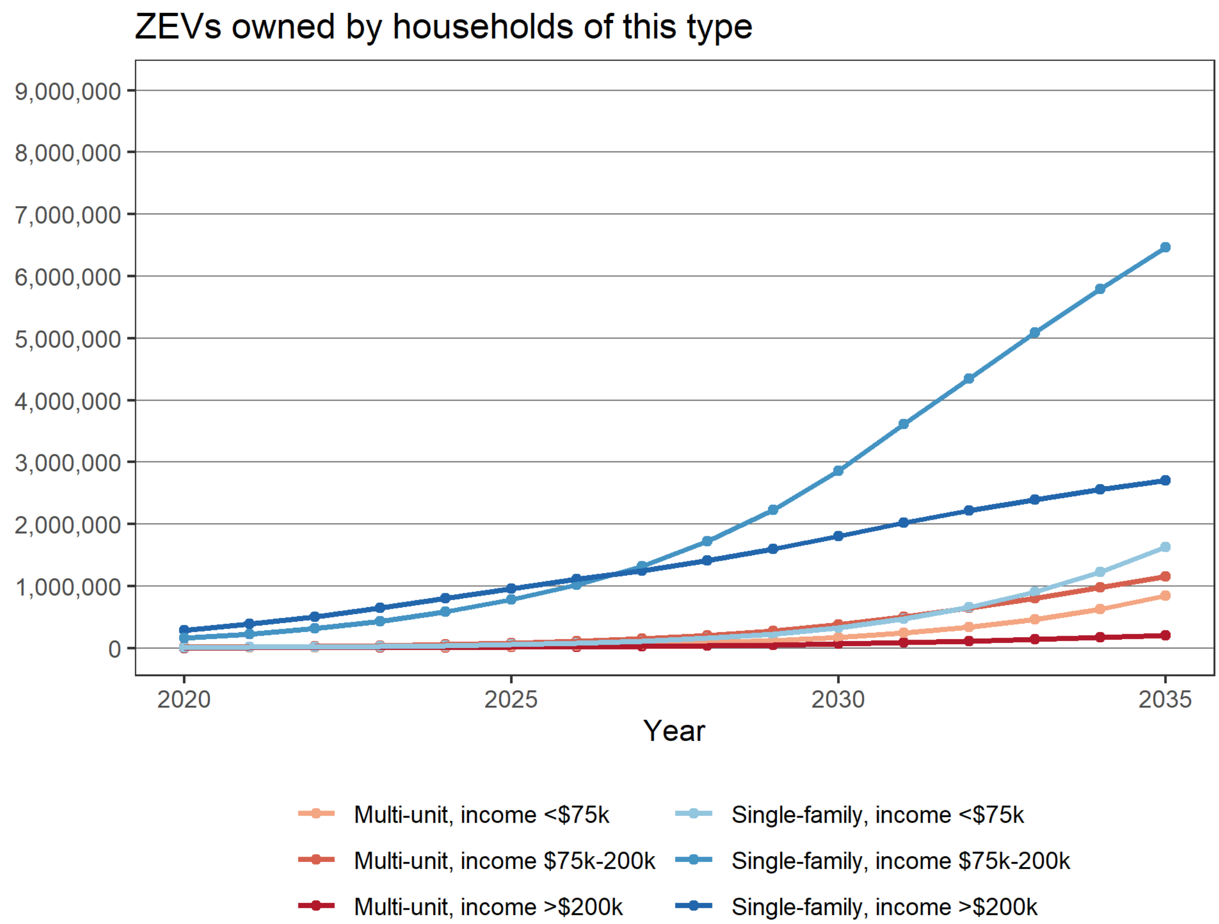

Figure 3. Total number of ZEVs owned by households of different incomes and housing types

Because this report focuses on the link between a temporary discount provided to ZEV purchasers, it is also important to identify the number of vehicles in each age group each year. As shown in Figure 4, while less than 5% of vehicles would be eligible for an express lane discount through 2025, the increase in ZEV adoption over the next 10 years will in turn greatly increase the proportion of vehicles that would be eligible for an express lane discount. By 2030, 11% of all light-duty vehicles in California will be ZEVs up to 3 years old and 16% will be ZEVs up to 5 years old. By 2035, these proportions will be 20% and 32%, respectively.

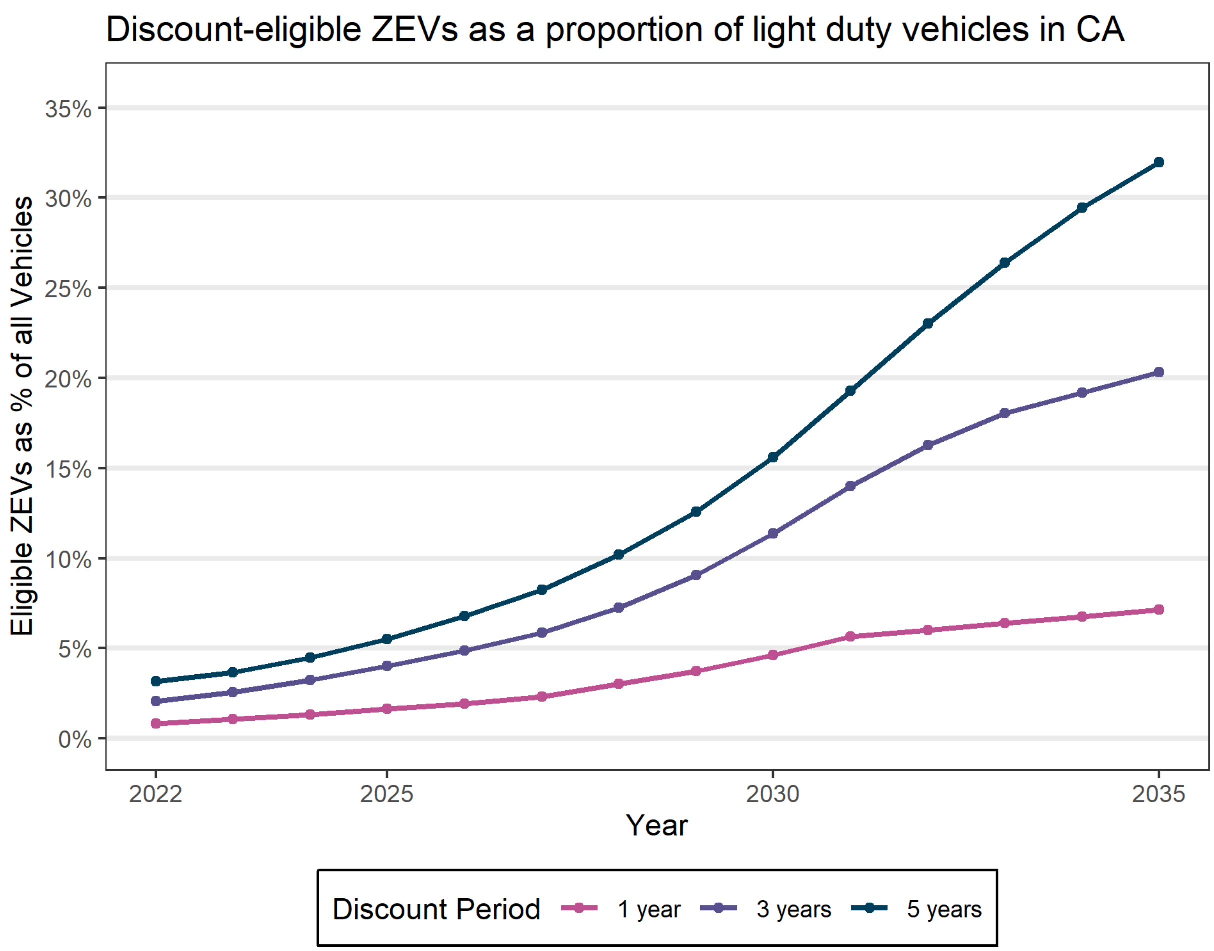

Figure 4. Proportion of vehicles eligible for discount by duration of discount

Finally, ZEV sales and fleet information are downscaled to the census tract level based on the number of households with each combination of income, housing type, and number of vehicles in each census tract from a synthetic population of California households produced using the 2015-2019 5-year American Community Survey and associated Public Use Microdata Samples. In the rest of this report, these baseline sales numbers will serve as a starting point for the impact of express lane discounts and as the basis for express lane usage by ZEVs. Sales generated by the incentives will be in addition to the sales generated by the existing policies incorporated into the baseline scenario.

ZEV Usage of Express Lanes Under Existing Adoption Scenario

After generating the baseline adoption scenario, we determine how much each of these households would use express lanes and how much they would benefit from discounts. To do this, we extract household and trip records from the California Statewide Travel Demand Model (CSTDM) and match households in each Traffic Analysis Zone (TAZ) with households in corresponding census tracts in our ZEV adoption scenario. We compute the distance traveled by each household on roads with express lanes during AM and PM peak travel using shortest paths for a network constructed from highways and major roads. Express lanes were identified from the Caltrans GIS portal (*29*), and are current as of February 2022. Finally, we aggregate the household results within each adoption category and census tract by daily distance traveled on roads with an express lane to understand the potential total impact that an express lane discount would have.

California's existing express lanes can be roughly divided into Northern California and Southern California regions, and all trips in the CSTDM made on these express lanes were made by residents of surrounding TAZes, as shown in Figure 5. The Northern California express lanes are located in Contra Costa County (I-580), Alameda County (I-680), and Santa Clara County (I-680, CA-237), but draw traffic from residents of many surrounding counties. The Southern California express lanes are located in Los Angeles County (I-110, I-10), Orange / Riverside Counties (CA-91), and San Diego County (I-15). While ZEV ownership will expand significantly throughout the state, areas where express lanes are available will have somewhat higher levels of ZEV adoption throughout the study period, as shown in Figure 6.

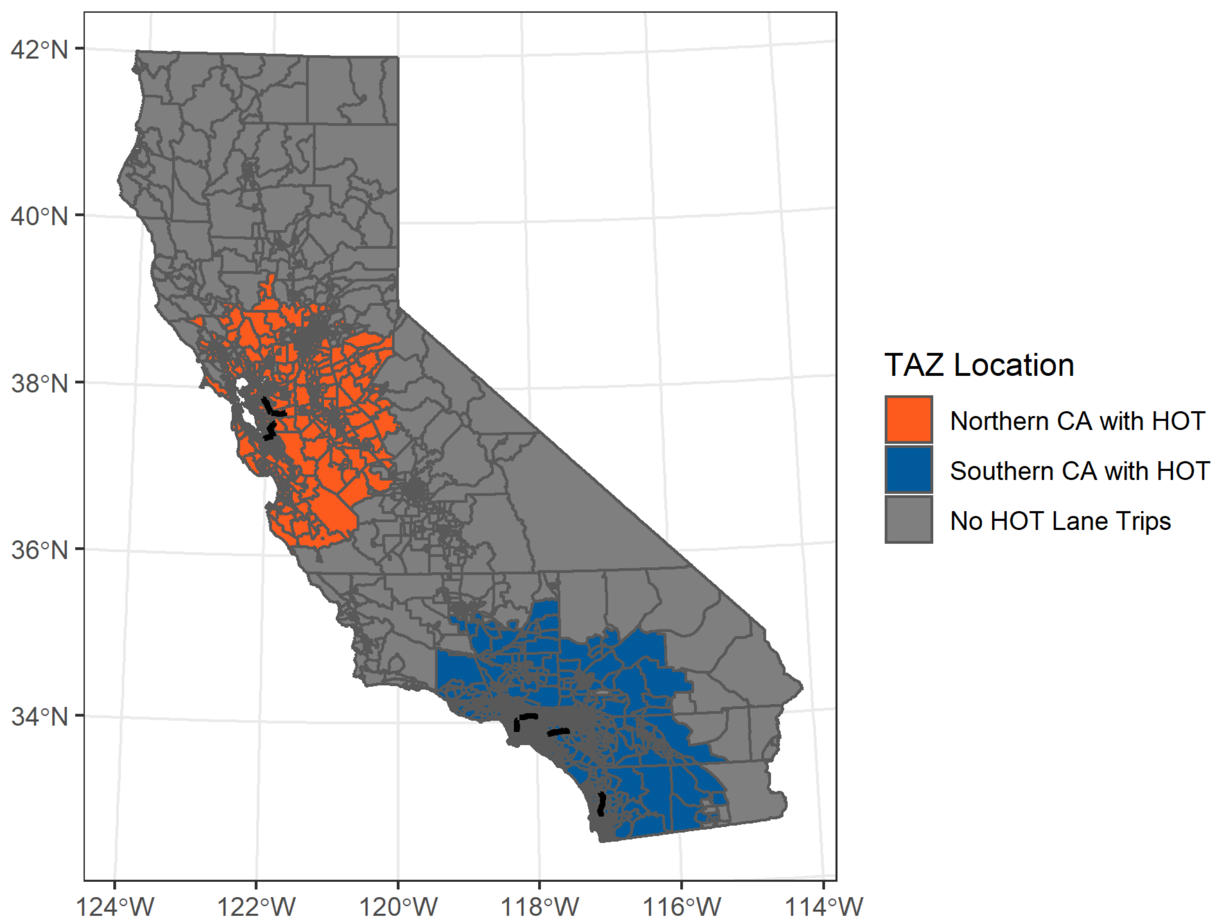

Figure 5. Map of current express lanes and TAZes colored by whether residents make any trips on roads with express lanes

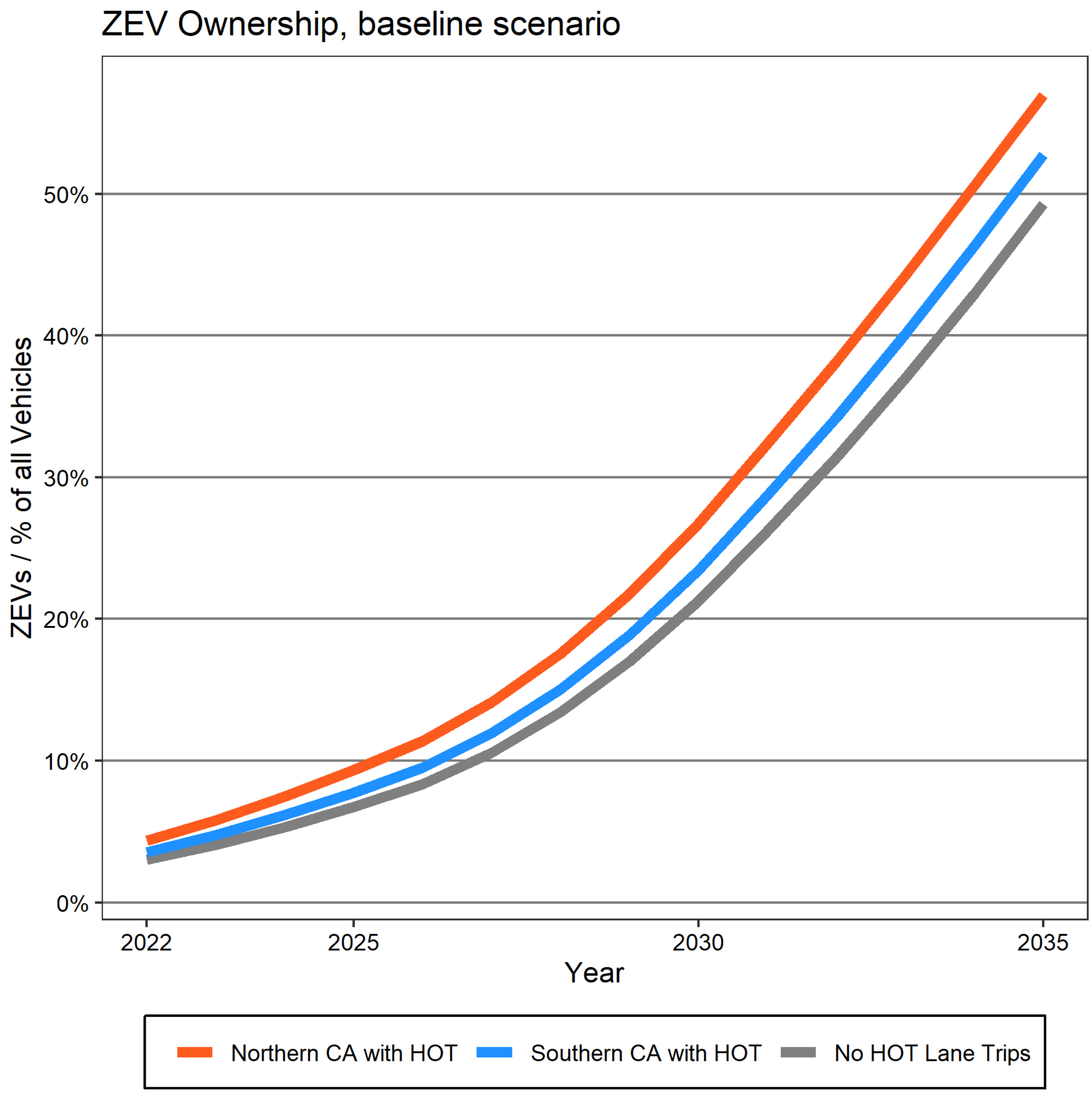

Figure 6. Under baseline scenario, ZEV ownership is somewhat higher in regions with express lanes

Peak Hour Travel

While express lanes provide some benefits to travelers throughout the day, the analysis on this report focuses on AM and PM peak travel because 1) the time savings from express lanes and potential cost savings of an express lane discount are concentrated during these periods, 2) the frequency and predictability of these benefits mean they can add up to something large enough to affect vehicle purchase decisions, and 3) ZEVs are much more likely to be used for commuting than other vehicles. While these lanes can provide significant time savings at all times of day, the total potential benefit from using these lanes twice a day on a regular commute when congestion is worst is much greater than what can be gained from occasional use; this is a particularly important consideration because there will likely be a substantial difference in purchase cost between ZEVs and ICEVs throughout the study period. New ZEVs are also disproportionally likely to be purchased for commuting, both because they are primarily available in body types that are used for commuting and because their lower operating cost per mile makes them better suited to predictable high mileage uses than vehicles with power systems. Figure 7 shows the proportion of vehicles used for commuting by fuel type and body type in the 2019 California Vehicle Survey (*30*).

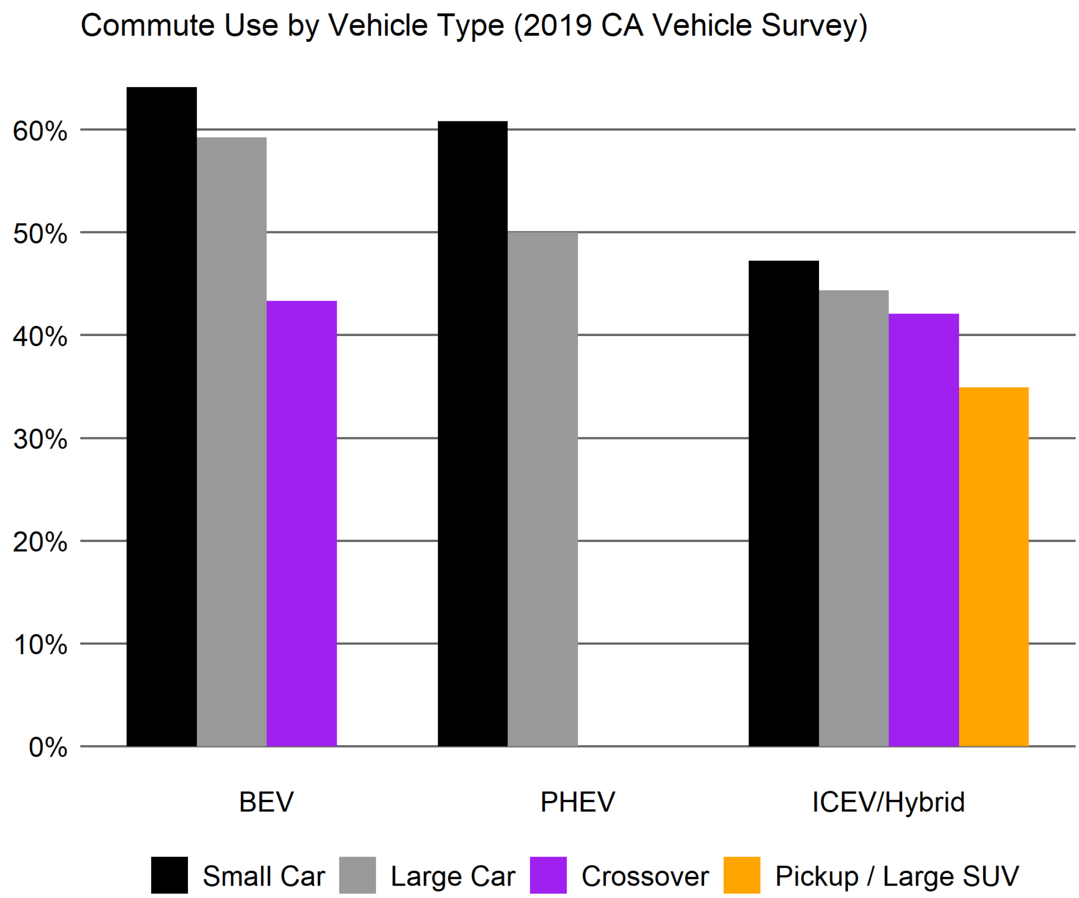

Figure 7. Commute usage by vehicle type and power source, 2019 California Vehicle Survey

While the expanded availability of larger format ZEVs and a general increase in ZEV ownership will likely decrease the proportion of ZEVs used for commuting in the long run, the baseline adoption scenario suggests that commuting will likely remain the major use of these vehicles throughout the study period. Under the baseline scenario, ZEVs will represent the majority of first vehicles among upper-income households by 2025 and of middle-income households by 2030, as shown in Figure 8. Because of the high likelihood of commute use and relatively high incomes, ZEV owners may make up a disproportionately large share of express lane users even without providing additional incentives for them to use these lanes.

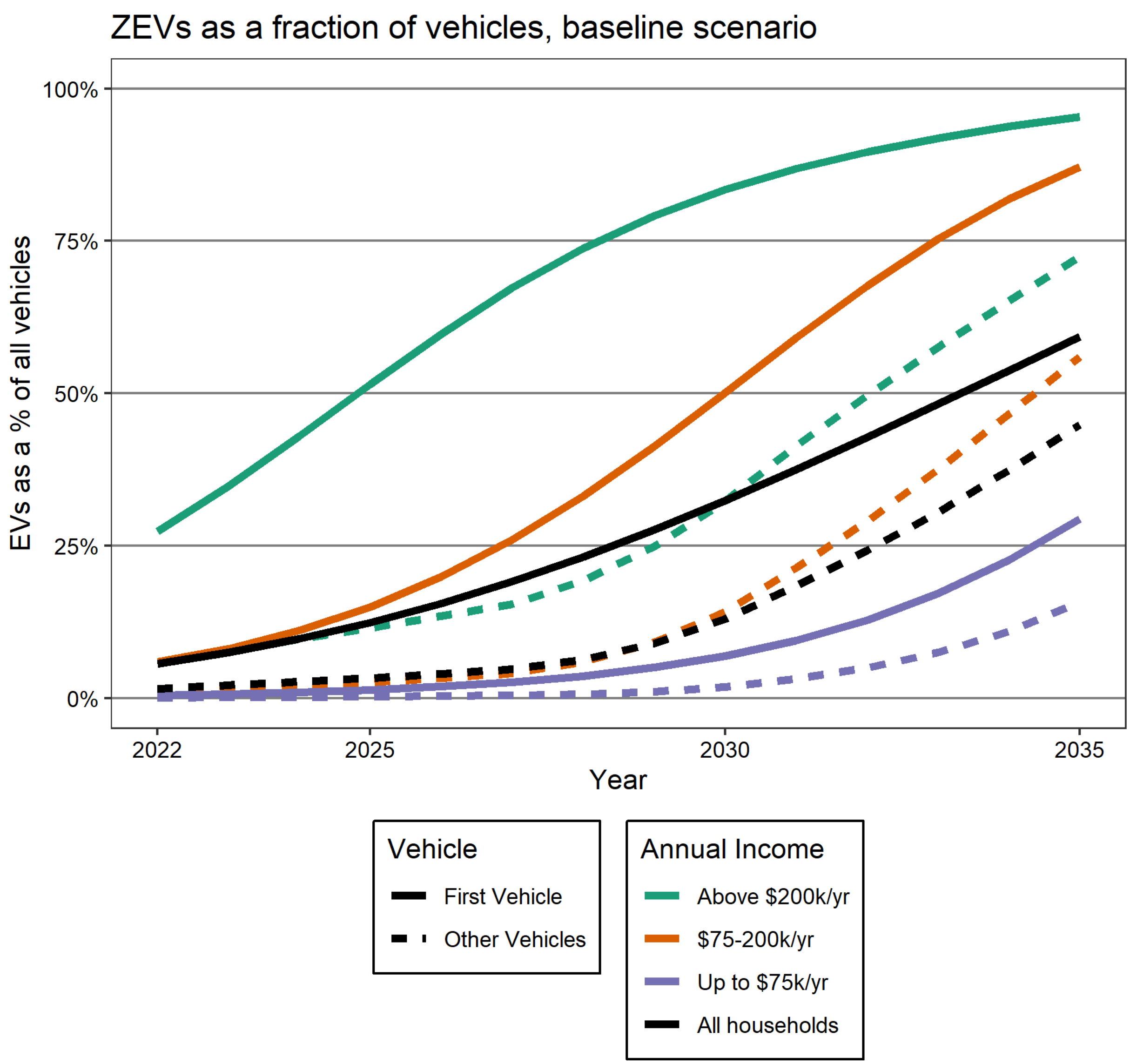

Figure 8. ZEVs will be particularly common as the first vehicle in middle- and high-income households

ZEV Usage of Express Lanes Under Existing Adoption Scenarios

While all express lanes are located on major commute routes, they are currently only an option for about 5% of peak-hour trips by in the Southern California region and about 4% in the Northern California region. The potential impact of a toll discount for ZEVs is limited to vehicles that can make use of these lanes as part of their commute, but some households will likely have a very high potential benefit. If the express lanes are added to more highways throughout the state, the potential impact of any adoption discount would increase correspondingly. In both regions, express lanes are an option for a higher proportion of ZEV commuters than ICEV commuters, as shown in Figure 9, but Northern California ZEVs are more heavily concentrated in areas with potential for toll lane usage than Southern California ZEVs. As ZEV adoption expands throughout the state, their potential use of express lanes will gradually converge towards the regional average.

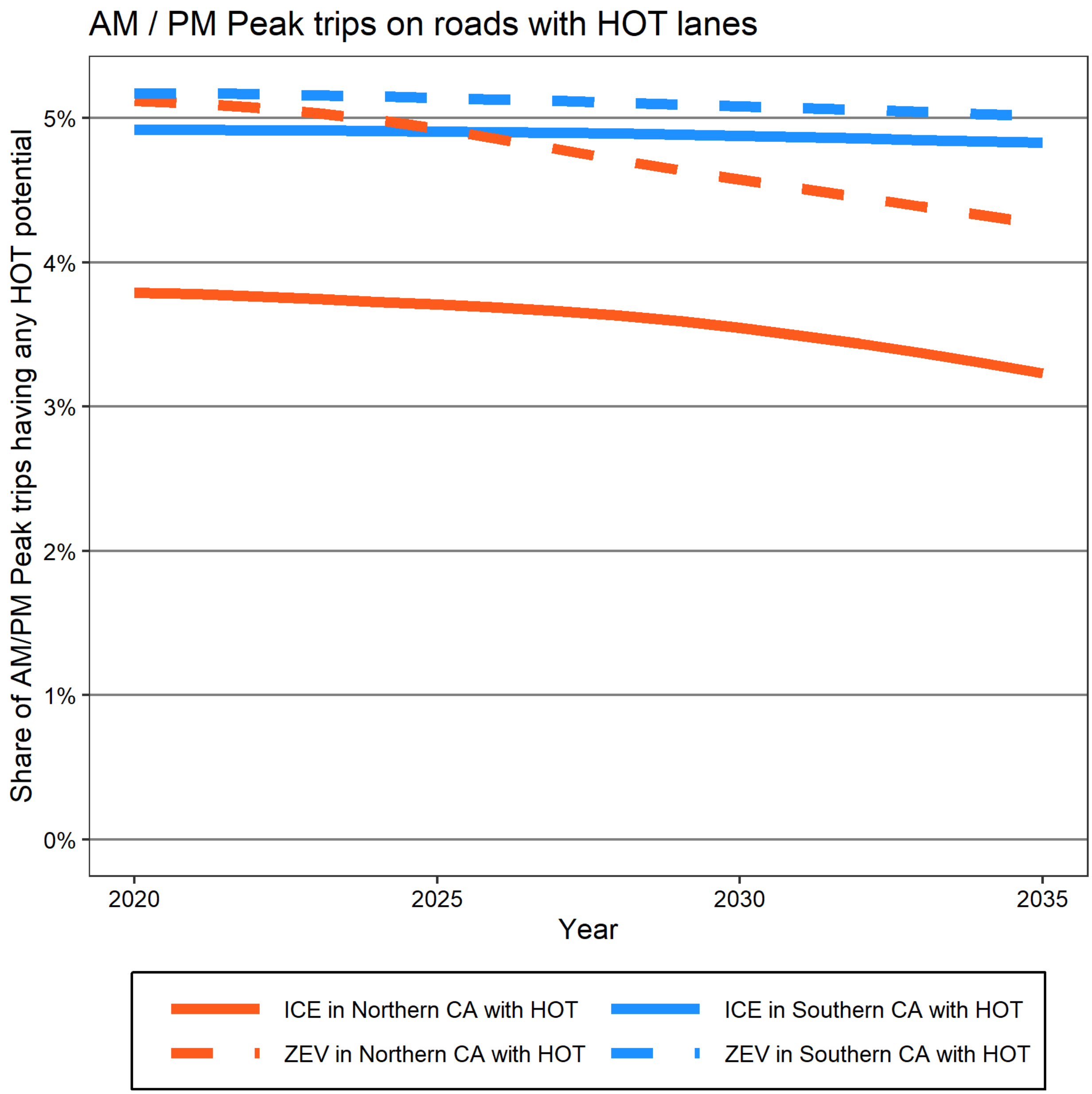

Figure 9. Potential express lane trips as a proportion of all peak hour trips by ZEVs and ICEVs

The number of ZEVs using express lanes will increase over the study period regardless of whether a discount is applied. While they are slightly less than 5% of all light duty vehicles in the state today, their high likelihood being used for commuting means they make up a much larger proportion of commute hour trips. Figure 10 shows the proportion of all peak-hour trips made by ZEVs on highways with express lanes under the baseline adoption scenario. In 2022, the proportion of trips made by ZEVs ranges from around 5% on some of the routes in Southern

California to around 10% in Northern California. As adoption expands, these rates will increase rapidly; all the Northern California routes being over 20% ZEVs by 2026 and over 45% by 2030, and all the Southern California routes will reach 15% by 2025 and 30% by 2030.

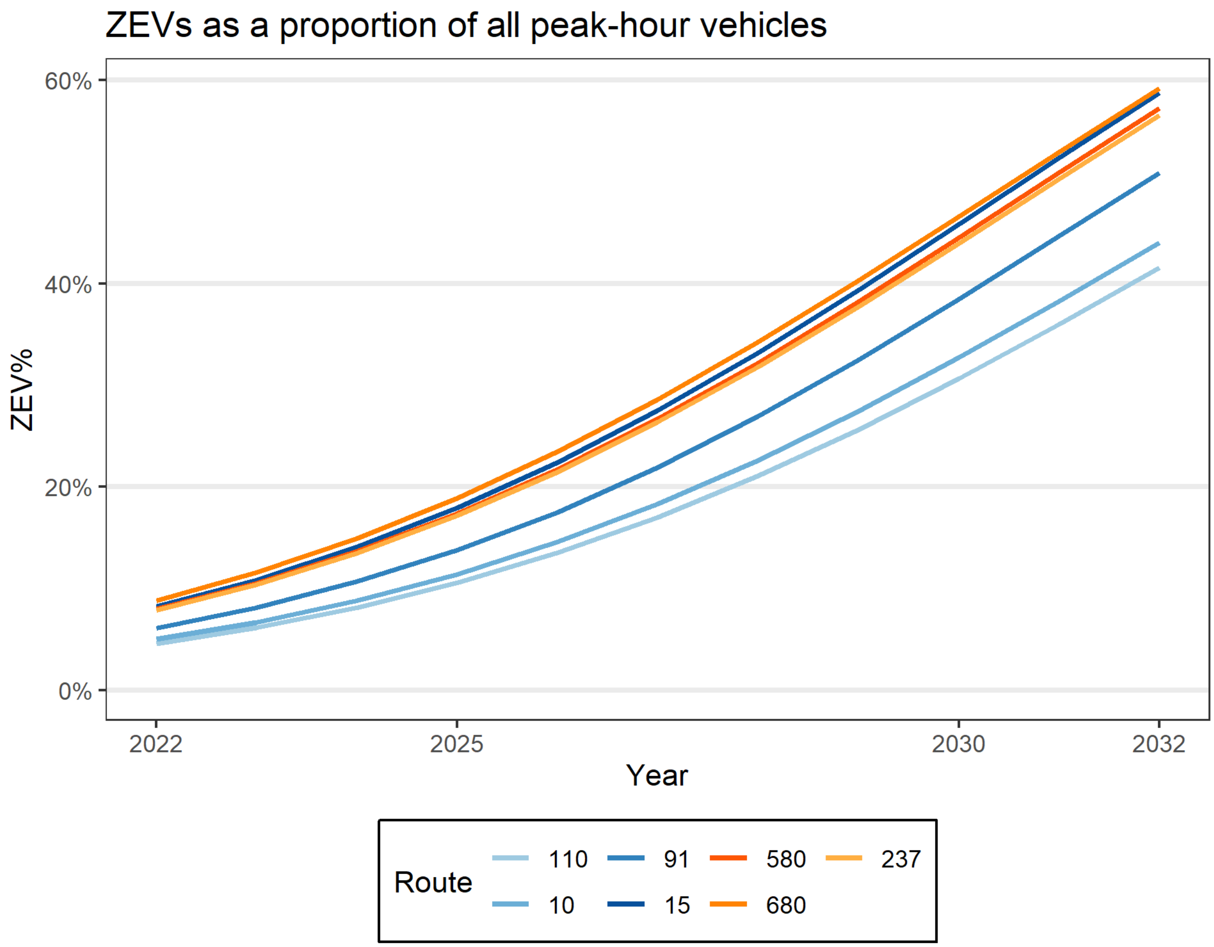

Figure 10. ZEVs will increase from 5-10% of commute hour traffic today to over 40% by 2032

Impact of Discounts on ZEV Adoption

This section discusses the method for computing the impact of express lane discounts on ZEV adoption, the size of that impact under three discount scenarios, and introduces the Excel tool, which can be used to generate additional scenarios.

Express Lane Discount as Financial Incentive

Governments have tried a wide range of policies to incentivize the adoption of light duty ZEVs, but studies have consistently shown that the most effective methods are large financial incentives for vehicle purchase and allowing vehicles to use HOV lanes at all times (*6*, *10*, *31*, *32*). The analysis in this report considers an express lane discount to be a fundamentally monetary incentive, rather than a travel time or convenience incentive like access to HOV lanes. The basis for this assumption is that the time savings drivers receive from express lanes is already available for purchase and discounts would only allow ZEV users to purchase it at a lower price.

Because we treat toll discounts as a subsidy for ZEV adoption, the key considerations are to determine how large of an incentive it is for various drivers and in turn how much of an impact that would have on their vehicle purchase decisions. To determine the size of the incentive under a given discount scenario, we compute the potential time savings from using the express lane, determine how much the driver would be willing to pay for that travel time savings, compare that to the discounted toll, and multiply it by the number of times they would be able to accrue that savings over the duration of the discount plan. Once the incentive has been computed for a subset of drivers, their ZEV adoption rate is adjusted above the baseline in proportion to the size of the discount.

Calculating the Incentive and Impact on Adoption

This section details the process for computing the equivalent financial incentive for a given express lane discount scenario and the range of parameters that make up a scenario. The computation can be divided into three steps: **travel time savings** (which is controlled by each driver's potential distance traveled on express lanes and two adjustable parameters), **effective financial savings** (which is controlled by the travel time savings and five adjustable parameters), and **impact on adoption** (which is controlled by the financial savings, baseline adoption rate, and one adjustable parameter). Computed values are noted in **bold** and adjustable scenario parameters are noted in *italics* when they are discussed.

Travel time savings is calculated separately for drivers with different potential distance traveled on express lanes, in 5-mile bins. Figure 11 shows the proportion of households with at least one peak-hour trip on a road with an express lane that fall into each bin; drivers who could use an express lane for a larger proportion of their commute have a higher potential time savings and are more likely to be swayed to purchase a ZEV if a toll discount is available. To compute the travel time savings, we determine how long their trip would take at the *travel speed in express lane* and how long it would take at *travel speed on other lanes*. The difference in travel speed between the two lanes cannot exceed 25mph in a scenario, since this figure is generally identified as the largest speed difference drivers will accept in adjacent lanes (*33*). While there are several other factors that could impact this analysis, this report and the Excel tool use this simplified method because time savings are linked to adoption in aggregate. Each driver's **travel time savings** is equal to the difference between the two travel times, measured in hours per day saved by using the express lane.

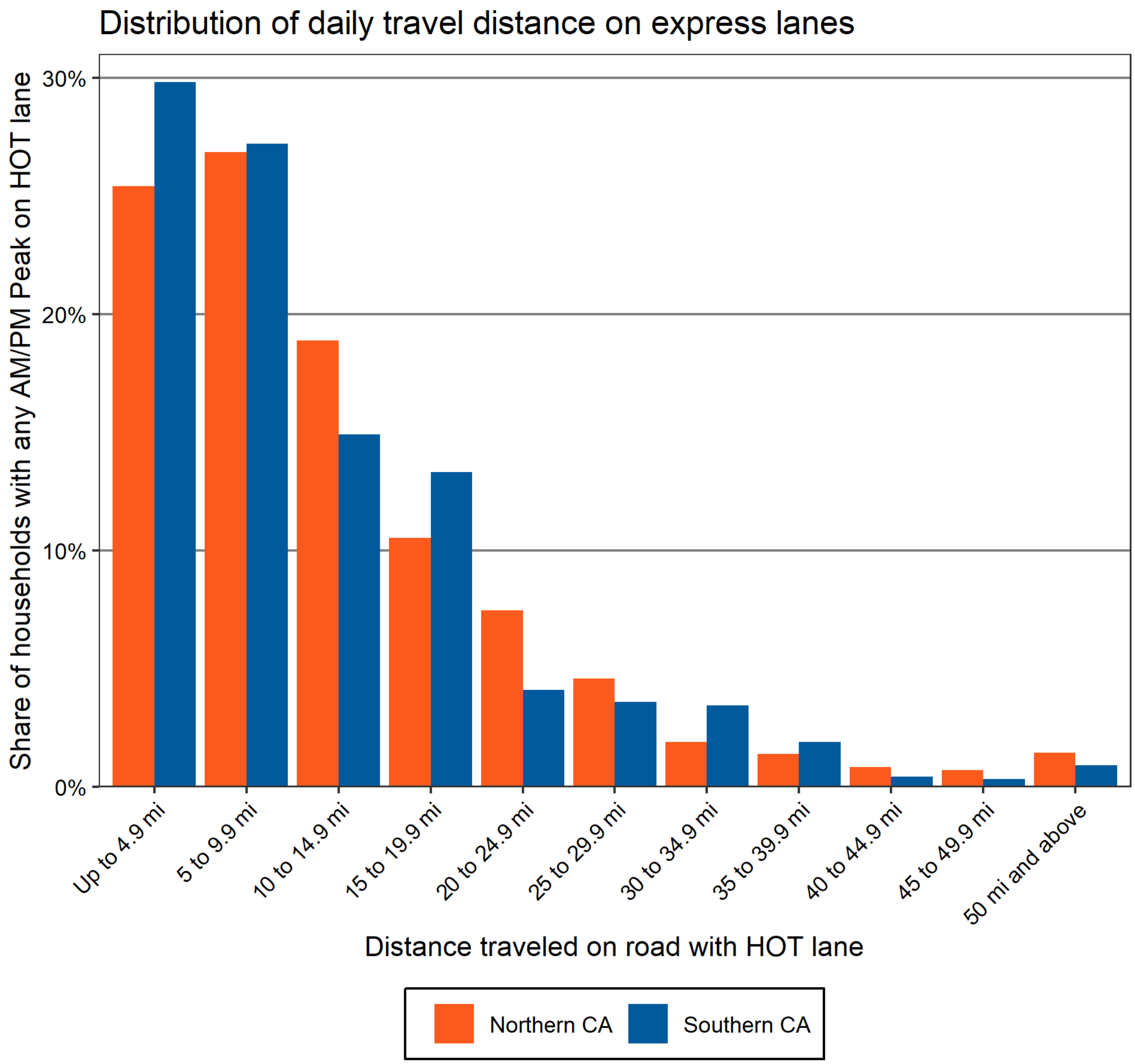

Figure 11. Proportion of households in each distance bin for peak-hour express lane usage

Effective financial incentive for each household per day based on their daily **travel time saved**, distance traveled, *toll* ($ per mile), *ZEV discount* (%), and *value of travel time savings* ($ per hour), it is then converted to a total value based on the number of *days per year* and *years of discount* for the given scenario. The size of the incentive per day is the driver's surplus value from using the discounted toll and depends on the relationship between the value of the **travel time savings**, the full price of the toll, and the discounted toll for ZEVs. First, compute the value of the travel time savings (Z) in $ by multiplying the driver's **travel time saved** by the *value of travel time savings*. Next, compute the full price toll (T) by multiplying the driver's distance traveled by the *toll* per mile and the ZEV toll (U) by reducing T by the amount of the ZEV discount. The daily incentive can take one of three values:

- When the value of travel time savings is less than the ZEV discount toll (Z < U), the driver would not use the express lane, so the benefit is $0 per day.
- When the value of travel time savings is between the ZEV discount toll and the full-price toll (U < Z < T), the driver would use the express lane only with discount, so the benefit is the difference between the value of travel time savings and the discount toll (Z – U).
- When the value of travel time savings is greater than the full-price toll (Z > T), the driver would use the express lane even without the discount, and the benefit is just the difference between the full-price and discount toll (T – U).

The benefit per day is relevant both for identifying the impact on adoption and for determining the number of addition users of express lanes. For this analysis, we assume that drivers will switch from not using the express lane to using it only in the second case, where the value of travel time savings is between the ZEV discount toll and the full-price toll. Additional trips are not counted when the full-priced toll was already cheap enough to make the express lane worth it for the driver. While other factors may impact the value of the incentive and the driver's willingness to use express lanes, existing studies have indicated that the proportion of drivers who will use of an express lane is almost completely explained by the expected travel time savings, toll, and difference in speeds between the express lane and other lanes (*34*).

The daily incentive is converted to total **effective financial incentive** by multiplying it by the number of *days per year* and the *years of discount*. In cases where a scenario combines multiple traffic situations that apply to different days of the year, the total **effective financial incentive** is equal to the sum of the incentive across all traffic situations. Finally, we determine the **impact on adoption** by multiplying the **effective financial incentive** by the *impact of incentives* parameter, which is measured as a % increase in sales per $1,000 of incentives available per household. The percent increase in sales is computed separately for households in the various express lane discount bands rather than being averaged across all households in order to capture the large potential impact of these discounts on households with a very high potential to use express lanes. This computation is derived from various studies of the impact of incentives on ZEV adoption, with potential values between 2.8% more sales per $1,000 (*10*) and 5-7% more sales per $1,000 (*31*).

While this report includes results from a range of selected scenarios, the Excel tool is designed to work with a range of parameter values, as shown in Table 2.

Table 2. Parameter Value Ranges and Descriptions

Parameter	Value Range	Comments
ZEV Discount	0-100%	
Discount Duration	1-5 years	How long can a vehicle receive the discount
Incentives Impact	2-10%	How many more ZEVs will be sold per $1,000 of incentive
Value of Travel Time Savings	$15-30 per hour	USDOT suggests $16.50, but this may be too low for California 2022-2035
Days per Year	0-365	How many days per year is this traffic situation in effect
Toll	$0.25-4.00 per mile	Toll range limits, LA Metro HOT lanes
Travel speed, general lane	15-70 mph	
Travel speed, express lane	20-75 mph	No more than 25 mph faster than travel speed in general lanes

Impact on ZEV Adoption

To demonstrate the potential impact of express lane discounts on ZEV adoption, we present three general scenarios, designed to capture approximate end members for the potential impact of this incentive. The Excel tool produced along with this report provides the ability to develop and explore a range of possible discount program designs, including scenarios that capture multiple traffic patterns that vary throughout the year. For all scenarios, additional ZEV sales caused by the discount are applied on top of the baseline adoption scenario, which tracks the net new sales of ZEVs (new ZEVs sold to replace an internal combustion engine vehicle) to households in each income range in a census tract. Table 3 shows the baseline scenario adoption totals aggregated to income levels. Because adoption is currently fastest among suburban commuters, which are also the category of vehicles most likely to use express lanes, vehicles used for commuting on roads with an express lane make up over 6% of new ZEV adoptions during the mid-2020s. While ZEV adoption accelerate statewide throughout the period, ZEVs will already make up a majority of vehicles that could use express lanes by 2032 and the rate of new adoptions begins to decrease after 2032.

Table 3. Baseline adoption scenario, net new ZEV sales for vehicles that could potentially benefit from express lane discounts and California totals

Income	Vehicles with potential express lane usage				California total				
Year	low	mid	hi	**total**	low	mid	hi	**total**	Express/ Total
2023	559	9,191	7,074	**16,824**	13,695	129,815	141,320	**284,830**	5.9%
2024	780	12,221	7,807	**20,807**	19,073	173,109	160,208	**352,390**	5.9%
2025	1,085	15,949	8,121	**25,155**	25,631	214,586	158,620	**398,838**	6.3%
2026	1,507	20,312	7,923	**29,742**	35,280	270,915	157,362	**463,557**	6.4%
2027	2,086	25,075	7,243	**34,404**	48,631	334,642	149,669	**532,942**	6.5%
2028	2,875	29,783	6,234	**38,892**	71,481	452,858	174,788	**699,127**	5.6%
2029	3,937	33,780	5,115	**42,833**	103,751	585,299	197,646	**886,696**	4.8%
2030	5,348	36,340	4,084	**45,772**	149,168	726,375	219,790	**1,095,334**	4.2%
2031	7,183	36,895	3,252	**47,330**	213,768	876,902	244,900	**1,335,571**	3.5%
2032	9,501	35,269	2,637	**47,406**	281,544	885,107	217,221	**1,383,872**	3.4%

Three general scenarios were produced to provide approximate estimates for the minimum, median, and maximum impact of this incentives. All three scenarios use a Value of Travel Time Savings of $20/hr, apply the discount for 200 days per year and use a discount duration of 3 years for each vehicle. The small impact scenario applies a 25% ZEV discount to a toll of $0.25/mi, assumes travel speeds of 40 mph in non-tolled lanes and 65 mph in express lanes, and assumes that sales will increase by 2.6% for every $1,000 of incentives. The medium impact scenario applies a 50% ZEV discount to a toll of $0.50/mi, assumes travel speeds of 35mph in non-tolled lanes and 60mph in express lanes, and assumes that sales will increase by 5% for every $1,000 of incentives. The large impact scenario applies a 75% ZEV discount to a toll of $1.50/mi, assumes travel speeds of 20mph in non-tolled lanes and 45mph in express lanes, and assumes that sales increase by 8% for every $1,000 of incentives.

The small and medium general scenario suggest a very low impact on ZEV adoption, and even the large impact scenario suggests that the program would only increase ZEV sales by a few thousand vehicles per year. Table 4 shows the number of additional ZEV sales generated by each incentive program over the next ten years. The small impact scenario represents an increase in ZEV adoptions of roughly 0.1% among vehicles that could use express lanes and is insignificant in the scope of ZEV adoptions statewide. The medium impact scenario represents an increase in ZEV adoptions of roughly 1.5% among affected vehicles and roughly 0.1% among all ZEV adoptions in the state. The high adoption scenario represents an increase in ZEV adoptions of roughly 12% among affected vehicles, which amounts to a 0.7% increase in ZEV sales throughout the state.

Table 4. Increased ZEV sales from three general express lane discount scenarios, separated by household income

Income / Year	Small Impact				Medium Impact				Large Impact			
	Low	Mid	High	**Total**	Low	Mid	High	**Total**	Low	Mid	High	**Total**
2023	0	9	7	**16**	7	135	107	**248**	50	1,020	808	**1,878**
2024	1	12	8	**20**	9	179	118	**306**	70	1,357	891	**2,318**
2025	1	15	8	**24**	13	233	122	**369**	98	1,771	927	**2,796**
2026	1	19	8	**28**	18	297	119	**435**	136	2,255	905	**3,295**
2027	2	24	7	**33**	25	367	109	**501**	188	2,784	827	**3,798**
2028	2	29	6	**37**	34	436	94	**564**	259	3,307	712	**4,277**
2029	3	32	5	**41**	47	495	77	**618**	354	3,750	584	**4,689**
2030	4	35	4	**43**	63	532	61	**657**	481	4,034	466	**4,982**
2031	6	35	3	**44**	85	540	49	**674**	646	4,096	371	**5,114**
2032	7	34	3	**44**	113	516	40	**669**	855	3,916	301	**5,071**

In all scenarios, the discount will have a much larger impact on ZEV sales for households with long commutes where express lanes could provide a substantial time savings. Figure 12 shows the distribution of added ZEV sales over the entire study period under the three major scenarios. In all scenarios, the total number of new sales is greatest for vehicles that have between 5 and 20 miles of potential express lane usage per day, but vehicles with a greater distance traveled on these roads per day all see disproportionate increases in sales. In contrast to the population totals shown in Figure 11, where vehicles with over 20 miles of potential express lane usage are relatively uncommon, these long-distance express lane commuters would benefit tremendously from a discount program, particularly under the large impact scenario. It is worth noting that electrifying long-distance commutes may be a particularly high priority, because these commutes likely have an outsized impact on emissions.

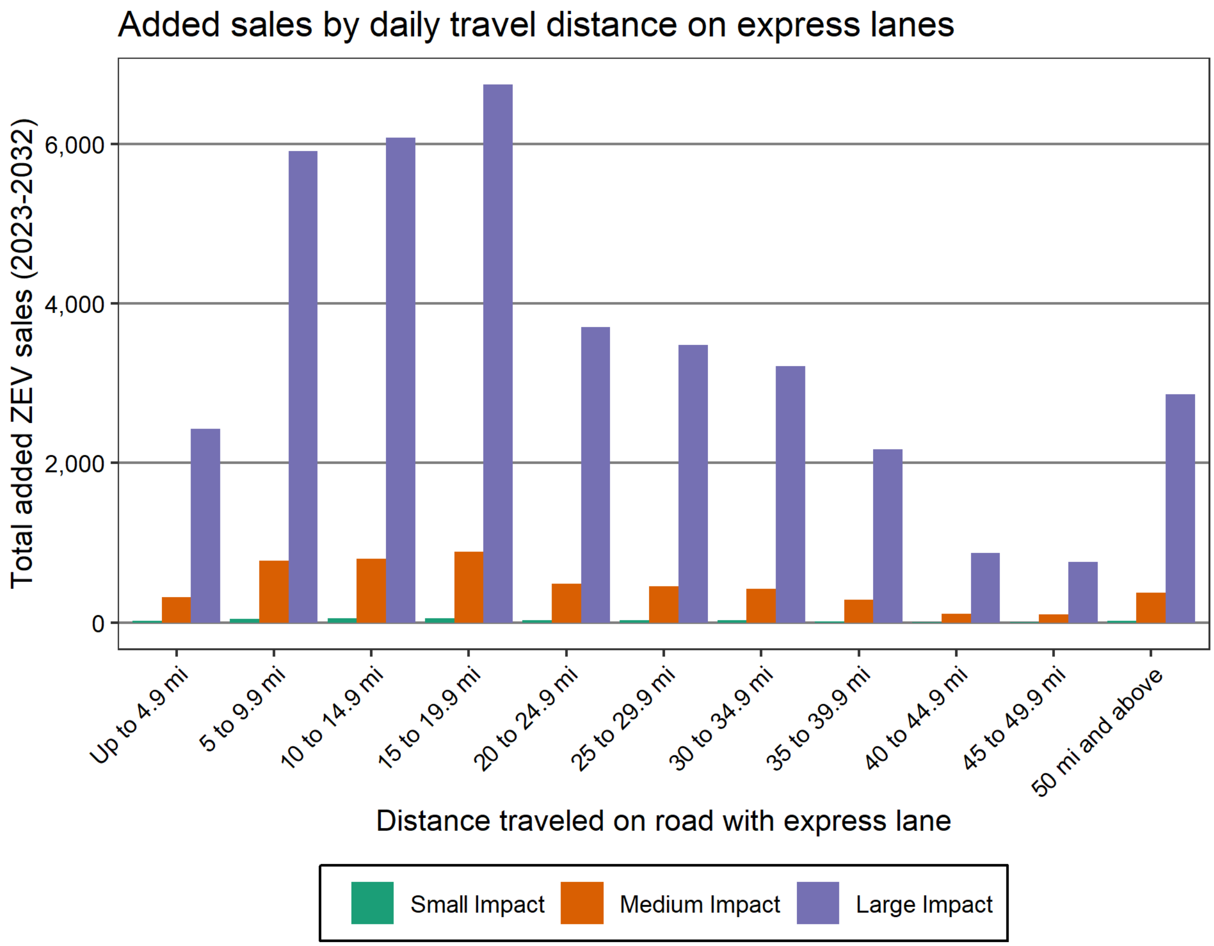

Figure 12. Extra ZEV sales by distance band over entire study period, three major scenarios

While the discounts described in these adoption scenarios would support small to moderate increases in ZEV sales, the discounts would also be available to drivers who would have purchased ZEVs even if the discount were not available, and these vehicles may have the potential to swamp express lanes. Express lane users are already among the most likely drivers to buy ZEVs and because the study period overlaps a period of rapid expansion for ZEV sales for all users. Figure 13 shows the proportion of all vehicles using roads with express lanes at peak hours that would be eligible for a three-year discount. All three discount scenarios described in this section provide a benefit to ZEV drivers. By 2032, nearly 30% of vehicles in the Northern California section and nearly 25% of the vehicles in the Southern California section would be eligible for, and likely to benefit from, the discount. Essentially, a discount of 75% on express lane tolls would make the lanes an attractive option for roughly a third of cars on the road while only supporting a 1% increase in ZEV sales statewide over the next decade.

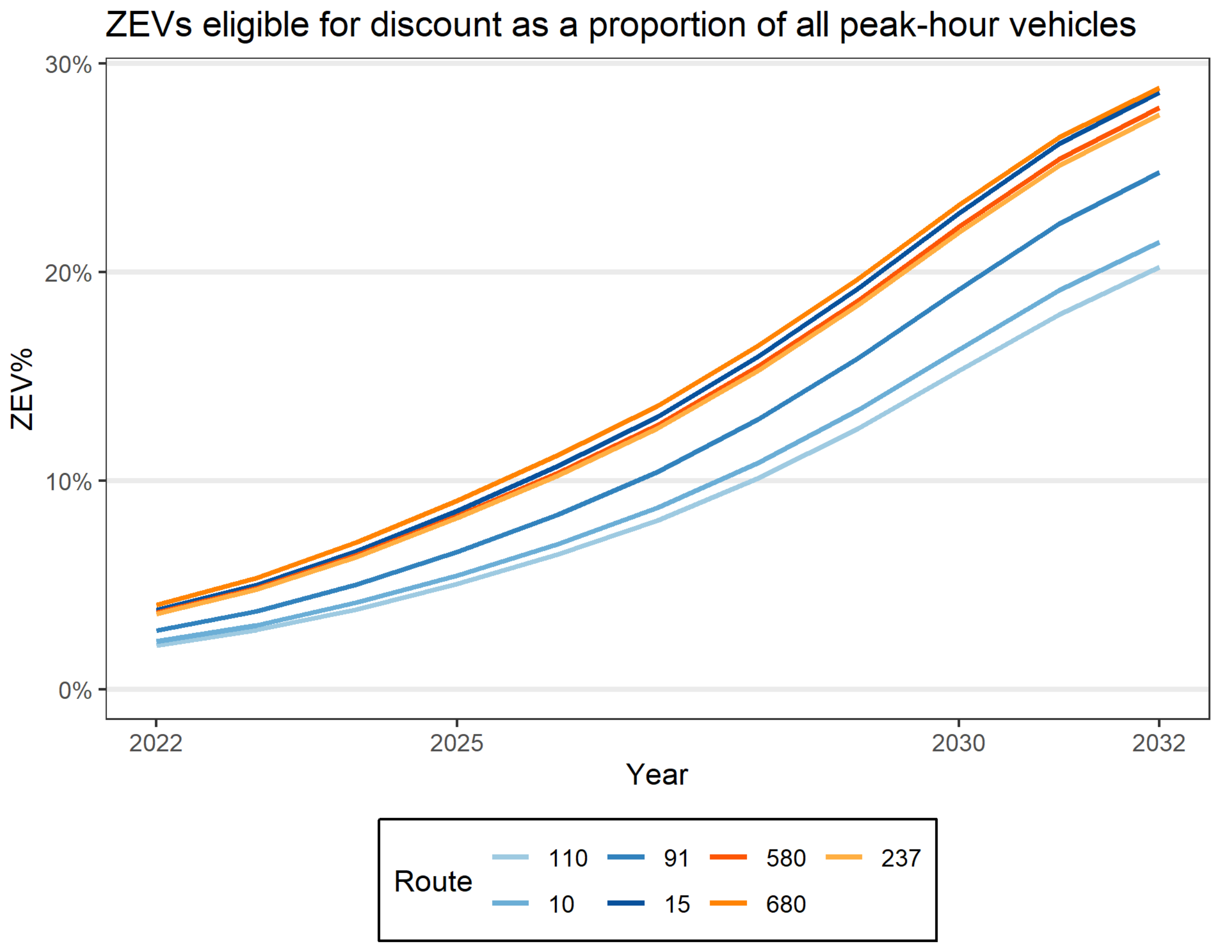

Figure 13. Vehicles eligible for the express lane discount will greatly increase over the study period under all scenarios

Excel Tool Use Instructions

This section provides a basic user guide for the Excel workbook *EV_ExpressLane_Tool.xlsx* that was produced as part of this project.[3] The results produced by this tool should generally match those found for generic scenarios included in the report but there may be slight discrepancies due to the need to slightly simplify the analysis in order to produce a usable interactive tool. Apart from the highlighted cells on the **Scenario Parameters** sheet, all sheets and cells in the workbook are locked by default, to prevent accidental changes. Each sheet can be unlocked using the password "zev" if needed. The **bolded words** at the start of each paragraph correspond to the workbook sheet that paragraph is describing.

Scenario Parameters. The first step of creating an express lane discount scenario is to select the ZEV discount and the range of traffic conditions users will face, as shown in Figure 14. To create a scenario, choose values for the three parameters that affect the entire scenario in the first set

[3] https://ncst.ucdavis.edu/research-product/ev-express-lane-excel-tool

of yellow cells B4, B5, and B6: the size of discount ZEV users will receive on express lane tolls, the duration of the benefit in years, and the impact of the policy on ZEV adoption in % sales increase per $1000 of benefit. The parameter values chosen should be within the range of values indicated in the adjacent cells. Next, choose traffic and toll parameters for up to 5 sub-scenarios in highlighted cells B12:F17. Each sub-scenario can be given a nickname to keep track of it in the **Vehicles** sheet. This set of parameters includes the number of days per year in which the sub-scenario is in effect, the speed of travel in the non-tolled lanes, the speed of travel in the express lanes, the toll in $/mile, and the value of travel time savings by road users under this scenario. The effect of these scenarios is additive. Once you have created a scenario, it's a good idea to check the generic results in cells A19:F24. Toll discounts are most effective when the value of travel time savings is less than the full price toll but greater than the discount toll, which is indicated by the row of True/False values in row 24. If the express lane provides more value in travel time savings than the full price toll, the toll should be increased. If the express lane provides less value in travel time savings than the discounted toll, then the discount does not support ZEV adoption.

	A	B	C	D	E	F	G	H	I	J
1	**All non-highlighted cells locked with password "zev"**									
2				Suggested values						
3	Parameters for all scenarios		Min	Typical	Max					
4	ZEV Discount	50%	0%	--	100%					
5	Duration (yrs)	3	1	3	5					
6	Impact / $1000	4%	2%	4%	10%					
7										
8										
9										
10				Parameters for Sub-Scenarios						
11	Scenario	1	2	3	4	5		Suggested values		
12	Nickname	Normal	Busy	Holiday			Min	Typical	Max	
13	Days per year	200	50	10	0	0	0	--	365	
14	Speed (general lanes, mph)	40	35	20			15	--	70	
15	Speed (express lanes, mph)	65	60	45			no more than 25 mph faster			
16	Toll ($/mi)	$0.25	$0.50	$1.50			$0.25	--	$4.00	
17	Value of Travel Time Savings ($/hr)	$20.00	$25.00	$30.00			$14.00	$16.20	$30.00	
18										
19				Sub-Scenario Generic Results / 100mi						
20	Hours saved per 100 mi	0.96	1.19	2.78	0.00	0.00				
21	Toll ($/100mi)	$25.00	$50.00	$150.00	$0.00	$0.00				
22	Value of Time Savings ($/100mi)	$19.23	$29.76	$83.33	$0.00	$0.00				
23	Discount Toll ($/100mi)	$12.50	$25.00	$75.00	$0.00	$0.00				
24	between?	TRUE	TRUE	TRUE	FALSE	FALSE				
25										
26	For best results, value of time savings should be between the discount toll and full-price toll									
27										

Figure 14. Starting values for the Scenario Parameters sheet of the Excel Tool

Vehicles. This sheet computes the impact of the discount on ZEV adoption for a ten year period from 2023-2032 for households in different regions, income categories, and with different amounts of potential peak-hour express lane use. The values on this sheet provide results at too granular a level for users to benefit from, but columns AU to BB can be useful for understanding the total impact of a toll discount on ZEV adoption by a range of different household categories.

Constants. This sheet contains baseline information used in the scenario computation process. The current version of the tool uses two tables in this sheet: baseline ZEV adoption values broken down by year and income category, and the proportion of ZEVs that would be eligible for a discount each year under discount durations from 1-5 years.

Total ZEV Sales. This sheet contains aggregate annual results for the scenario. The columns in this sheet show the baseline net ZEV sales, both statewide and specifically among vehicles that could make use of the discount, as well as the number of sales added by the discount. Two plots are included, one of which compares the scenario adoption results with the baseline adoption results, and one which shows the percent increase in sales among potentially affected vehicles and all vehicles in the state.

Income Group ZEV Sales. This sheet contains annual results for the scenario broken down by income category. For each group, the sheet provides the baseline sales, added sales, and total scenario sales. These values are only provided for vehicles that could make use of the discount. One plots is included, showing the annual net ZEV sales to households in each income category.

Extra ZEVs on Road. This sheet provides information about the potential crowding of express lanes caused by the discounts designed under this scenario. The table of values shows the percent of peak-hour trips on each freeway with an express lane that could be eligible for the discount. The plot presents the same values in a visual form.

Equity Impacts

So far, ZEV adoption has been most significant among individuals with the financial resources to purchase these vehicles. Numerous suggests that ZEVs continue to be purchased by high-income households, early adopters, and enthusiasts (*4*, *25*, *32*). Any policy designed to promote ZEV adoption runs the risk of further favoring these groups at the expense of lower-income households and others. In addition to decreasing greenhouse gas emissions, ZEVs have the potential to nearly eliminate local air pollutants from light duty transportation. The harms from local air pollution are especially concentrated in some areas of the state, identified as Disadvantaged Communities by the California EPA (*35*). This section discusses the potential equity impacts of ZEV discounts on express lanes in terms of the proportion of benefits going to households of different incomes and the proportion of benefits going to households in disadvantaged communities. The analysis in this section focuses on the Large Impact scenario, and other scenarios should be assumed to have a much smaller effect across the board.

The scenario adoption impacts shown in the previous section show how strongly ZEV adoption currently tilts towards high- and middle-income households, and an untargeted express lane discount is likely to only increase that tilt in the short-run. As ZEV ownership expands throughout the state over the next decade, ZEV ownership statistics should begin to more closely reflect the state’s population, but any policy that focuses on new car sales will primarily benefit households that can afford to buy new cars. In of the scenario results shown in Table 4, households making below $75,000 per year do not make up even 10% of the increase in ZEV sales until 2031.

While income is a strong predictor of who will buy ZEVs under an express lane discount policy, geography is perhaps an even stronger one. Since the impact of a discount on adoption is primarily estimated through the financial value of time savings, it is greatest in areas where people have the longest commutes. Figure 15 shows the spatial distribution of benefits per ZEV commuter in Northern California and Figure 16 shows the spatial distribution of benefits in Southern California, with express lanes shown in blue and disadvantaged communities outlined in black. In both cases, commuters relatively far from the urban core have the most potential to benefit from these policies because they have the longest potential commute on these routes. The large impact of this discount on drivers with long commutes may mean that the policy favors electrification of longer commutes, which may have significant benefits for emissions.

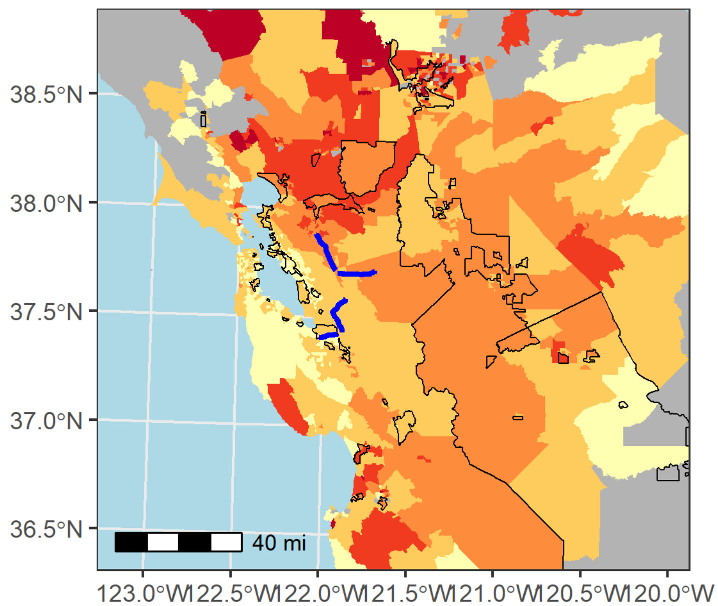

Figure 15. Spatial distribution of benefit per commute ZEV under the high impact scenario in Northern California

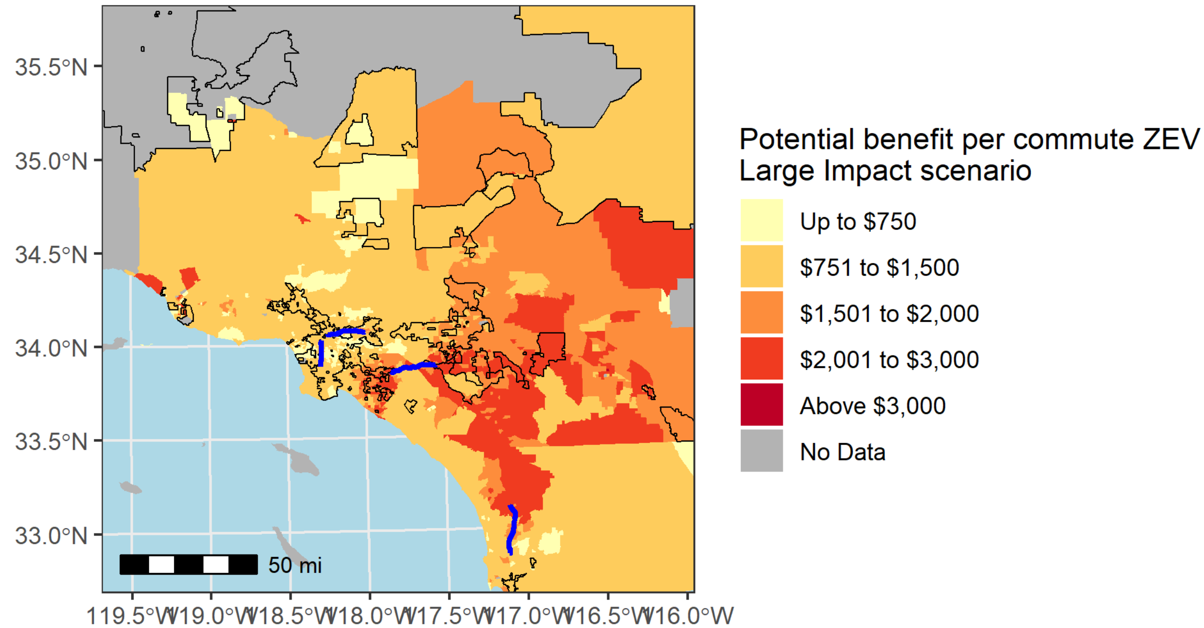

Figure 16. Spatial distribution of benefit per commute ZEV under the high impact scenario in Southern California

While the benefits per vehicle are heavily concentrated further out, the proportion of vehicles that could benefit from an express lane discount is relatively more consistent over space. Figure 17 shows the extra sales by census tract from 2023-2032 under the Large Impact scenario in Northern California, and Figure 18 shows the same values for Southern California. In both regions, closer-in tracts have many more vehicles that could benefit somewhat from the policy, whereas farther out tracts have smaller numbers households that could benefit greatly from the policy. On balance, this policy would increase sales modestly throughout both regions. Interesting, disadvantaged community tracts, outlined in black on both maps, appear to have little relationship to the distribution of ZEV sales, with some disadvantaged community tracts seeing substantially higher sales increases than surrounding areas and others seeing substantially lower increases. While these tracts have many low-income households, they also have some higher-income households, and ZEV adoption in disadvantaged communities has been mostly among the highest-income households in the area (*36*).

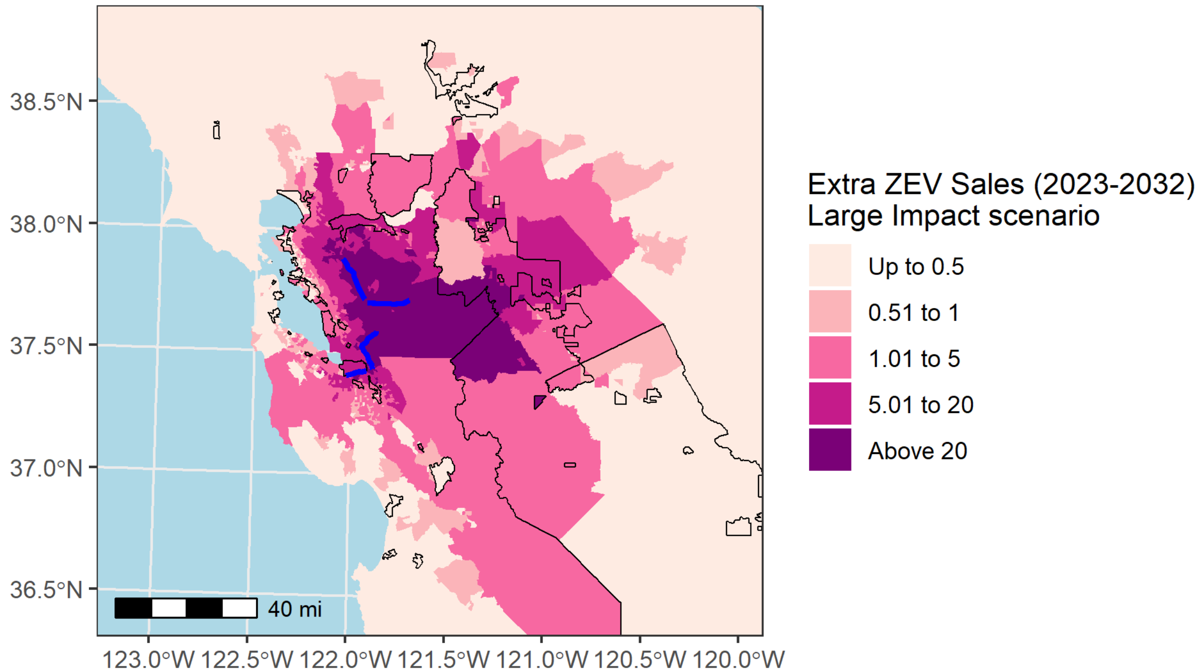

Figure 17. Extra ZEV sales from 2023 to 2032 by block group under the high impact scenario in Northern California

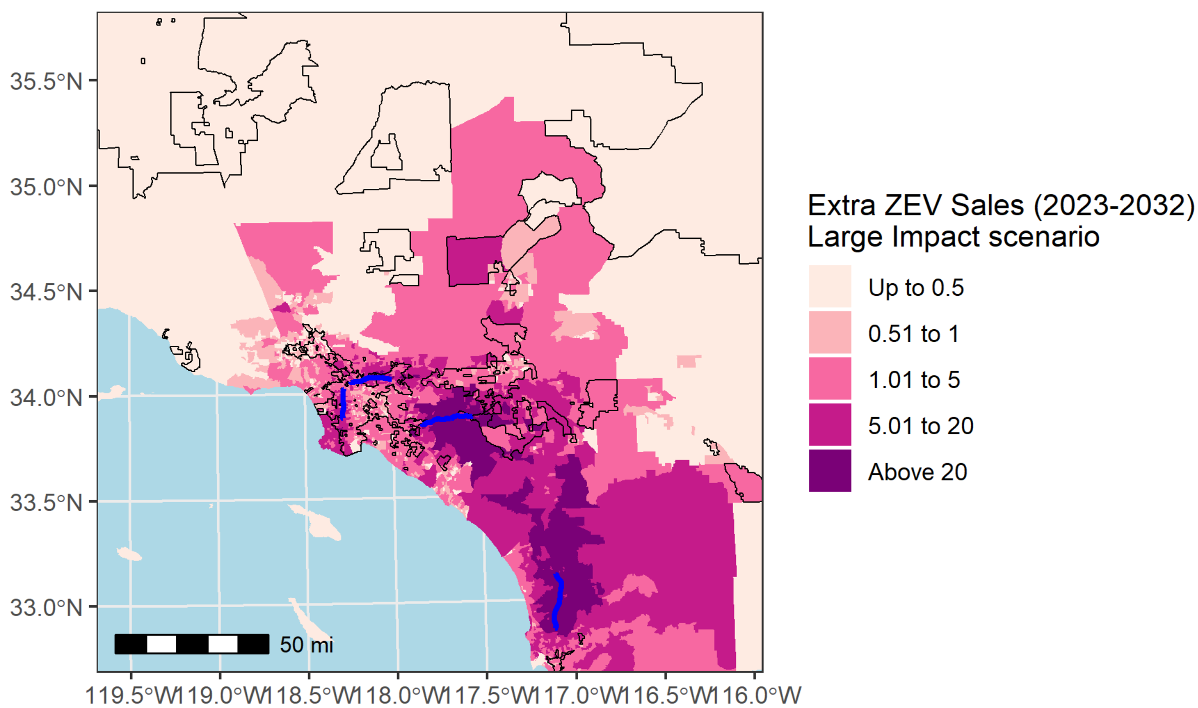

Figure 18. Extra ZEV sales from 2023 to 2032 by block group under the high impact scenario in Southern California

Policy Options

The policy scenarios presented in this report suggest that express lane discounts are not an effective method to help California reach its ZEV sales targets over the next decade. The Small and Medium impact scenarios show very little potential for this sort of policy to boost sales of new ZEVs, apart from in the areas where express lanes are most important. Even the Large Impact scenario, which provides ZEV users with a 75% discount and assumes severe traffic and high express lane tolls would increase ZEV sales in California by less than 1% per year throughout the study period. This would come at the cost of providing potentially up to 1/3 of the state's commute vehicles with heavily discounted access to express lanes by the early 2030s, potentially eliminating any benefits provided by the lanes.

The reasons for this lack of impact are easy to understand:

- In contrast to HOV lane stickers, express lane discounts are less impactful because the service they offer is already available to purchase. The current cost of purchasing this benefit, and thus the potential scale of any discounts, is small compared to the purchase price of a new ZEV.
- Less than 5% of the commute trips in California include any potential for travel on an express lane, providing a low ceiling for the potential impact of this policy.
- Most importantly, the incentives target the groups that are already most willing to buy ZEVs—medium- and high-income households with moderate commutes—and these groups are on track to electrify most of their commute vehicles by 2030 with or without the support of this incentive.

An alternative policy that the state could consider would be to prioritize these benefits for communities where ZEV adoption has been slower, either by instituting income caps, prioritizing disadvantaged communities, or allowing people who buy used vehicles to access this incentive. While the secondary market for ZEVs is currently limited, the rapid increase in new ZEV sales currently planned in California will solve this issue as current drivers of ZEVs will transition to newer generations of ZEVs. The growing secondary market of ZEVs will be critical to future personal mobility options and will mainly support low-and-middle income drivers wanting to transition towards ZEVs. Ideally drivers of used ZEVs will be able to reap the environmental benefits of clean mobility as well the systematic benefits, such as access to HOV lanes or discounts for express lanes. This sort of incentive may be a major incentive especially for low-and-middle income drivers who tend to drive further distances to key life resources and can begin to make a transition toward cleaner mobility technologies.

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Data Summary

The ZEV adoption model uses American Community Survey (ACS) 2015-2019 Five-Year Public Use Microdata Samples as its main input. This data source is available in consistent format throughout the United States and provides a combination of detail and sample size not available in any similar dataset.

Products of Research

No additional data was collected for this study.

Data Format and Content

Not Applicable

Data Access and Sharing

The data used for developing the model to conduct this study is available at American Community Survey Microdata, https://www.census.gov/programs-surveys/acs/microdata.html.

Reuse and Redistribution

This data is publicly available, and guidelines for use of the data is available at the US Census website here: What ACS Public Use Microdata Sample File Users Need to Know, https://www.census.gov/programs-surveys/acs/library/handbooks/pums.html.