

Palo Alto Electrification Funding Study

EV Charger Needs Assessment (FINAL DRAFT)

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Acronym Definitions

Acronym	Definition
S/CAP	Sustainability and Climate Action Plan
ICE	Internal combustion engine
EV	Electric vehicle
L1	Level 1 charger
L2	Level 2 charger
DCFC	Direct current fast charger
GHG	Greenhouse gas
VMT	Vehicle miles traveled
80x30	Palo Alto's goal of 80% below 1990 GHG levels by 2030

Executive Summary

Palo Alto’s Sustainability and Climate Action Plan (S/CAP) sets a community-wide emissions reduction target of 80% below 1990 levels by 2030 (“80x30”) that will require both electrification of most vehicles and an overall reduction in vehicle miles driven. Transportation electrification refers to the replacement of internal combustion engine (ICE) vehicles with battery-powered electric vehicles (EVs). To enable the level of transportation electrification needed to meet emissions reductions, Palo Alto will need to develop supportive EV charging infrastructure. EV chargers vary by type (L1, L2, DCFC, etc.), and location (home, public, workplace, etc.). The Palo Alto charging network will need to include a mix of all charger types in order to support EVs on the road. Planning for the EV charging network will involve several important policy considerations, including the prioritization of and resources dedicated to: public vs. private infrastructure and the business models used to ensure recovery of capital investments; home charging vs. public charging to serve multifamily EV charging needs; public charging in support of commuters and visitors; and L2 vs. DCFC public charging to match commuter preferences and optimize utilization.

This report presents quantitative findings from E3’s EV Charger Needs Assessment analysis regarding potential EV adoption scenarios, the number of EV chargers needed to support different EV adoption scenarios, and the cost to develop an EV charging network in Palo Alto. The following provides insights that will help with the City make decisions regarding the policy considerations noted above. In addition, the outputs from the modeling for this analysis are used as inputs to the *E3 Palo Alto Electrification Funding & Financing Study Final Report*.

The Role of EVs in Reducing Emissions

Palo Alto will need to reduce transportation-related emissions 65% below 1990 levels by 2030 to meet the S/CAP GHG reduction goals. Strategies to reduce transportation-related emissions in Palo Alto include both reducing vehicles miles traveled (VMT) through increased public transit ridership and active transportation modes, as well as transitioning to widespread electric vehicle adoption. Reducing overall VMT in Palo Alto not only results in lower GHG emissions – it also offers significant co-benefits, such as improved health and mobility. At the same time, the electrification of passenger vehicles will result in the greatest amount of transportation emissions reductions.

This report shows that transportation electrification is a highly cost-effective way to reduce GHG emissions due to the significant cost savings in vehicle fuel and maintenance. Even in 2025, it is cheaper for an individual customer to own and operate an EV than an ICE vehicle.

E3 modeled three adoption scenarios that represent distinct EV adoption levels under different conditions: business-as-usual (BAU) conditions, mid-level adoption assumptions, and aggressive 80x30 emissions targets. However, because of the influence of strong State regulation in every scenario at the time of modeling, the three scenarios have similar growth rates. Even the BAU scenario results in 54% adoption of EVs in single family households and 18% in multifamily households. Only 20% higher adoption (57% adoption in single family households and 30% in multifamily households) is needed to achieve 80x30 targets. Building a strong EV charging network, particularly for multifamily residents, could help support higher adoption levels.

It should be noted that all modeling assumptions around policies such as Advanced Clean Cars II and Advanced Clean Trucks were made in 2024, prior to the revocation of the applicable waivers, which are still being litigated. Therefore, the level of EV adoption included in these results are not as currently mandated but represent the point in time at which the model was created. This is most impactful to the Low Local Action scenario, which assumes a “business as usual” rate of EV growth that would be lower without these regulations, as opposed to the High Local Action, which is a scenario in which it is assumed the community takes action as needed to achieve the 80x30 goals, regardless of regulation.

EV Charger Buildout and Costs

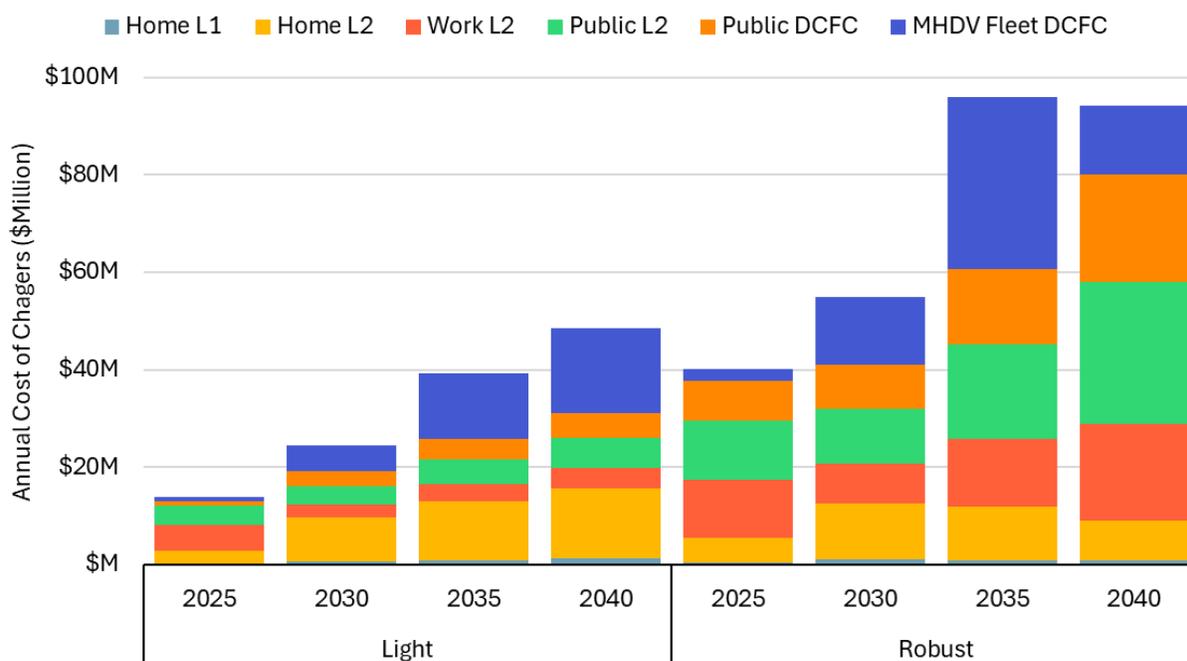
The number and types of EV chargers that Palo Alto will need to build to support these levels of transportation electrification will depend on a number of factors, including the share of EV owners with access to home charging, whether charging is done at home or at shared chargers, the level of commuter and visitor charging infrastructure provided, and the amount of local financial investment in EV charging infrastructure.

This study evaluated two EV charging access scenarios. The “Light EV Charging Scenario” assumes a business-as-usual EV adoption scenario, a low level of investment in public charging, and lower multifamily EV adoption. The “Robust EV Charging Scenario” assumes a higher EV adoption scenario, a high level of investment in public charging to make Palo Alto a “charging hub” for residents, visitors, and commuters, and greater multifamily EV adoption.

The study results show that by 2040, Palo Alto is likely to need somewhere between **41,000 (in Light EV Charging Scenario) and 50,800 (in Robust EV Charging Scenario) total EV chargers to serve Palo Alto**. The greater amount of EV charging infrastructure in the Robust EV Charging Scenario is due to three factors: 1) a higher number of EVs served, 2) pursuing a strategy of making Palo Alto a charging hub, which requires additional EV chargers to serve commuters and visitors, and 3) a focus on providing more charging access to multifamily residents.

The total upfront cost to install these chargers depends on the number of chargers needed and the types of chargers installed. The cost of installing chargers in single family homes is significantly less than in multifamily buildings. The cost of providing chargers for multifamily residents depends on whether the City invests in home charging for multifamily residents or public charging that is conveniently located for multifamily buildings. In addition, investing in charging infrastructure to make Palo Alto a charging hub for commuters and visitors increases costs. Overall, the annual capital investment needed for EV charging is projected to be **between \$14M/year (in the Light EV Charging Scenario) and \$40M/year (in the Robust EV Charging Scenario) in 2025**, growing to **between \$55M/year and \$90M/year by 2040** (Figure 1) at a cost of between \$500 million and \$1.17 billion cumulatively by 2040 community-wide (noting that this represents both private and public investment).

Figure 1: Annual cost of chargers by location (Light vs. Robust EV Charging scenarios)



In analyzing these two scenarios, E3 found that the upfront capital cost of investing in home charging for the multifamily sector is lower than the cost of a public charging strategy that serves multifamily customers, since reliance on public charging includes higher cost DCFC installations. It is important to note, however, that this result depends on installation of L1 chargers in multifamily buildings wherever possible, which leads to significantly lower installation costs in aggregate. Individual customers using L1 chargers may need to be supplemented by occasional public charging, since an overnight charge on an L1 charger typically yields 30-50 miles of charge, which can suffice for local trips and shorter commutes, but may not meet the needs of all trips for some drivers. This analysis

was modeled with the best available data, but depending on observed preferences and future program design, the ratios between charger types may need to shift over time to reflect localized driver needs. Changes to this ratio could influence the costs of public versus home charging.

E3 also identified the need for public charging based on both employment data, in addition to data on vehicle trips, using the National Renewable Energy Laboratory's (NREL's) EViPro Lite modeling tool. By 2040, this model yielded a need **between 3,500 and 12,000 public EV chargers** to serve Palo Alto employees, visitors, and residential charging needs, to enable Palo Alto to serve as a public EV charging hub. The estimated charger need was split between public L2 (93% of total installations, serving 13% of public charging load) and DC fast charging (7% of total installations, serving 87% of public charging load). The differences between total installations and load served reflect the time it takes for a customer charge, energy served per minute, and customer convenience preferences. Since L2 chargers require longer dwell times, conversations with EV owners suggest that some customers may prefer DCFC when prices are similar between charger types. To avoid an overinvestment in L2 charging infrastructure, Palo Alto should be selective with its deployment of public L2 charging infrastructure and should track utilization regularly.

E3 estimates the charging revenue needed to cover both the **cost of energy and the cost of the EV charging investment is about \$0.42/kWh**, as compared to PG&E's lowest cost residential EV retail rates of \$0.35/kWh in winter and \$0.40/kWh in summer. Public charging rates within PG&E territory are often set at a premium to these energy costs. With some design considerations, it may therefore be possible for Palo Alto to achieve public charging rates designed to recoup the cost of the initial infrastructure investment (\$500M to \$1.2B total) over time while still remaining competitive with regional charging rates.

A significant investment in MHDV Fleet DCFC is shown in Figure 1. This represents high power chargers needed to charge medium duty fleet vehicles, such as box trucks and vans, in Palo Alto. By 2040, Palo Alto is likely to need somewhere **between 530 (in the Light EV Charging Scenario) and 1,300 (in the Robust EV Charging Scenario) total DCFC chargers to serve Palo Alto medium-duty vehicles**. Costs for these chargers are projected to be **between \$1M/year (in the Light EV Charging Scenario) and \$2M/year (in the Robust EV Charging Scenario) in 2025, growing to between \$63M/year and \$46M/year in the highest cost years for each scenario**.¹ By 2040, the Robust EV Charging Scenario reaches full saturation and costs are below those in the Light EV Charging Scenario, which continues to grow overtime.

While the upfront capital costs for EV charging infrastructure are high, there are several program design and business model options to manage the upfront costs and ensure effective cost recovery. Ultimately the costs of EV chargers will either be paid upfront by

¹ Due to the timing of vehicle adoption in each scenario, the highest cost year occurs in different years with different charging installation costs.

property owners, recovered from taxpayers and ratepayers (e.g., City incentives or City-owned equipment), or recovered from drivers based upon utilization (e.g., City or third party managed Charging-as-a-Service). Each of these program designs and business models recovers costs at different rates and from different entities. This can affect the cost of EV charging, which can in turn affect EV adoption. Overall, the level of emissions reductions in Palo Alto will be dependent on effective buildout of EV charging infrastructure and ensuring the proper incentives for EV adoption.

E-Bikes as a Means of Vehicle Miles Traveled Reduction

In addition to the electric vehicle charging analysis, E3 conducted an analysis into the use of e-bikes to support Palo Alto's vehicle miles traveled (VMT) reductions goals. VMT reductions support emissions reductions by reducing vehicle usage but also support co-benefits such as increased physical activity for riders, improved air quality, and reduced traffic congestion. This analysis used assumptions about how much a rider might use an e-bike and which vehicle trips could be replaced with an e-bike in order to calculate the costs of e-bike ownership and the emissions benefits of e-bike adoption. Depending on usage and CPAU incentive levels, riding an e-bike may be more costs effective to customers than driving a vehicle. Similarly, the overall carbon dioxide abatement cost is highly sensitive to modeling inputs, ranging from **-\$100/tCO₂e to \$2,400/tCO₂e**.

Introduction

Context and Motivation

In 2015, Governor Jerry Brown signed Executive Order (EO) B-30-15, which mandates a 40% emissions reduction below 1990 levels by 2030. In 2016, California passed Senate Bill 32 (SB 32), codifying EO B-30-15 into state law. In the context of California’s already aggressive climate policy, Palo Alto stands out as a leading actor in the fight to cut emissions. In 2016, Palo Alto City Council adopted a community-wide emissions reduction target of 80% below 1990 levels by 2030 (“80x30”) and developed the preliminary Sustainability and Climate Action Plan (S/CAP). This plan was then revised as the 2022 S/CAP, which outlines a comprehensive roadmap to reaching Palo Alto’s ambitious climate goals.

As outlined in the S/CAP, meeting Palo Alto’s 80x30 emissions targets will require electrifying a substantial number of vehicles – a 2021 S/CAP impact analysis assumed about 55% of single-family vehicles by 2030 and about 33% multifamily vehicles by 2030. To support the influx of electric vehicles on the road, Palo Alto will need to drastically increase the EV charging infrastructure in both the public domain and at private residences. In addition, Palo Alto is a destination for commuters, visitors, and delivery vehicles. Depending on how Palo Alto chooses to prioritize charging access, some of these drivers may need to be supported as well. This charging infrastructure is likely to incur significant additional costs to the City of Palo Alto. To advance the equity goals of Palo Alto, targeted investments will need to be made for locations that currently lack chargers, such as low-income areas and multifamily residences. This study provides the City of Palo Alto insight into the scale of EV charging infrastructure that is needed to support future transportation electrification, the cost to install those chargers, and the economics of different business models to pay for the infrastructure investments.

Objectives

The objective of this report is to answer the following questions to support the City of Palo Alto in developing policy and programs to support EV charging infrastructure in a way that supports the region’s climate and equity goals:

- + **EV adoption:** What are some possible scenarios for the pace of EV adoption in Palo Alto over the next several decades?
- + **EV charger needs:** How many chargers will be needed to support each EV adoption scenario? Where should these chargers be located?
- + **EV charger costs:** How much will it cost to build out the number of chargers needed under each EV adoption scenario?
- + **EV charging loads:** What are the load shapes for EV charging in Palo Alto and how much electricity will it require under each EV adoption scenario?

- + **Charging costs:** How much will it cost consumers to charge their electric vehicles under each EV adoption scenario? How will those charging costs change if different electric rates are implemented? How will those charging costs change if the consumer manages their charging?
- + **Business models:** How will the allocations of upfront and ongoing costs change under different potential business models? How can Palo Alto provide funding, such as incentives and loans, to help cover costs previously borne by residents?

Methodology

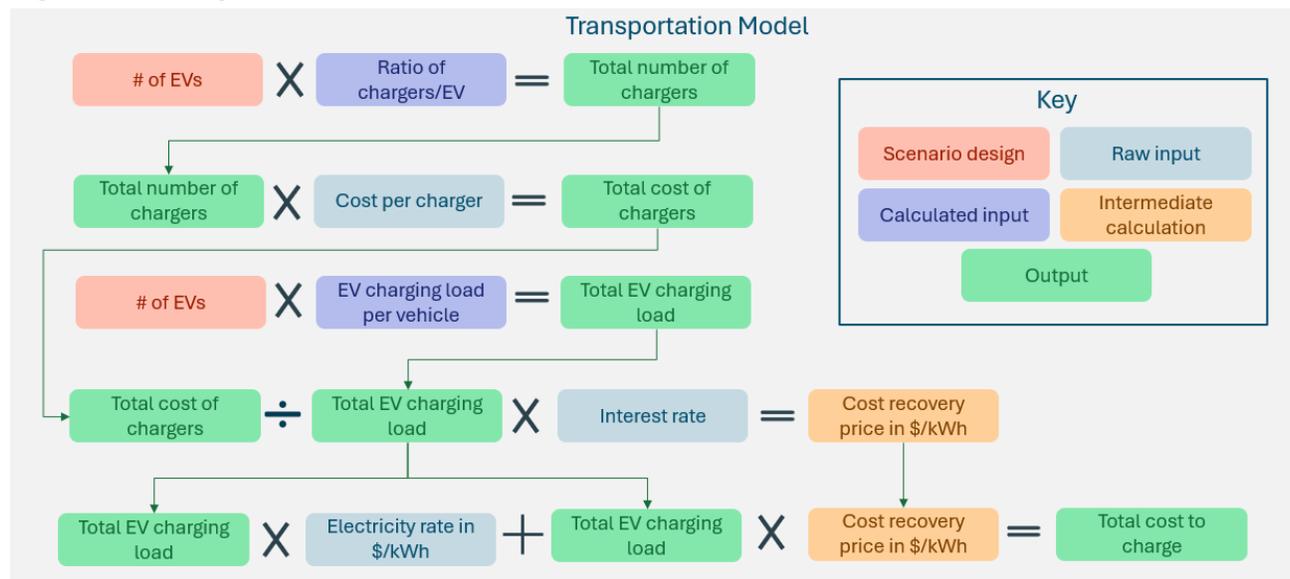
Overview

The EV Charger Needs Assessment seeks to quantify and analyze:

- + The number of EVs needed to reach Palo Alto’s climate goals;
- + The number, types, and locations of EV chargers that would be needed to support them; and
- + The costs to build and serve those chargers under several different business models.

The quantitative analysis for the EV Charger Needs Assessment was conducted within the transportation module of the E3 S/CAP Funding model, an Excel-based model that was created for the City of Palo Alto Utility to study the cost and funding impacts of city-wide decarbonization. Results from the S/CAP Funding model were also fed into the E3 Palo Alto Affordability Calculator to calculate the cost impacts on individual households. The transportation module was developed using a modeling framework that leverages both in-house E3 models and inputs from external modeling tools. The modeling framework calculates the type, scale, and cost of EV charging infrastructure needed to support different levels of transportation electrification in Palo Alto. A visualization of this modeling framework is shown in Figure 2 below.

Figure 2: Transportation Model Framework



EV Adoption Scenarios

E3 developed two key EV adoption scenarios for both light-duty vehicles (LDV) and medium-duty vehicles (MDV), representing what transportation electrification may look like under Light EV adoption versus Robust EV Adoption.

The Light EV Adoption scenario reflects business-as-usual (BAU) conditions. A BAU adoption scenario is one that forecasts electrification under all currently adopted policies but assumes no new policy intervention. These modeling assumptions reflect adopted policies as of 2024, which is when the modeling was completed. The primary policy driver informing the Light EV Adoption scenario is California’s Advanced Clean Cars II (ACCI) – which requires 100% of new passenger vehicle sales in California to be zero-emission vehicles (ZEV) by 2035.² The primary policy drivers informing the MDV Light EV Adoption scenario is California’s Advanced Clean Trucks (ACT) and Advanced Clean Fleets (ACF). ACT requires that truck sales in California be increasingly made up by ZEVs, with the required sales shares determined by truck weight class. ACF requires medium- and heavy-duty (MHDV) fleets that are high priority, perform drayage, or belong to the State, local, or the federal government comply with certain ZEV requirements, with many required to be 100% ZEV by 2035.³

As noted in the footnotes, as of June 2025, the Federal administration has rescinded the waivers that enable these regulations, though this is still being litigated. Therefore, the level of EV adoption included in these results are not as currently mandated but represent the point in time at which the model was created. This is most impactful to the Low Local Action scenario, which assumes a “business as usual” rate of EV growth that would be lower without these regulations, as opposed to the High Local Action, which is a scenario in which it is assumed the community takes action as needed to achieve the 80x30 goals, regardless of regulation.

The Robust EV Adoption scenario represents the EV adoption that would be necessary to reach the 80x30 emissions targets as set by the S/CAP, which requires a 65% reduction in transportation emissions below 1990 levels by 2030.

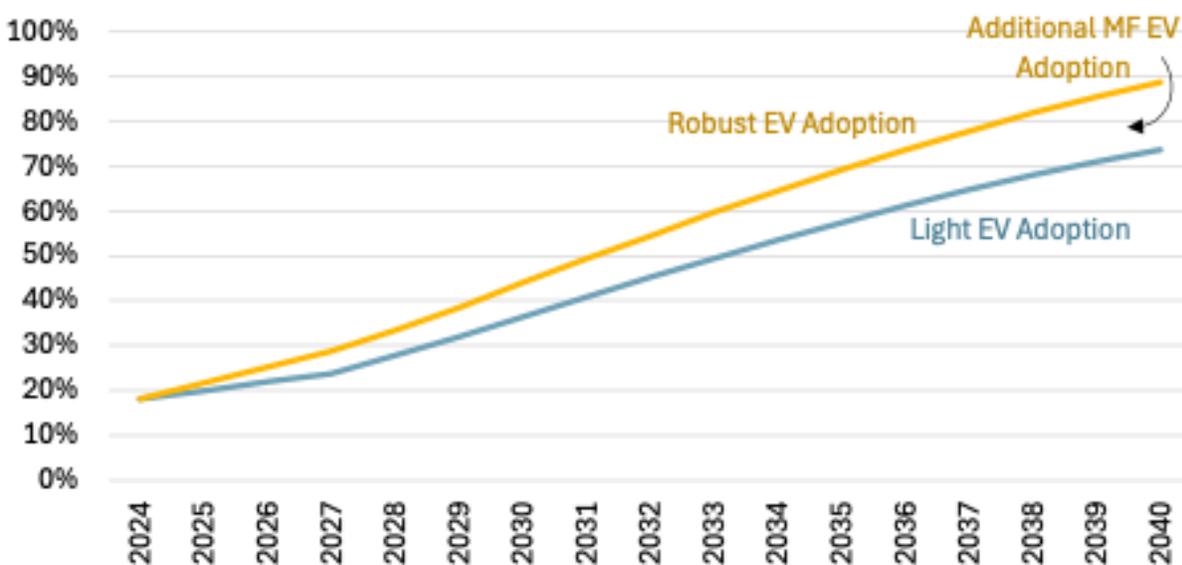
The two primary EV adoptions scenarios are shown in Figure 3 below, and the detailed methodology describing how these scenarios were developed is included in A.1.2 EV

² It should be noted that ACCII is enabled by the Environmental Protection Agency’s Clean Air Act federal preemption waiver to California to set their own vehicle emissions standards. As of June 2025, the current Federal administration has rescinded the EPA’s waiver, thus terminating the ability for CA to set vehicle emissions standards such as ACCII. All modeling assumptions for this project were made in 2024, prior to the repeal of the CA waiver. Therefore, the EV adoption assumed may not be reflective of the current policy context.

³ It should be noted that ACT and ACF are enabled by the Environmental Protection Agency’s Clean Air Act federal preemption waiver to California to set their own vehicle emissions standards. As of June 2025, the current Federal administration has rescinded the EPA’s waiver, thus terminating the ability for CA to set vehicle emissions standards such as ACT and ACF. All modeling assumptions for this project were made in 2024, prior to the repeal of the CA waiver. Therefore, the EV adoption assumed may not be reflective of the current policy context.

Adoption Scenarios. Current EV adoption in Palo Alto (reflected in the Light EV Adoption scenario) is at a pace to fall slightly short of the 2040 80x30 goals (74% and 89% EV adoption, respectively). However, since the Light EV Adoption scenario is only about 15-percentage points away from the Robust scenario, the two scenarios do not differ significantly. The primary difference is that in the Robust EV Adoption scenario there is significant additional multifamily EV adoption.

Figure 3: Light Duty Vehicle EV Adoption Scenarios



Charger Types and Locations

E3 utilized the transportation model to analyze EV charging impacts for three groups of customers:

- + Light-duty vehicle Palo Alto residents (multifamily and single family);
- + Light-duty vehicle commuters or visitors who live outside of Palo Alto but work within or travel to the City (commuters and visitors); and
- + Medium-duty fleet vehicles (both City-owned and private commercial fleets).

Each of these customer types can charge at different locations (different charger types are explained in the section below):

- + Home charging (Level 1 and Level 2);
- + Public charging (Level 2 and DCFC);
- + On-street charging (Level 2); and
- + Workplace charging (Level 2 for light-duty vehicles and DCFC for medium- and heavy-duty vehicles).

Each type of charger has its benefits (shown in green) and downsides (shown in red), as seen in Table 1 below.

Table 1: Characteristics of Chargers by Type and Location

Type	Charging Speed (mi/night) ⁽¹⁾	Upfront Cost	Use of Charging as a Service	Grid Impact ⁽⁴⁾	Relevant Vehicle Owner Types			
					SFR	MFR	Commuter	Visitor
Home Level 1	40-50	Very Low	No	Very Low	X	X		
SFR Home Level 2 (20A) ⁽²⁾	~100	Low	Not likely	Lower	X			
SFR Home Level 2 (40-50A)	~200-250	Medium Low	Not likely	Medium	X			
MFR Home Level 2 (20A) ⁽³⁾	~100	Medium High	Possible strategy	Medium		X		
MFR Home Level 2 (40-50A)	200-250	High	Possible strategy	Medium		X		
Public/Workplace Level 2	200-250	High	Likely strategy	Medium	X	X	X	X
DCFC	Full charge in ~ 1 hour	Very High	Yes	High	X	X	X	X

(1) Miles per 10-hour overnight charge, except DC Fast Charging

(2) may avoid panel upgrade

(3) may avoid panel, switchgear, transformer upgrades

(4) All types of EV charging could benefit from charge management to reduce grid impact by avoiding charging during the grid peak hours. Lower power level L2 charging could also help mitigate grid impacts.

Charger-to-Vehicle Ratios

The number and type of EV chargers that need to be built out to support different levels of electric vehicle adoption is determined by using charger-to-vehicle ratios. Charger-to-vehicle ratios determine how many, and what type of, EV chargers need to be active to support a given level of EV adoption.

For home charging, E3 utilized EVI-Pro Lite, a tool created by the National Renewable Energy Laboratory (NREL) to produce charger-to-EV ratios under different adoption scenarios and

assumptions about home charging access.⁴ NREL models this by designing a bottom-up charging network that is able to satisfy the necessary charging load given assumptions about vehicle travel patterns. The model uses data from regional household travel surveys to simulate individual travel days and optimizes EV charging behavior accordingly. Charging pattern optimization is dictated by the underlying assumption that consumers prefer charging scenarios that allow them to complete planned travel patterns while minimizing cost.⁵ The model also assumes that drivers prefer to not fully deplete their battery range to reduce “range anxiety”.⁶ These simulations are then repeated for all travel days and all vehicle types to capture all potential combinations of charging behavior. Using these simulations, EVI-Pro Lite determines the type and quantity of chargers needed to support the number of EVs on the road.

For LDV public and MHDV work charging, charger-to-EV ratios were derived from CEC’s Implementation of AB 2127 Electric Vehicle Charging Infrastructure Assessments⁷. These values are derived from the CEC and Lawrence Berkeley National Lab’s HEVI-Load tool using a bottom-up simulation of travel patterns and probabilistic weighting of where and when charging would need to take place. These charger-to-vehicle ratios were used to calculate the number of chargers needed to sustain the EV population in each year under each scenario. Using the current number of EV chargers, the transportation model calculates how many additional chargers must be built in each year to reach the total number of chargers needed.⁸ The inverse of these ratios shows how many EVs, on average, can be supported by a single charger. It’s worth noting that DCFC chargers can serve significantly more EVs than L2 chargers due to their high-voltage direct current and fast energy transfer. The high-voltage direct current that DCFC provides to EVs results in much shorter charging times. This capability means that each DCFC charger can serve more EVs than an L2 charger. The detailed methodology for how charger-to-EV ratios were derived is included in A.1.3.4 Charger-to-Vehicle Ratios.

It’s important to note that these charger-to-EV ratios are very sensitive to scenario design assumptions such as the total number of vehicles being supported and the breakdown of public versus home charging. Both of these assumptions impact the charger ratios nonlinearly due to the minimum number of chargers needed and changes to utilization, which causes there to be different ratios under different scenarios. Additional details on this nonlinearity can be found in the EVI-Pro Lite documentation.

Figure 4 shows the number of EVs served by a DCFC and L2 charger under two scenarios: one in which a high share of residents with access to home charging, and one in which a

⁴ EVI-Pro Lite, <https://www.nrel.gov/docs/fy23osti/85654.pdf>

⁵ [Regional Charging Infrastructure for Plug-In Electric Vehicles: A Case Study of Massachusetts \(nrel.gov\)](https://www.nrel.gov/docs/fy23osti/85654.pdf)

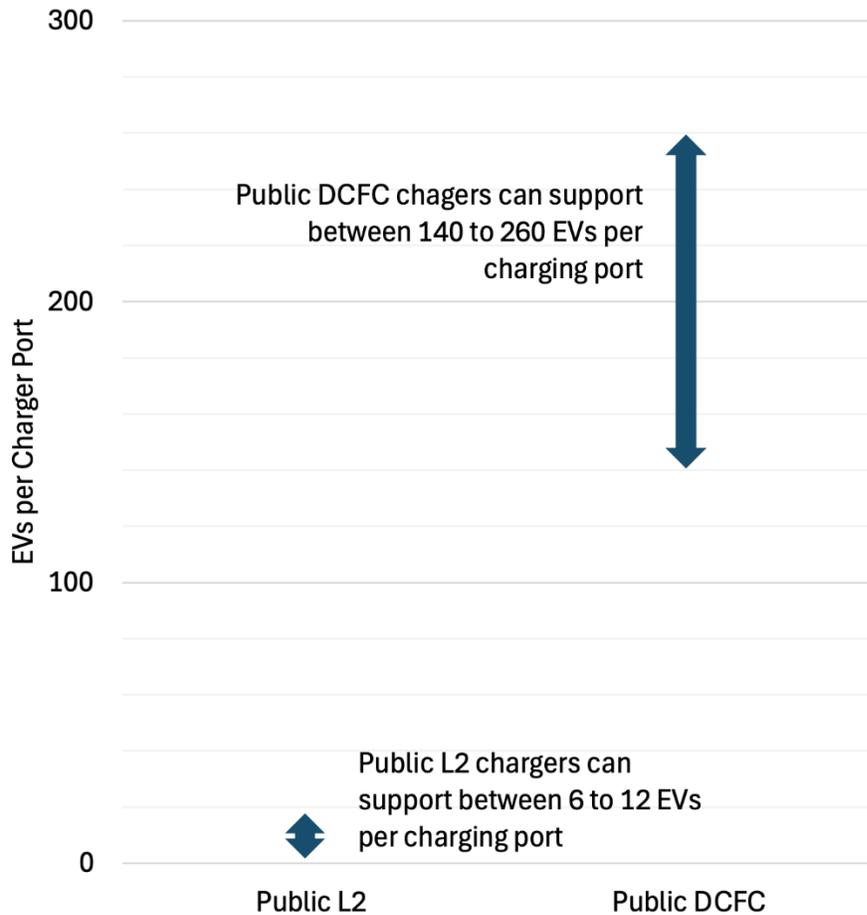
⁶ [CEC Report 2018](#)

⁷ CEC, “Implementation of AB 2127 Electric Vehicle Charging Infrastructure Assessments.” Accessible at: <https://efiling.energy.ca.gov/GetDocument.aspx?tn=254869>

⁸ The user also has an option to choose whether chargers will retire at the end of their life and need to be rebuilt, or if the model should assume the chargers do not retire. Chargers that need to be rebuilt also rely upon the charger-to-vehicle ratios.

lower share of residents has access to home charging. Under scenarios with high access to home charging, and therefore lower reliance on public charging, each public charger can support a greater number of EVs since they're not used as heavily for residential charging needs. Conversely, under low home charging access scenarios, the EVs supported per charger port value is lower due to the reliance on those public chargers for residential charging.

Figure 4: Number of EVs Served by Charger Type Under High and Low Home Charging Access Scenarios



Charger Costs

EV charger costs used in the transportation model were calculated on a \$/charger basis, as seen in Figure 5. These costs were determined using E3’s subject matter expertise and a literature review of industry sources, including market reports, state program analyses, and utility data. The costs of the chargers include upfront costs, such as to-the-meter (TTM) and behind-the-meter (BTM) infrastructure and EV supply equipment (EVSE), which are costs

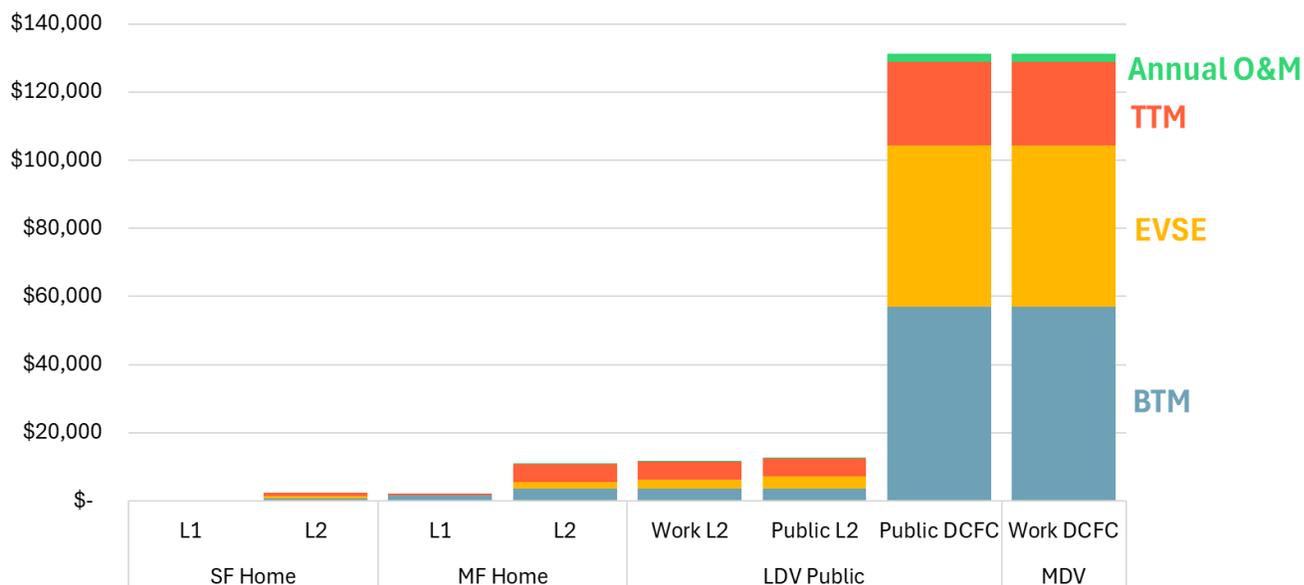
incurred in the year a charger is built, as well as operations and maintenance (O&M) costs, which are incurred each year a charger is active.

Overall, public charging is more expensive than home charging, but there is a significant variance in the cost of public chargers based on the type. Notably, DCFC are the highest cost chargers by a large margin. While any DCFC adoption will yield high costs on a per charger basis, the cost of the full charging portfolio will depend on the number of DCFCs built, their utilization, and if their build results in fewer L2 chargers needed. In addition to the standard types of chargers seen in Figure 5, the model allows a user to allocate public L2 chargers to be pole-mounted instead of ground mounted. These use the base costs for public L2 chargers but subtract the TTM costs and 25% of the BTM costs due to the infrastructure and labor cost components that have been avoided by pole mounting EV chargers on utility poles or otherwise integrating the chargers into existing on-street infrastructure (based on pilots at other utilities – the City would need to evaluate this technology in more detail to determine actual cost savings in Palo Alto).

Home chargers for single family homes are modeled as used by a single household and therefore have much lower costs than home chargers for multifamily homes, which are assumed to be shared within the building. Since they are shared, they are modeled to have additional infrastructure, more similar to a public L2 charger, to allow them to handle billing and be resistant to wear and tear. Some of these costs could be potentially mitigated via other methods of L2 multifamily charging, including installing L2 chargers in assigned parking spots, load management technologies to reduce electric infrastructure costs, and mobile charging. None of these approaches are modeled within this analysis and additional piloting and resources are needed to determine the most cost-effective strategy.

For additional details, see A.1.3.5 Charger Costs.

Figure 5: 2024 EV Charger Costs by Location and Charger Type



EV Charging Loads and Charging Costs

E3 utilized an E3 in-house load shape tool called EVGrid to produce EV charging load shapes for the transportation module. EVGrid aggregates driving patterns from thousands of drivers, considering driver travel needs, access to different charger types based on location, and price signals from potential time-of-use (TOU) rates to produce an average annual hourly load shape across all customers for each case that is run. As a pre-processing step for the transportation model, these annual load shapes are aggregated into TOU periods (e.g., summer peak, winter off-peak, etc.) that reflect potential time designations under hypothetical TOU electric rates. The model uses a weighted average of the loads from EVGrid to create a variety of desired scenarios with varying levels of home charging access. Finally, the loads are multiplied by the number of vehicles to calculate the city-wide load impacts at each charging location.

To calculate the costs of charging, these loads are multiplied by different residential and commercial rates, depending on the location of the charger.

E-Bike Assumptions

Additional bike and e-bike ridership in Palo Alto can offset miles traveled by automobile (which can in turn yield emissions reductions). The share of bikes and e-bikes that offset automobile trips, as opposed to walking, transit trips, etc. is a function of the destination of the e-bike trip. These values are derived from the North American Survey of Electric Bicycle

Owners report.⁹ High, medium, or low scenarios reflect policy-driven actions that the City could take to target certain e-bike uses cases, such as commuting. Number of miles biked per person per week and the total number of bikes in the city are also key assumptions used to calculate the passenger miles traveled by e-bike, the corresponding avoided vehicle miles traveled, and the associated emissions reductions and avoided fueling costs. E-bike upfront costs are derived from a survey of industry sources, including data from RMI's E-Bike Environment and Economics Impact Assessment Calculator.¹⁰ Fixed annual operations and maintenance costs, battery replacement costs, and battery cost declines are calculated with data from the RMI model.

⁹ <https://www.calbike.org/wp-content/uploads/2019/02/A-North-American-Survey-of-Electric-Bicycle-Owners.pdf>

¹⁰ <https://rmi.org/insight/e-bike-environment-and-economics-impact-assessment-calculator/>

Results

Cost of EV Ownership

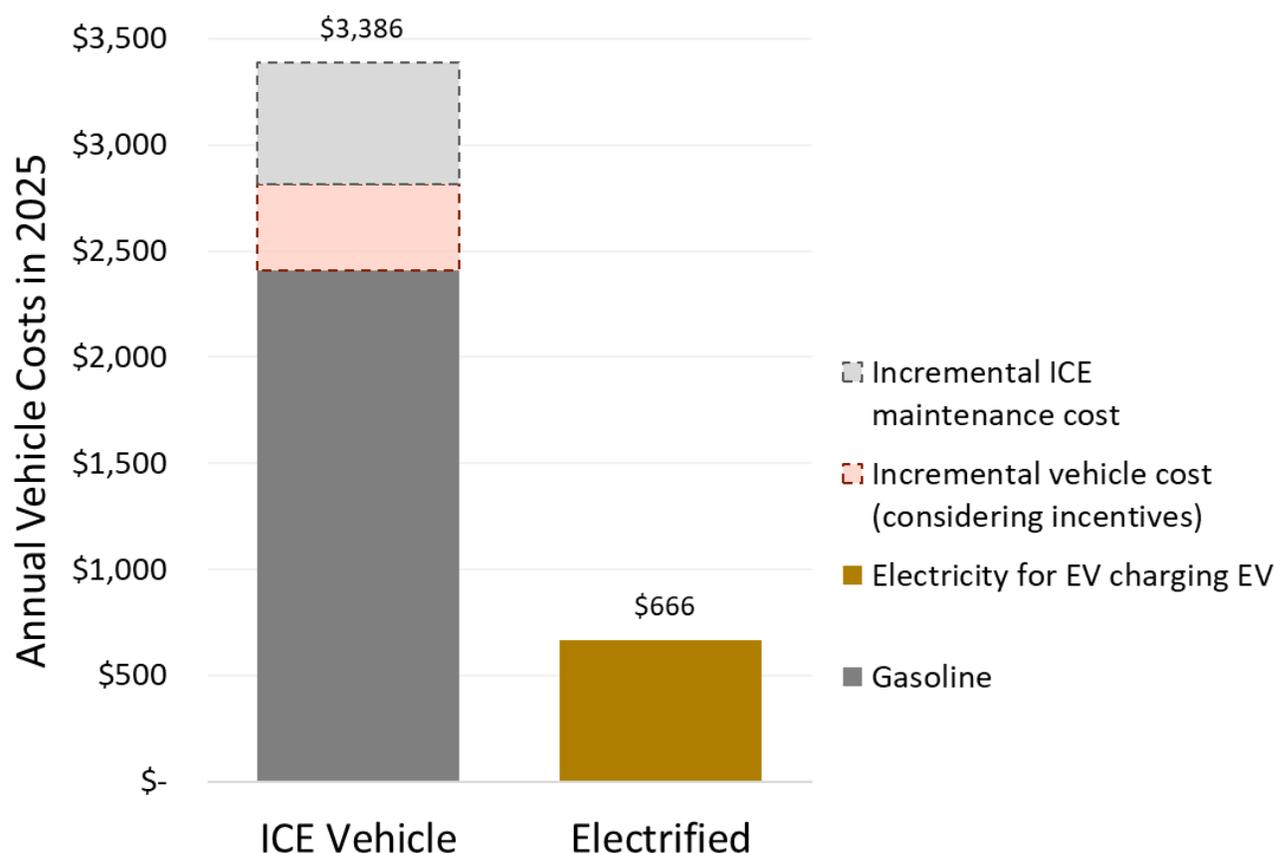
For individual customers, transportation electrification is likely to be cost effective. The cost of EVs themselves is projected to decrease over time, especially as more EV models become available and the used EV market grows, and EVs have much lower operational and maintenance costs than ICE vehicles. These factors, combined with the high cost of gasoline, result in the overall cost to own and operate an EV in 2025 to be cheaper than the cost to own and operate an ICE vehicle for an individual driver, as seen in Figure 6.¹¹ While Figure 6 assumes home charging costs, similar savings are seen when public charging is primarily used due to limited home charging access. However, Figure 6 does not include the amortized cost of EV charger upfront costs. This upfront cost and how it is paid for can vary significantly from use case to use case, as discussed throughout this report, but in nearly all cases, the savings from switching from an ICE Vehicle to an EV are expected to be significant enough to cover these costs.

However, there are many choices that are associated with EV charging beyond cost optimization. Some drivers have challenges building home charging infrastructure, particularly multifamily drivers and renters. Even if the space is available and allowed, the upfront cost of home chargers is much more expensive for multifamily residents, as seen in Figure 5, and finding the upfront capital will be challenging.

If some of these costs are undertaken by other entities, for example if the costs are funded by the City, covered by outside grants, or paid for by landlords or Homeowners Associations (HOAs) and passed on via rent, or assessment fees, the direct costs of EV ownership may remain low. Another viable strategy is to pass the cost of charging through via a Charging as a Service (CaaS) strategy, as described in the following sections.

¹¹ Note that the EV charging costs shown in this figure assumed managed EV charging patterns. Managed charging refers to optimized charging strategies that reduce costs, such as charging during off-peak hours when electricity rates are lower.

Figure 6: Annual vehicle costs in 2025 for a representative driver (ICE Vehicle vs. EV)¹²



Emissions Reductions in the Transportation Sector

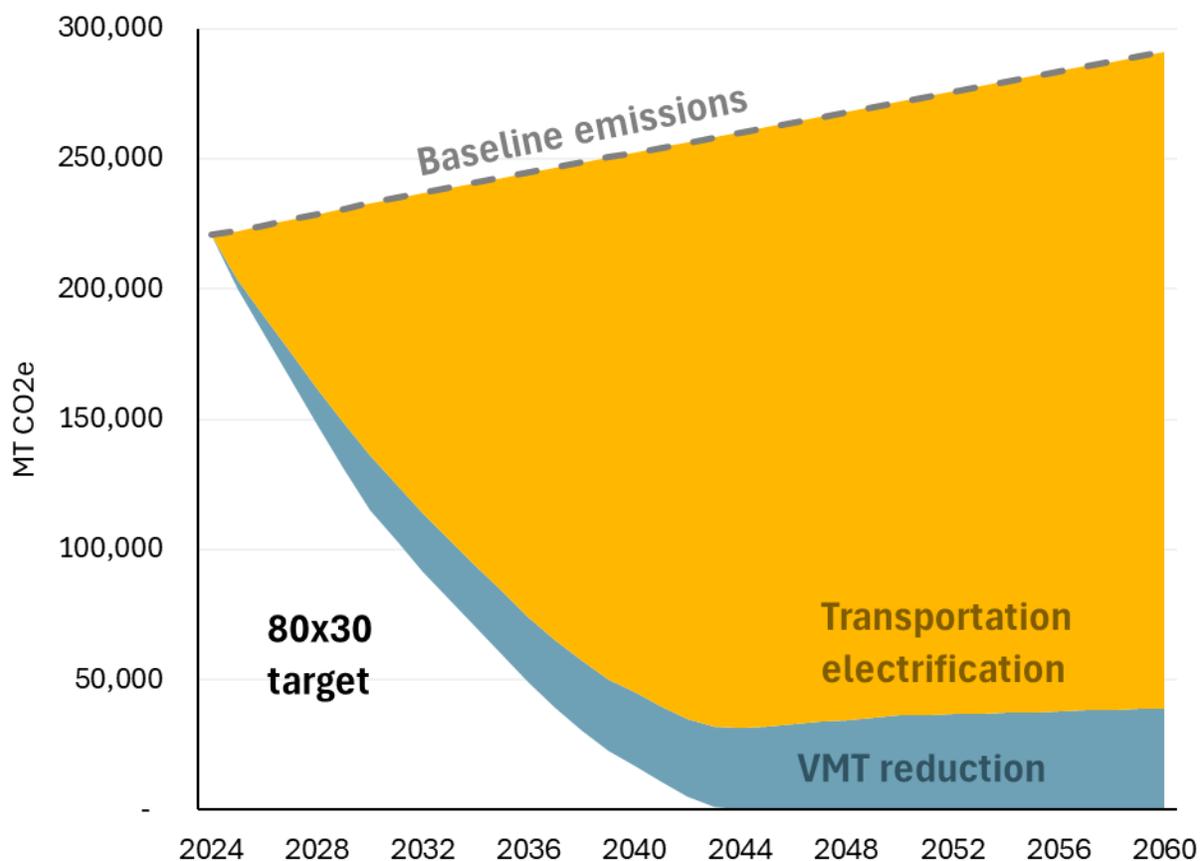
Transportation electrification reduces greenhouse gas emissions and is needed to meet Palo Alto’s climate goals. As set out in the S/CAP, Palo Alto will need to reduce emissions from the transportation sector 65% below 1990 levels by 2030. Palo Alto’s transportation emissions reductions strategy entails reducing vehicle miles traveled (VMT) through increasing public transit and active transportation (walking, biking), as well as widespread vehicle electrification.

VMT reduction includes increasing public transit as well as pedestrian and bike infrastructure. This includes efforts to promote both conventional bikes and e-bikes. VMT reduction strategies are prioritized in Palo Alto due to the associated co-benefits and lower costs. VMT reduction also includes e-bikes and other micromobility devices, which provide less impact on the electric grid and are more energy efficient forms of electric

¹² Note that costs in Figure 6 may not perfectly align with Figure 15 since Figure 6 represents annual customer costs in a single representative year, whereas Figure 15 represents the annual levelized cost from years 2024-2060, taking into account increased electricity prices, etc. Also note that this does not include the costs of the charger, which varies between single-family and multi-family residences.

transportation. Overall, VMT reduction can be seen as a form of energy efficiency, in that transportation is completed at a lower kWh per mile – using an e-bike uses less electricity than an EV and walking or biking uses no electricity at all. However, a significant amount of VMT is still projected to involve passenger vehicles in the future, and so vehicle electrification is likely to provide the largest emissions reductions in Palo Alto (Figure 7). Baseline emissions represent emissions if there were no additional electrification (as opposed to a “business as usual” scenario with no local action). This baseline is shown just to illustrate the magnitude of savings from transportation emissions reduction strategies. Changes in baseline emissions over time are due to population growth. ‘VMT Reductions’ represents the portion of ICE vehicle emissions reductions that would occur under the Baseline scenario given the modeled levels of VMT reduction.

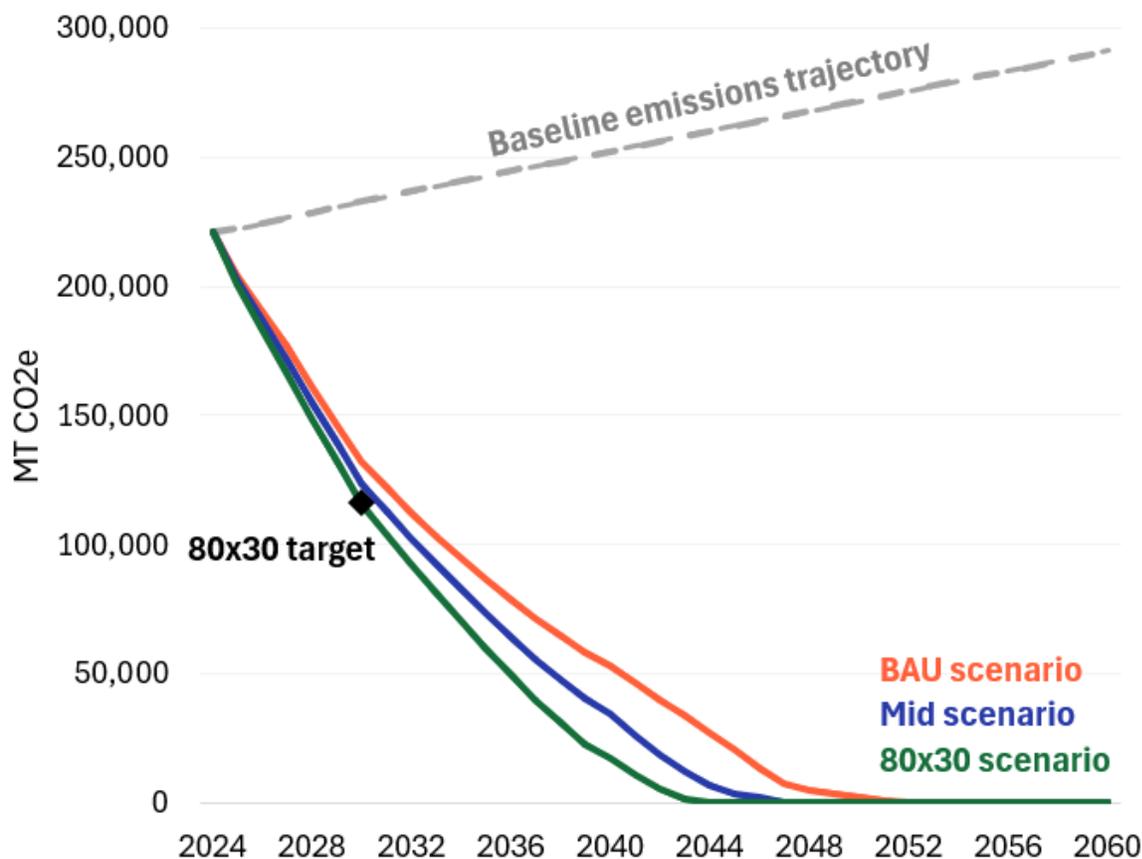
Figure 7: Emissions reductions in the transportation sector (LDV and MHDV) by measure (high EV adoption)



Transportation electrification will be a key driver of emissions reductions in Palo Alto, and emissions reductions will be greatest in the scenarios with the highest EV adoption (Figure 8). In the 80x30 EV adoption scenario, total transportation emissions decrease by 65% below 1990 levels by 2030, reaching the goals as set out by the S/CAP. This will include about 50,000 light-duty EVs owned by residents of Palo Alto. In the BAU EV adoption scenario, there are about 42,000 light-duty EVs owned by residents, causing transportation emissions

to decrease by 60% below 1990 levels. LDV EVs represent the lowest cost and the highest potential sources of emissions reduction in the strategies modeled in the E3 *Palo Alto Electrification Funding & Financing Study Final Report*, so long as adequate charging can be provided.

Figure 8: Transportation emissions across three EV adoption scenarios



Summary of EV Charging Infrastructure Needed to Support EV Growth

Upfront capital costs and practical installation challenges for EV charging infrastructure can be major barriers to EV adoption, both in the public and private arenas. While EV charging infrastructure will require a significant amount of investment (as discussed in a separate report, the S/CAP Funding and Financing Study) and planning, vehicle electrification is an important and cost-effective decarbonization strategy. Lifetime savings from fuel use and lower maintenance costs outweigh upfront electric vehicle costs, making EVs a cost-effective choice for customers and society as a whole. The buildout of robust charging networks is essential to support the transition to widespread EV adoption in Palo Alto and unlocking these long-term societal benefits.

The number and type of EV chargers that need to be built to support Palo Alto’s decarbonization goals depends on several factors, including the number of EVs adopted, the share of EV owners with access to home charging, the primary locations that charging occurs, and the level of commuter and visitor charging support provided. Depending on each of these factors, it is anticipated that by 2040, Palo Alto will need between 35,000 and 60,000 total EV chargers to support 42,000 to 50,000 residential light-duty EVs, 1,000 to 2,000 Palo Alto-registered medium-duty EVs (about 11% of which are owned by the City of Palo Alto) and 22,000 to 130,000 commuter and visitor light-duty EVs who wish to charge in Palo Alto.¹³ This includes both public chargers and private in-home chargers to support residents and some number of public and workplace chargers to support commuters and visitors. The exact breakdown of these chargers by location and type depends on the chosen investment strategy. The City will need to determine how to prioritize programs that influence this charger buildout, some of which may not be completed without City action or investment. Key decision points will include whether to pursue a multifamily charging strategy based primarily on home or public charging, how many commuters and visitor EVs should be supported by Palo Alto’s charging infrastructure, and how to ensure the most efficient ratio of DCFC vs. L2 charger buildout.

The total cost to install EV chargers across the city varies greatly by scenario. Two scenarios were modeled to show scenarios requiring higher and lower capital investment. Both scenarios are intended to serve as bookends. However, in reality, the future will likely look like something between the two scenarios.

- A “Light EV Charging” scenario involving a “business-as-usual” level of EV adoption and a continuation of current EV ownership trends, low investment in public charging, and a greater reliance on home charging.
- A “Robust EV Charging” scenario involving a 80x30 compliant level of EV adoption, high investment in public charging to make Palo Alto a “charging hub” for visitors and commuters, high investments in multifamily charging infrastructure, and a greater focus on public charging.

Table 2: EV Charging Scenario Definitions

	Light EV Charging	Robust EV Charging
EV Adoption Levels	Business-as-Usual	80x30 Compliant
Multifamily EV Adoption	Low	High
Access to Home Charging	High	Low
Access to Work Charging	Low	High

¹³ The number of commuter and visitor EVs is highly dependent on the number of visitors and commuters each day, as well as the level of charging support Palo Alto provides for those EVs.

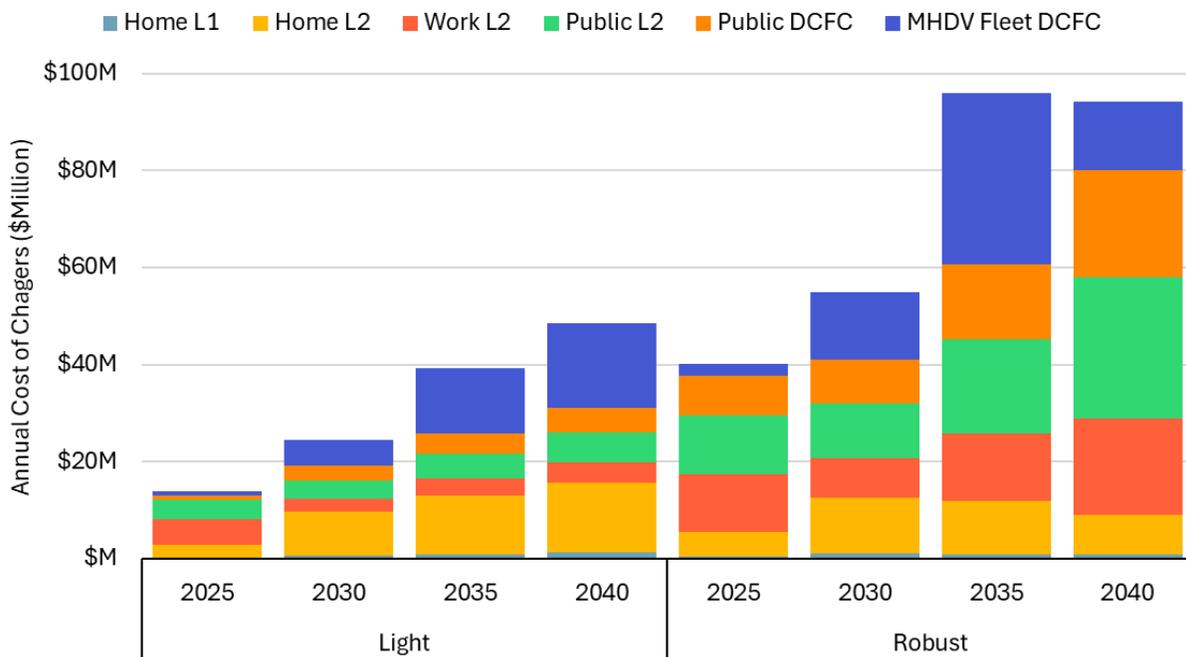
Commuter Charging	High	Low
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The Robust EV Charging scenario yields higher costs, in large part due to increased public charger buildout, with a greater presence of DCFC charging, which can be seen in **Error! Reference source not found..** Higher costs are also incurred in the Robust EV Charging scenario, in part, simply due to higher EV adoption, which requires more residential and public charger buildout to serve all electric vehicles. Note that even with higher levels of capital investment, depending on program design (as discussed in later sections), the Robust EV Charging scenario may have a similar net impact on community costs as the Light EV Charging scenario because it would generate more charging revenue to recover the higher initial capital investment.

Error! Reference source not found. shows several categories of chargers:

- Home L1 and L2 chargers in both single family and multifamily residences
- Workplace charging (Work L2)
- Public charging (Public L2 and Public DCFC) serving residents’ public charging needs as well as the needs of commuters and visitors
- MHDV Fleet DCFC, which represents high power chargers used for MHDV charging by fleet owners. In the Robust EV Charging scenario, MHDV electrification approaches 100% by 2040, leading to a spike in charger investment in 2035, with lower costs in subsequent years.

Figure 9: Snapshot of cost of chargers by location in key years



The Robust EV Charging scenario involves significantly higher capital investment primarily due to the cost of serving a greater number of EVs, the capital investment required to make Palo Alto a charging hub, and the assumed faster rate of MHDV adoption in this scenario.

Business Models for Providing EV Charging

A significant consideration when building out EV charging infrastructure in Palo Alto will be the balance of public vs. private investment strategies. That is, the reliance on private capital and ownership as opposed to publicly funded and operated charging stations.

There are a number of different business models that could be employed in Palo Alto that use a mix of public vs. private investment and cost recovery strategies. The total upfront cost of charging infrastructure in Palo Alto does not change under different business models, but rather these alternative business models explore potential pathways for allocating the upfront and ongoing costs of chargers between resident drivers (via paying a surcharge on charging costs), building owners (via paying directly for capital investment or repaying loans), third party providers of home or public charging via “Charging as a Service” models, and the community at large (via incentives). Different business models can be employed by Palo Alto as mechanisms to cover the high upfront costs and to enable ongoing cost recovery.

Distinct business models can potentially be utilized for different customer types, including single family residents, multifamily residents, and commuters, as well as for different charging locations (e.g., Home L1, Public L2, etc.). This means Palo Alto has the opportunity to explore the impact of prioritizing investments in EV charging infrastructure for certain customer segments, such as multifamily EV chargers, which have historically had lower levels of investment.

The following general business models were considered in this study:

- + **Publicly funded:** in this business model, chargers are entirely publicly funded. The City covers all BTM charging infrastructure, charging hardware, and O&M costs for home and public charging. There is no recovery of upfront capital investment, and the EV charging rates are designed to cover only the cost of energy and maintenance. This would represent a scenario where the charger investment is publicly funded via grants, incentive funds, or similar funding sources. An example of this model currently in operation is the City-owned public chargers installed within various City garages. This model is not expected to yield significant numbers of chargers, but provides the lowest cost to resident and commuter/visitor drivers where it can be implemented.
- + **Charging as a Service (CaaS):** In this business model, the upfront capital investment for chargers is provided by a third party who receives a return on investment through a surcharge on the EV charging rate. This model is more expensive for resident and

commuter/visitor drivers, but enables access to a wider range of capital sources. This model could be utilized by a private company, nonprofit, or public agency, with private companies likely requiring a higher return on investment. This may result in higher costs to resident and commuter/visitor drivers unless private companies can offer lower installation costs than public agencies or nonprofits. The vast majority of existing publicly available charging stations are funded through this model. Some companies are providing multifamily charging through this business model as well.

- + **Private investment:** In this model, chargers are entirely funded by the building owner. Virtually all charging in single family homes is provided this way, as is some workplace charging. This business model can be challenging for landlords, who would need to invest in infrastructure that would be used by renters. The economic success of this business model for landlords would depend on the amount of demand for charging by tenants and the landlord's ability to recoup the cost of the EV charging infrastructure such as charging higher rents for the availability of EV charging as an amenity.

The modeling team then put together four hypothetical Palo Alto-specific business models for consideration¹⁴:

- + **Public investment only:** in this hypothetical business model, chargers are entirely publicly funded through City ownership and incentives. Under this business model the City could cover all BTM charging infrastructure, charging hardware, and O&M costs for residential and public charging. There is no upfront capital cost recovery for the City, and the EV charging rates are designed to cover only the cost of energy and maintenance. This model demonstrates how a heavy reliance on incentives results in charger costs being recovered from taxpayers and/or ratepayers.
- + **City CaaS:** in this business model, BTM charging infrastructure, charging hardware, and O&M costs are borne by the City, building owners, and drivers. It is assumed the City would pay for the upfront costs of public charging infrastructure, building owners would cover the costs of chargers at MFR buildings, and homeowners would pay for the cost of private SFR home chargers. There are no incentives provided in this business model. The City and MFR building owners would utilize CaaS to recover the upfront costs of public and MFR chargers, with drivers paying a \$/kWh fee upon use. Alternatively, the MFR building owner may recover costs through increased rent, but this was not modeled. This business model represents a scenario in which the costs of chargers are put entirely on building owners, homeowners, and drivers instead of taxpayers and/or ratepayer bus.

¹⁴ In the S/CAP Funding Model, business model implementation varies by sector and scenario. In the High/Medium Local Action scenarios, the Third Party CaaS + Public Incentives business model covers all sectors except for City-owned vehicles/chargers, which are all Public Investment Only. In the Low Local Action scenario, the set-up is the same except for Single Family drivers it is Private Investment Only.

- + **Third Party CaaS:** in this business model, BTM charging infrastructure, charging hardware, and O&M costs are borne by the third-party companies and tenant and commuter/visitor drivers. It is assumed the third-party companies would pay for the upfront costs of public and MFR charging infrastructure, and resident drivers would pay for the cost of private SFR home chargers. There are no incentives provided in this business model. Third party companies would utilize CaaS to recover the upfront costs of public and MFR chargers, with tenant and commuter/visitor drivers paying a \$/kWh fee upon use. In this model, the costs of chargers are put entirely on building owners, homeowners, and tenant/commuter/visitor drivers instead of taxpayers and ratepayers. One primary difference between this business model and City CaaS is the cost of capital; public agencies may be able to borrow more cheaply than private entities, though this distinction was not modeled.
- + **Third Party CaaS + Public Incentives:** this business model represents one of many potential real-world outcomes where there is a mix of both public and private funding. BTM charging infrastructure, charging hardware, and O&M costs are borne by third party companies for public chargers, with costs recovered over time through CaaS. In this model, the City provides incentives to building owners and private homeowners for home charging infrastructure. This model represents a more realistic scenario in which a mix of public funding, private capital, and CaaS could be utilized to provide the mix of charging needed to serve Palo Alto residents, commuters, visitors, and fleet vehicles. This model demonstrates a lower reliance on City incentives being recovered from taxpayers and/or ratepayers than the Public Investment only business model.

Under all business models, it is assumed that the City would own and operate all TTM infrastructure for public EV charging. For residential charging, it is assumed that the City would cover the cost of the transformer (about 10% of total costs) and the remaining residential TTM infrastructure needs would be borne by the building owner or private homeowner under utility service upgrade costs. For BTM, different parties (i.e., the City, a third-party EV charging company, a MFR building owner, or homeowner) may bear the upfront cost of charging infrastructure, charging hardware, and/or O&M costs, depending on the business model.

Private commercial fleets make up nearly 90% of all MHDV vehicles on the road in Palo Alto and are assumed to pay directly for fleet charger costs under all business models, unless public incentives are provided via the Third Party CaaS + Public Incentives business model.

Table 3 summarizes how upfront and O&M costs are allocated to different parties across the four different business models.

Table 3: Upfront cost allocation by business model¹⁵

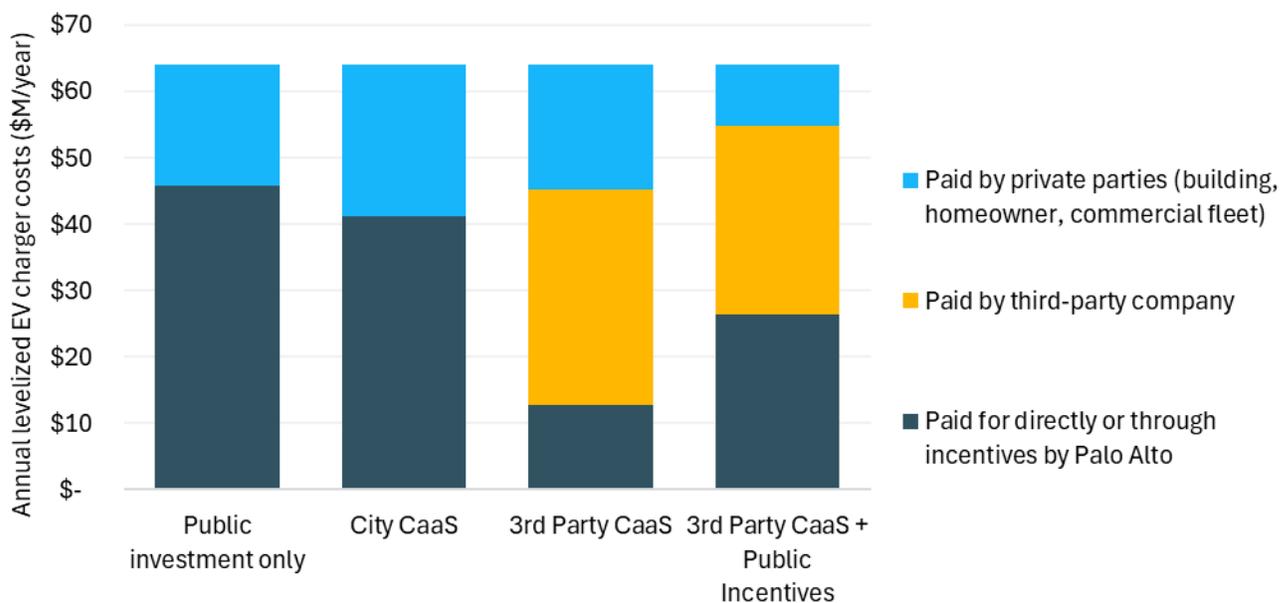
Who Pays Upfront Costs?	Public Investment Only	City CaaS	Third Party CaaS	Third Party CaaS + Public Incentives
Public/Workplace				
TTM Infrastructure	●	●	●	●
BTM Infrastructure, EV Supply Equipment, O&M	●	●	●	●
Commercial Fleet				
TTM Infrastructure	●	●	●	●
BTM Infrastructure, EV Supply Equipment, O&M	●	●	●	●
MF Residential				
TTM Infrastructure	● ●	● ●	● ●	● ●
BTM Infrastructure, EV Supply Equipment, O&M	●	●	●	●
SF Residential				
TTM Infrastructure	● ●	● ●	● ●	● ●
BTM Infrastructure, EV Supply Equipment, O&M	●	●	●	●

City (paid directly or via incentives)
 Private Parties (building, homeowner, commercial fleet)
 Third Party

Figure 10 shows how the levelized capital and O&M costs (~ \$64M/year) are allocated across different parties based on the active business model.

¹⁵ In the S/CAP Funding Model, business model implementation varies by sector and scenario. In the High/Medium Local Action scenarios, the Third Party CaaS + Public Incentives business model covers all sectors except for City-owned vehicles/chargers, which are all Public Investment Only. In the Low Local Action scenario, the set-up is the same except for Single Family drivers it is Private Investment Only.

Figure 10: Levelized upfront and O&M cost allocations across different business models (example shown for high EV adoption)



As mentioned above, different business models can also determine how costs are recovered over time. The two primary levers for cost recovery when designing business models are:

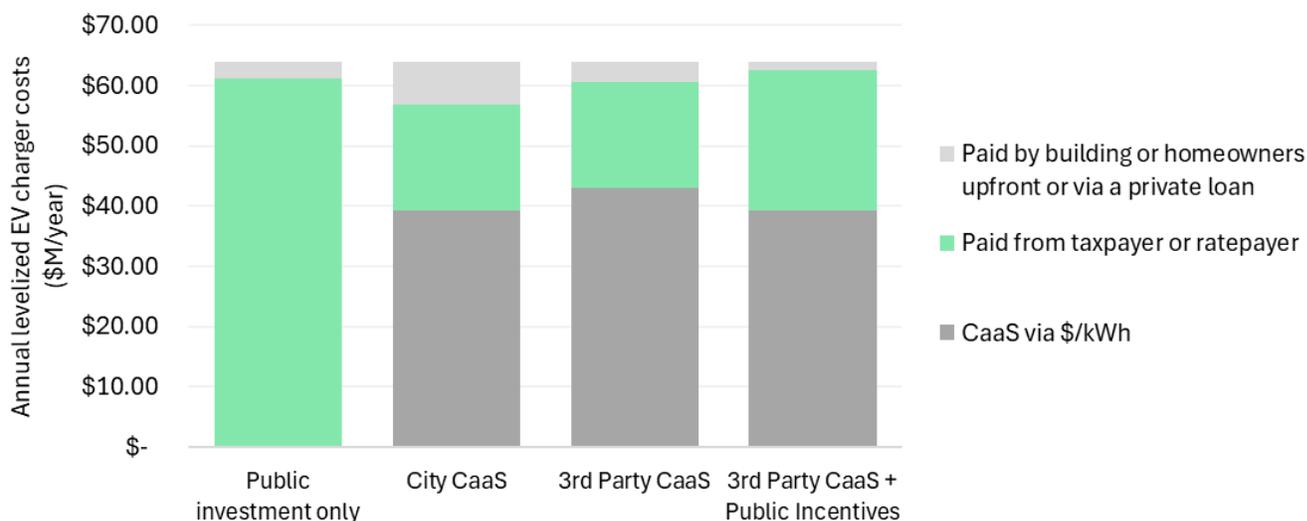
- + The portion of upfront and O&M EV charger costs that are paid for by incentives which are funded by taxes or utility rates, meaning the costs do not need to be repaid
- 1. The portion of upfront and O&M EV charger costs that are paid for by resident or commuter/visitor drivers over time, i.e., how much of the upfront investment is repaid by a \$/kWh surcharge upon use (known as CaaS).

Table 4 summarizes the different cost recovery mechanisms for the four different business models.

Table 4: Cost recovery mechanisms by business mode

Figure 11 shows the cost recovery mechanisms for annual levelized EV charger costs (~\$64M/year) for each business model. Note that cost recovery levels are equal across all business models. This is because in the model the interest rate for cost recovery under the CaaS business model is set up to be the same between City CaaS and 3rd Party CaaS. In reality, there may be differences in borrowing costs and interest rates between public and private providers. This input can be adjusted by model users.

Figure 11: Levelized ongoing cost recovery by mechanism across different business models (example shown for high EV adoption)



Each business model has its own set of strengths and drawbacks, with the ability to focus on different types of priorities within investments. The following factors are key considerations when weighing different business models:

- + **Publicly vs. privately owned asset:** Ownership of the asset determines who has the maintenance obligation and customer service obligation that goes with it. In a CaaS model, the charger ownership affects whether it is the public or a private company whose money is at risk. Under CaaS, whether the asset is publicly or private owned will also affect charging pricing, i.e., a private company will seek to maximize profits, meaning charging will almost always be priced at about the market rate, regardless of what incentives were provided or whether the asset costs less than other assets. Public agencies, on the other hand, can price charging at cost (including cost of repayment of the capital investment).¹⁶
- + **Use of grant or other funding from non-Palo Alto sources:** Publicly-owned, grant-funded chargers result in the lowest charging costs to customers. While grant funding will not be able to cover costs for all chargers, these types of sources should be pursued whenever available.
- + **City-provided incentives:** To pursue business models that involve City-provided incentives, residents must be willing to tax themselves or raise their own rates to fund the incentives.
- + **Use of CaaS:** Under CaaS business models, projects should only be pursued if the cost of charging can be competitive with other charging available to the target driver demographic

¹⁶ Note that in the Funding Model, the interest rate for public and private ownership is the same.

- + **Willingness of private market to serve specific target demographics:** Investing in charging infrastructure at low-income multifamily buildings might not be profitable enough for private developers to pursue, which leaves an opportunity for the City to intervene to support.

Projected Home EV Charging Needs

The need for residential charging varies among electric vehicle (EV) drivers; however, home charging is generally preferred when available.¹⁷ While some resident drivers are comfortable using Level 1 (L1) chargers, others prefer Level 2 (L2) chargers, with many finding a low-power L2 sufficient for their needs. The projected proportions of L1 and L2 home charging through 2040 were estimated separately for EV owners in single family and multifamily residences.

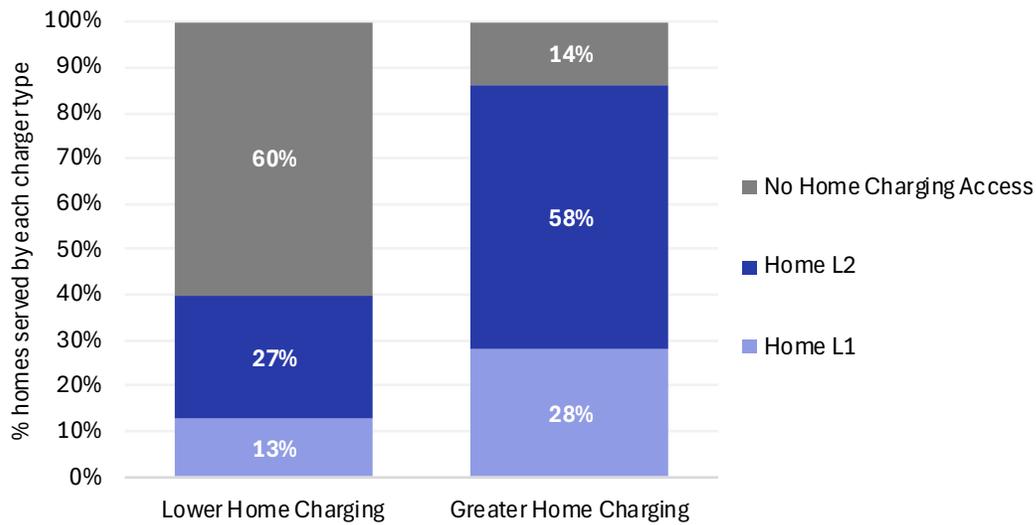
Because it can be more complicated to install EV chargers in multifamily buildings, additional analysis on the desirability of focusing on home vs. public charging was assessed for this group. The effect of different business models in building these chargers was also assessed.

Single family Home Charging

The projected percentage of single-family drivers served by L1, L2, or no home charging is shown in Figure 12 below for a scenario with lower home charging vs. greater home charging.

¹⁷ <https://www.bcg.com/publications/2023/what-ev-drivers-expect-from-charging-stations-for-electric-cars>

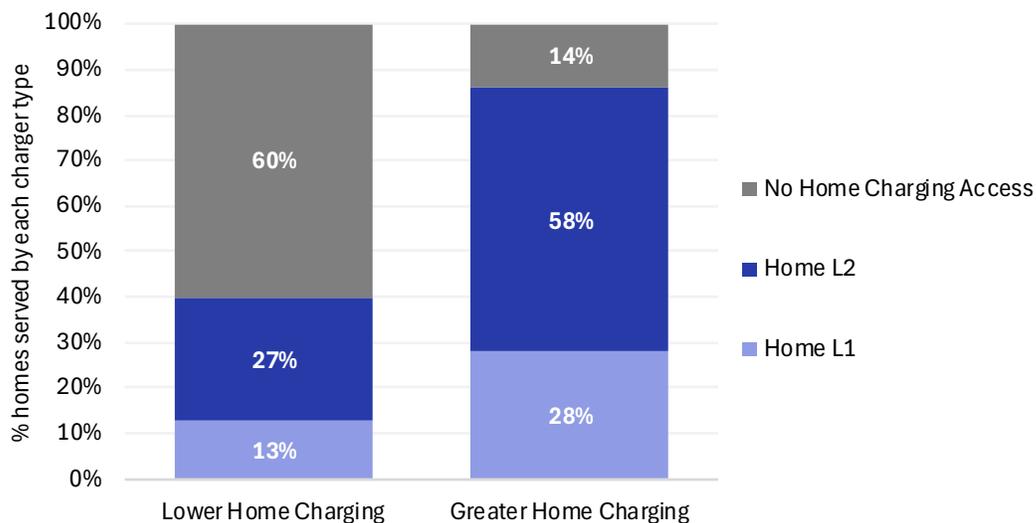
Figure 12: Single family home EV charger types for lower vs. greater home charging access



Multifamily Home Charging

Similarly, the projected percentage of multifamily drivers served by L1, L2, or no home charging is shown in Figure 13 below for a scenario with lower home charging vs. greater home charging.

Figure 13: Multifamily home EV charger types for lower vs. greater home charging access

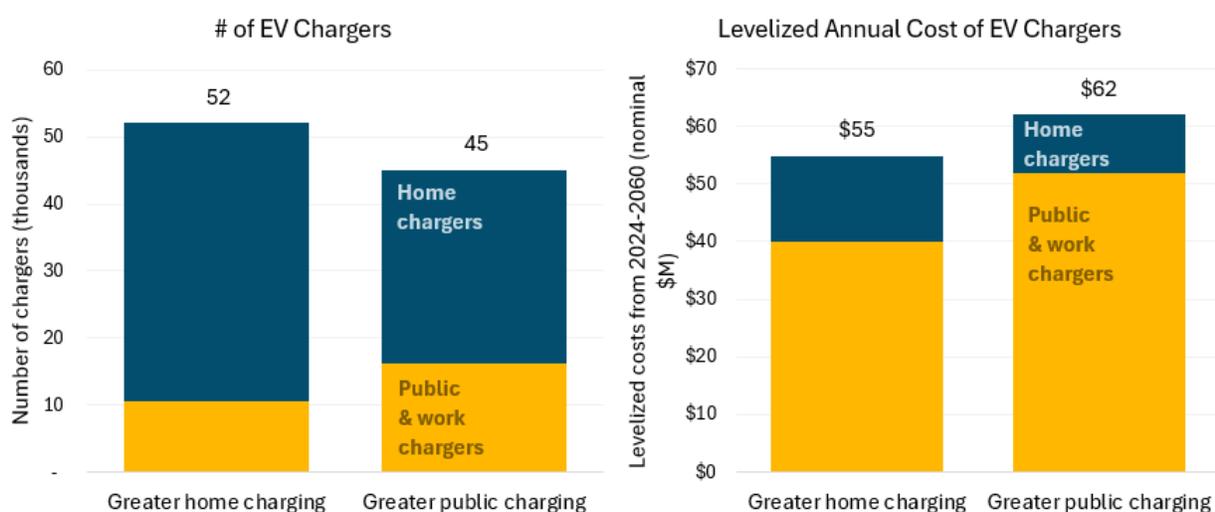


As vehicle sales approach 100% EVs, it is likely that more potential EV owners will be renters, multifamily residents, and drivers without dedicated home parking spots. This means that over time, a higher number of EV owners will not have the opportunity to easily install home

chargers, and therefore it is likely that a smaller share of EV drivers will have access to home charging based on the current state of multifamily charging infrastructure (i.e., the overall population of EV drivers will align more closely with the left bar in Figure 13 than the right). With less home charging access, Palo Alto will need to facilitate charging to meet the EV charging demand by either supporting the installation of home charging for EV drivers who are unable to install it themselves due to capital cost or other barriers, or by focusing on increasing the number of public chargers in Palo Alto. Scenarios with greater emphasis on home chargers will require a greater number of total chargers. This is because home chargers can only serve a limited number of vehicles that belong to the home’s residents. For single family homes that number is generally two vehicles, while public chargers can serve many more.

Figure 14 shows two different levels of access to home charging for the Robust EV Adoption scenario, assuming a moderate number of visitors and commuters. It shows that a greater focus on home charging will require about 52,000 chargers to serve residents, commuters, and visitors by 2040, while a greater focus on public charging may only require 45,000 chargers by 2040 to serve the same number of EVs. However, as seen in Figure 14, the total levelized cost of charger installations (including upfront charger costs and ongoing O&M) for a scenario with greater public charging is still larger than the levelized cost for a scenario with greater home charging. This is because the upfront cost of public chargers is significantly higher than that for home chargers, largely due to the ratio between L2 and DCFC installations for public charging (i.e., several of the public charging stations use DCFC, which have significantly higher capital costs than L2 chargers, as seen in Figure 5, above).

Figure 14: Impacts of home and public charging¹⁸ on number of chargers and cost of chargers for 80x30 EV adoption levels by 2040



¹⁸ Note this figure assumes a high level of EV adoption and the only variable that changes between the two bars is the level of home charging access

Palo Alto must consider the affordability of public vs. private investment strategies for people who have challenges building home charging. From a customer perspective, the upfront cost of multifamily home charging is expensive and finding the upfront capital will be challenging (see Figure 5). However, program design and choices around financing can impact how these costs get paid over time and can potentially relieve some of the upfront cost burden.

If the City funds the upfront charger costs or uses outside funding to build chargers, the direct costs for EV charging and charger ownership remain low. In Figure 15 (high public investment) below, total charger and electricity costs for an average MFR resident are around \$1,400 per year. This figure assumes that the City would cover charger costs such as BTM and EVSE, while landlords or homeowners associations (HOA) would be responsible for a portion of TTM infrastructure as a utility service upgrade. Figure 15 also assumes that the landlord or HOA would pass all TTM infrastructure costs onto multifamily residents through rent increases or assessment fees.

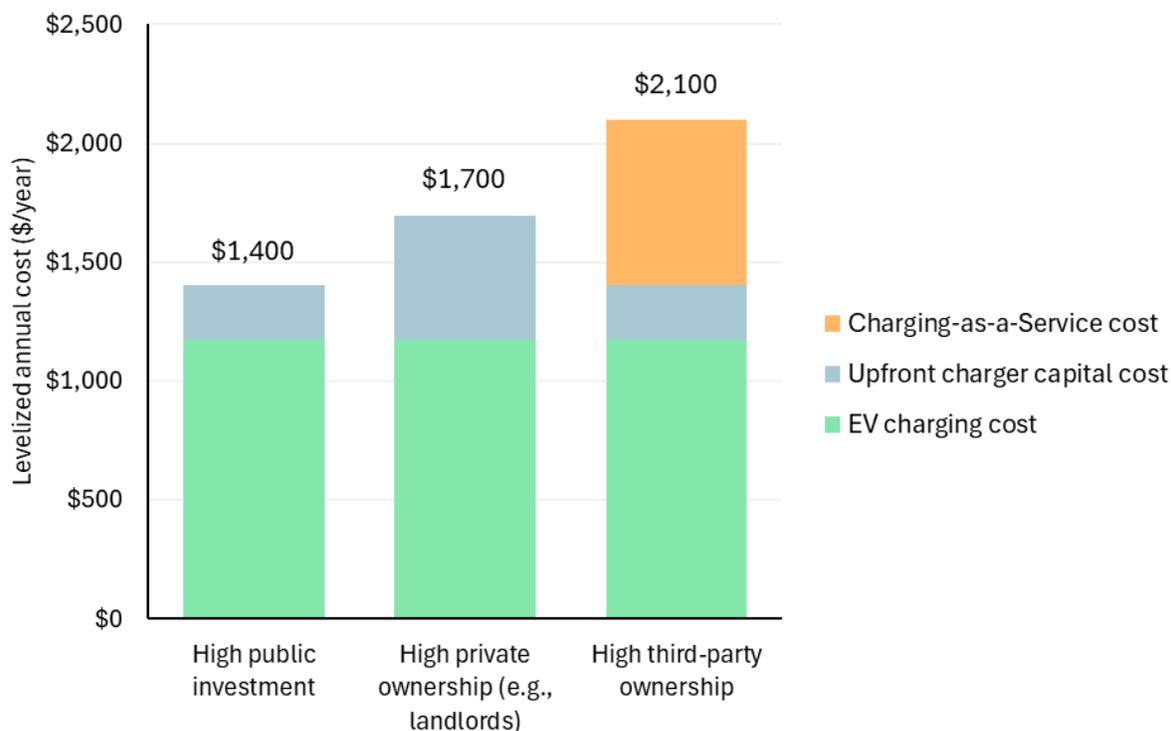
If landlords or HOAs are responsible for the full upfront cost of EV charging equipment, rather than relying on high public investment for the City, the annual EV charging costs for an average multifamily resident increase (Figure 15, high private ownership). If the City is paying less of the upfront cost of MFR charging infrastructure, it is assumed that those costs would be passed onto MF residents through rent increases or assessment fees by landlords or HOAs.

Another viable strategy is to pass the cost of EV charging through to tenant drivers via a Charging-as-a-Service (CaaS) strategy. Through third-party ownership of EV charging infrastructure, the use of CaaS can be used for cost recovery of financed capital expenditure on a \$/kWh basis, helping remove the upfront cost barrier to EV charging infrastructure by shifting upfront costs to ongoing costs. With high third-party ownership of chargers, as seen in Figure 15, high third-party ownership) there is less cash needed upfront from the City or from landlords, with a higher share of costs recovered on a \$/kWh basis from users over the charger lifetime. High charger utilization can drive down the \$/kWh cost recovery surcharge, making charging more affordable. Regardless, recovering charger costs on a per-kWh basis could make charging less affordable if the third-party company has a high interest rate (see higher CaaS costs in Figure 15, high third-party ownership) providing a disincentive to EV adoption, which is an important consideration when deciding on a business model for public or home EV charging.

In considering the impacts of CaaS on an individual customer, it's worth noting that even with the additional costs from MFR home charging CaaS, the cost of owning and operating an EV is still lower than an ICE vehicle (compared to ICE vehicle in Figure 6).¹⁹

¹⁹ Note that costs in Figure 6 may not perfectly align with Figure 15 since Figure 6 represents annual costs in a single year, whereas Figure 15 represents the annual levelized cost from years 2024-2060, taking into account increased electricity prices, etc.

Figure 15: EV charging costs under different program design scenarios for an average MF resident²⁰



Public Charging Needs

Another factor that informs charger buildout and the associated cost is the level at which Palo Alto wants to build its infrastructure to support commuters and visitors. As EV adoption increases across the state of California, a higher share of visitors and commuters will drive EVs and may need to charge. If Palo Alto wants to serve as a commuter or visitor charging hub, the number of public chargers and total cost of chargers will increase.

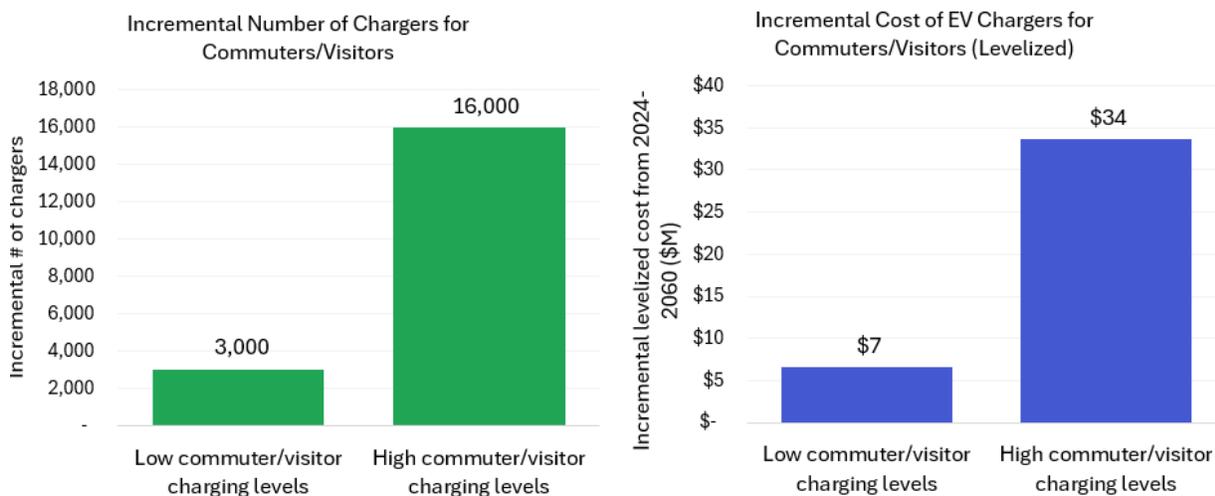
The modeling assumed public charging levels in Palo Alto ranging from ~28,000 kWh to ~72,000 kWh charging sessions per day. These charging sessions are expected to be made up of a combination of Palo Alto residents, commuters, and visitors. The lower end of the range represents a scenario in which there are fewer EVs on the road and a lower amount of public charging support is provided in Palo Alto. This scenario assumes that residents are charging primarily at home, and that commuters and visitors are charging mostly outside of Palo Alto. The higher end of the range represents a scenario in which there are more EVs on

²⁰ Some upfront costs, such as service upgrades for TTM infrastructure, fall on the landlord/HOA (and then are passed to MF residents) in all scenarios

the road and a higher amount of public charging support is provided in Palo Alto. This scenario assumes that more residents are reliant on public charging for their charging needs, and that commuters and visitors do most of their charging in Palo Alto. In this scenario, Palo Alto is acting as a public charging hub for commuters and visitors.

Under a low-support scenario, Palo Alto would build 3,000 additional chargers to support 25% of the total public and workplace charging need for commuters and visitors, but under the high-support scenario, Palo Alto would build an additional 16,000 chargers to support about 75% of the total public and workplace charging need for commuters and visitors (Figure 16). Both scenarios assume that in 2040, 70% of commuters and visitors have access to home charging in their respective communities in order to focus on the impacts of the commuter and visitor assumptions. Similarly, charging load shapes for commuters and visitors were modeled with the same tool used for resident LDVs. Since commuters and visitors do not live within Palo Alto, these would all be public or workplace chargers, and therefore more expensive to build than residential chargers. Annual levelized costs range from \$7M/year for the low-support scenario to \$34M/year for the high-support scenario (Figure 16). Under both levels of support, Palo Alto would need to generate charging revenue at roughly \$0.20/kWh to recover the costs associated with these chargers, in addition to the cost of electricity, yielding a total charging cost of about \$0.42/kWh.

Figure 16: Impacts of commuters and visitors on number of chargers and cost



As of October 2024, the PG&E E-ELEC rate, which is a common rate for EV owners who live outside of Palo Alto, has an overnight volumetric rate of \$0.40/kWh in summer and \$0.35/kWh in winter. With lower public L2 rates, public charging in Palo Alto may be cost competitive with home charging in neighboring municipalities, pending a project-by-project competitive analysis. In the future, if Palo Alto adopts TOU rates, off-peak periods may have even lower rates, making them more cost competitive. Whiles data on public charging costs

outside of Palo Alto is difficult to gather since rates are often set by the site host, and structures and rates vary site to site, the generally lower cost of electricity could provide an economic advantage for Palo Alto becoming an EV charging hub.

These results do not represent the optimized level of cost-effective charging to support commuters and visitors but rather show “what if” scenarios of different levels of support in the future. More analysis, likely on a project-by-project basis, is needed to explore the cost-effectiveness of providing charging access for commuters and visitors, as well as what the optimal level of charging support would be. Additional considerations include the use of Public L2 for combined multifamily overnight and commuter/visitor daytime charging.

Program design and maximizing utilization

Virtually all current public charging is operated on a CaaS model, with upfront costs recovered through a \$/kWh surcharge on charging rates. If Palo Alto chooses to focus on expanding public charging, the City should consider customer preferences and siting factors to encourage high utilization of EV chargers. Increasing utilization not only reduces ongoing costs on a \$/kWh basis for customers but also reduces the number of chargers that need to be built. Competing factors, such as the price premium to charge at DCFC as opposed to the longer dwell times to charge at L2 chargers, provide uncertainty in customer choice between the two types of chargers. NREL’s EVI-Pro tool favors L2 build out and assumes that only 10% of drivers will prefer fast charging²¹, whereas other sources show users may prefer to do their public charging at DCFC in the future.^{22,23} This insight holds especially if there is a minimal price differential between DCFC and L2 charging rates. An example of this dynamic can be seen in Figure 17, where a significant number of L2 chargers are built, but the majority of EV charging load comes from DCFC. While some of this can be attributed to the fast-charging nature of DCFC, much of it points to our limited understanding of large-scale EV rollout. Historically, customers have relied more on L2 charging, but as the mix of available chargers and customer preferences and needs change, this may also change. The slower charging speed of L2 chargers can be a barrier, especially in aligning the longer required dwell time with public use cases. Mismatch in charger planning and customer preferences or needs could lead to an over-investment and under-utilization of public L2 chargers. As EV adoption increases, it will be important for system planners observe utilization of different types of chargers over time to best understand the needs of the local community.

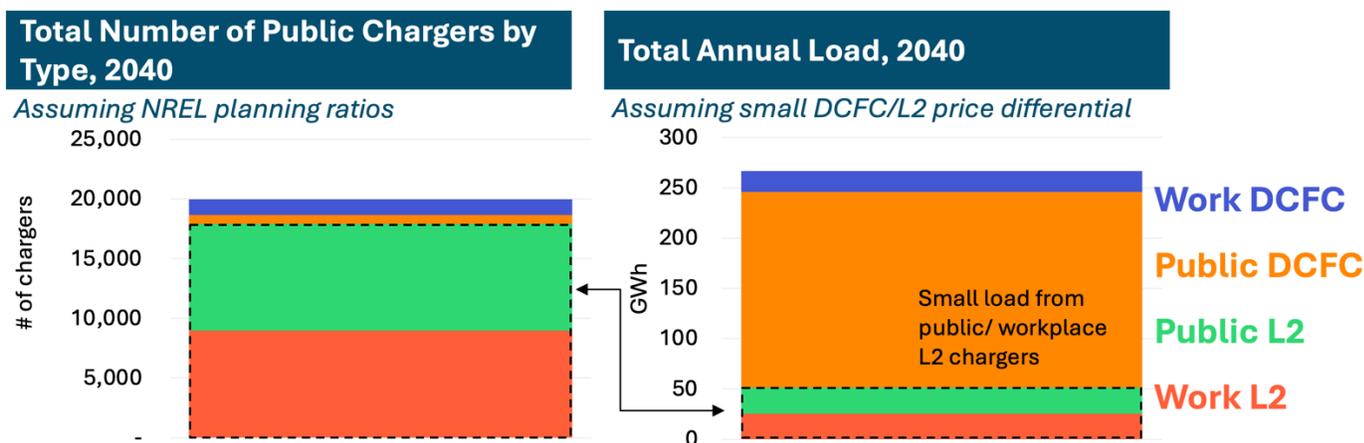
²¹ <https://afdc.energy.gov/evi-x-toolbox#/evi-pro-ports>
<https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/electric>
<https://www.energy.ca.gov/data-reports/reports/electric-vehicle-charging-infrastructure-assessment-ab-2127>

<https://www.nrel.gov/docs/fy23osti/85654.pdf>

²² <https://www.energy.ca.gov/data-reports/reports/electric-vehicle-charging-infrastructure-assessment-ab-2127>

²³ E3’s EVGrid EV load shaping tool

Figure 17: Public Charger Build and Load by Charger Type



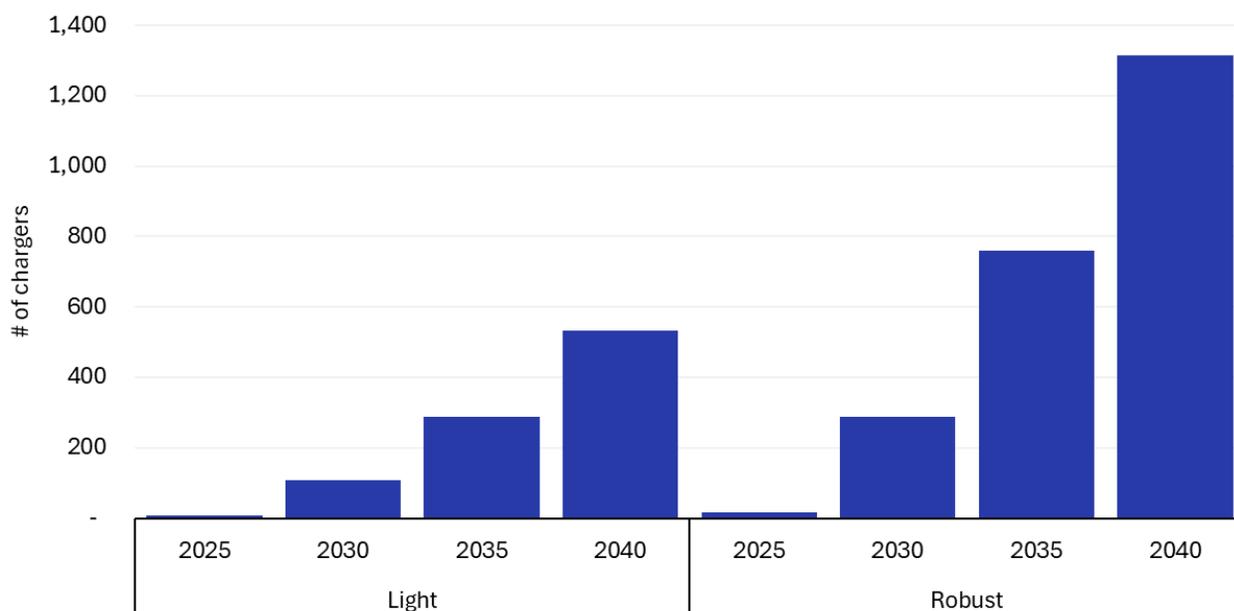
Visitor and commuter charging preferences will also play a role in public charger siting and investment. For the purposes of this study, visitor and commuter charging were treated the same, but in reality, there will be differences in how they decide where and when to charge. For example, a visitor that is passing through may prefer fast charging if they do not plan to spend a long time in Palo Alto, whereas a commuter that will be at the office all day may prefer to charge at a workplace L2 while they work.

Medium- and Heavy-Duty Vehicle Charging Needs

Charging for MDHV requires different planning than for LDVs. In the Light and Robust EV Charging scenarios, MDHV adoption of 1,000 MDHVs and 2,000 MDHVs, respectively, were modeled. The vast majority, if not all, were assumed to be medium-duty vehicles, and about 11% were assumed to be owned by the City and the remaining owned and operated by private commercial fleets. To charge the large batteries on these types of vehicles much higher powered (and more costly) chargers are needed, as shown in Figure 18. Between 500 and 1,300 workplace DCFC chargers are needed by 2040 to serve these vehicles at a cost of between \$150 million and \$360 million cumulatively by 2040. It is assumed that the City would provide investment for the 11% of MHDV chargers that are City-owned and operated. For the remaining 89% of MHDV chargers assumed to be owned and operated by commercial fleets, it is assumed that private commercial fleets would cover the investment for charging infrastructure.²⁴

²⁴ Note that for simplification, business model mechanisms, such as Third-Party CaaS, do not apply to the 89% of MHDV costs that are covered by commercial fleets. It is assumed those private companies would pay for the chargers directly, once Palo Alto-provided incentives have been applied.

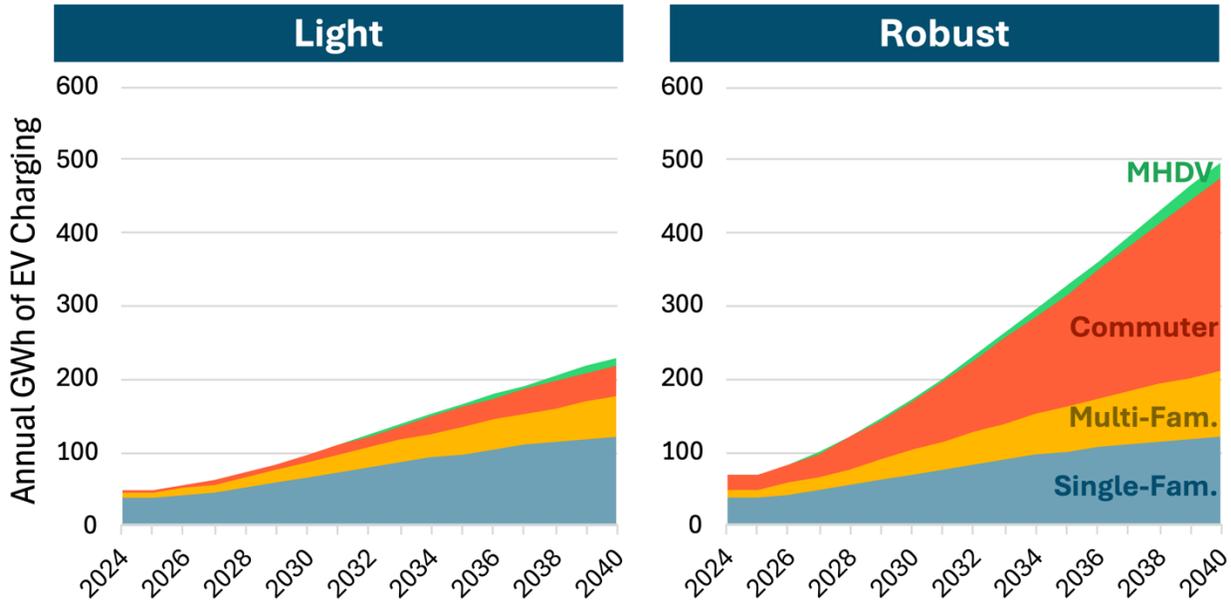
Figure 18: Number of MHDV Fleet DCFC by Scenario



Estimated EV Charging Electric Loads

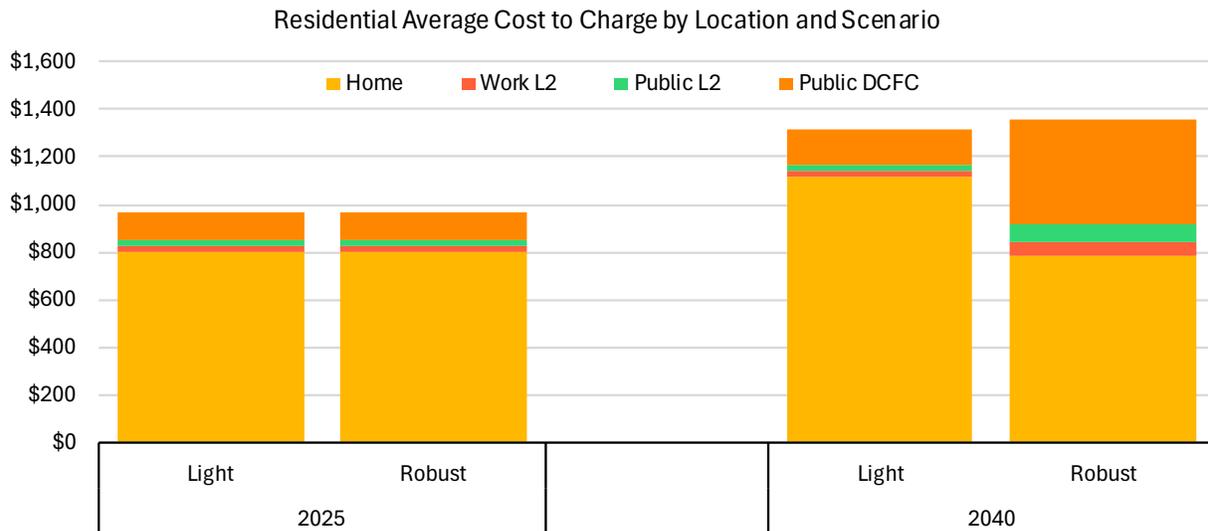
The total electricity demand from charging across the city is a function of EV adoption and commuter charging support within city bounds. Figure 19 shows two scenarios, the Light EV Charging capturing business-as-usual adoption (aligned with compliance of Advanced Clean Cars II) and low commuter charging support, while the Robust EV Charging captures high EV adoption (aligned with 80x30 targets) and high commuter charging support. By 2030, the two scenarios show an annual EV charging load ranging from 100 to 175 GWh, and by 2040, 230 to 500 GWh. This modeling assumes that EVs drive a similar amount as ICE vehicles. It is important to note that some households may maintain a single EV and single ICE vehicle, using the EV for primarily local trips and the ICE vehicle for longer-distance trips. This dynamic is not explicitly modeled in this analysis, as data was not available on how much of an impact this phenomenon might have. However, the model does use aggregated trip data from many customers, some of whom may be exhibiting this behavior already.

Figure 19: Annual EV Charging Load (GWh) Under High and Low EV Charging Demand Scenarios



Costs for Residential Customers to Charge

Figure 20: Residential Average Cost to Charge by Location and Scenario



Costs for customers to charge their vehicles varies by scenario and year. Under the robust scenario, a higher reliance on public DCFC yields a slightly higher cost to charge for customers. The majority of residential load, and therefore cost, comes from home charging.

This modeling also includes an analysis of charging under a residential TOU rate. The modeled TOU is based on an early draft of Palo Alto’s TOU rate, but does not represent the

Staff Report TOU rate (E-1 TOU)²⁵. The modeled TOU rate has two periods, off-peak and peak. Peak period is during early evening on weekdays, as seen in Figure 21. Peak period is about \$0.03 higher in winter and \$0.04 high in summer. About 85% of the hours across year are in off-peak periods, while 15% are within peak periods. The modeled rate is shown in Figure 21 and the E-1 rate that was proposed in the CPAU Staff Report is shown in Figure 22. The main difference in these rates is the inclusion of the midday Super Off-Peak period. This period would incentivize midday EV charging, especially for residents who can home charge during the midday Super-Off-Peak period. The proposed E-1 TOU rate also has a larger rate differential between Peak and Off-Peak periods, which would further encourage customers to manage their charging to save money.

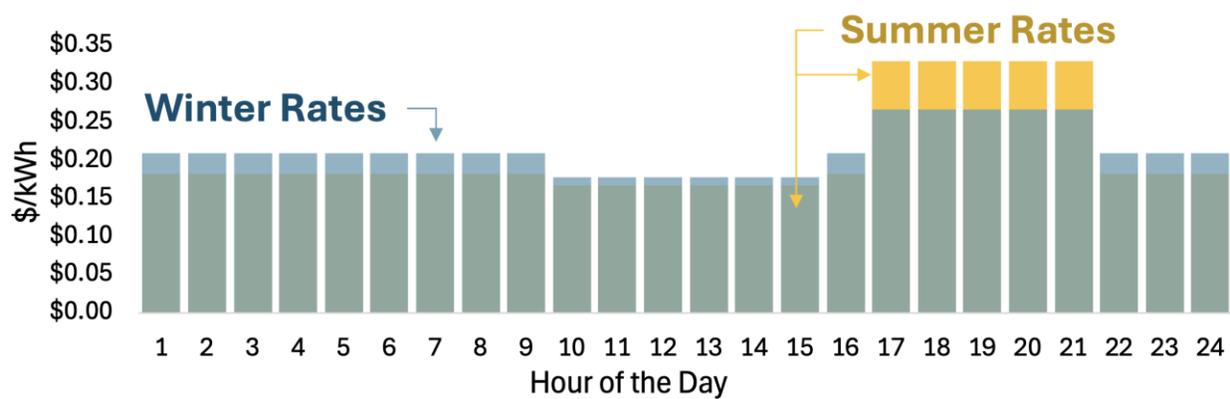


Figure 23 shows that across both the Robust and Light EV Charging scenarios, LDV home charging disproportionately occurs during the peak period (81% of load is off-peak, as opposed to 85% of hours), while by 2045, LDV home charging disproportionately occurs during the off-peak period (87% of load is off-peak, as opposed to 85% of hours). This reflects a future where more residential customers choose to manage their charging to align with economic signals. Home charging is constrained to when the resident is parked at home, and most vehicles are parked at home overnight, providing an opportunity to charge using late-evening and early-morning off-peak rates. But this requires an active effort to either physically plug the car in after the peak period or program the car to only begin charging after the peak period. The City could work to ensure that customers are leveraging these bill and grid benefits by supporting customer education and further examining the TOU period differential to ensure that they align with desired behavior. With a relatively small TOU differential on the modeled rate providing only a modest economic incentive, outreach and assistance would likely be important in making sure charging occurs outside peak periods. This is mitigated by the larger TOU differential in the Staff Report E-1 TOU.

²⁵ <https://cityofpaloalto.primegov.com/api/compilemeetingattachmenthistory/historyattachment/?historyId=a193f374-f0af-479d-bf30-ce2b7a3c6a05>

Figure 21: Residential Modeled TOU Rate Weekday Pricing (2024)

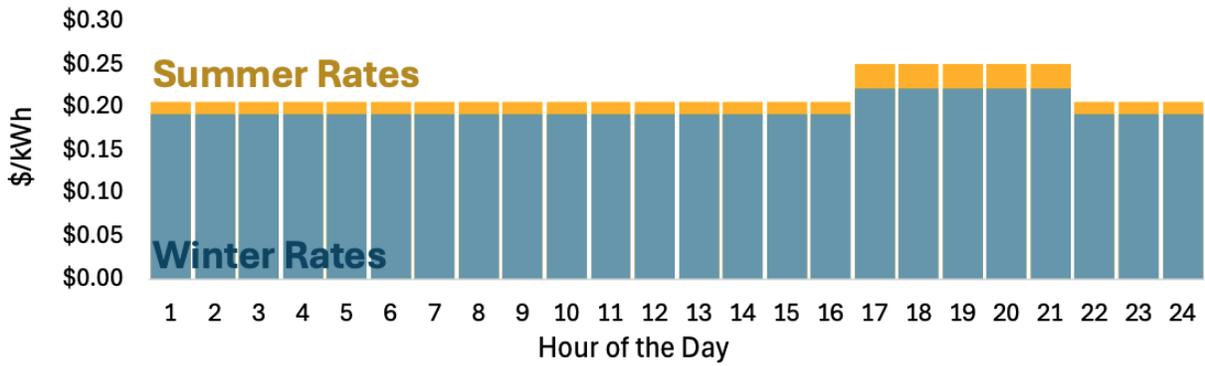


Figure 22: Staff Report Proposed Residential E-1 TOU Rate (2026)

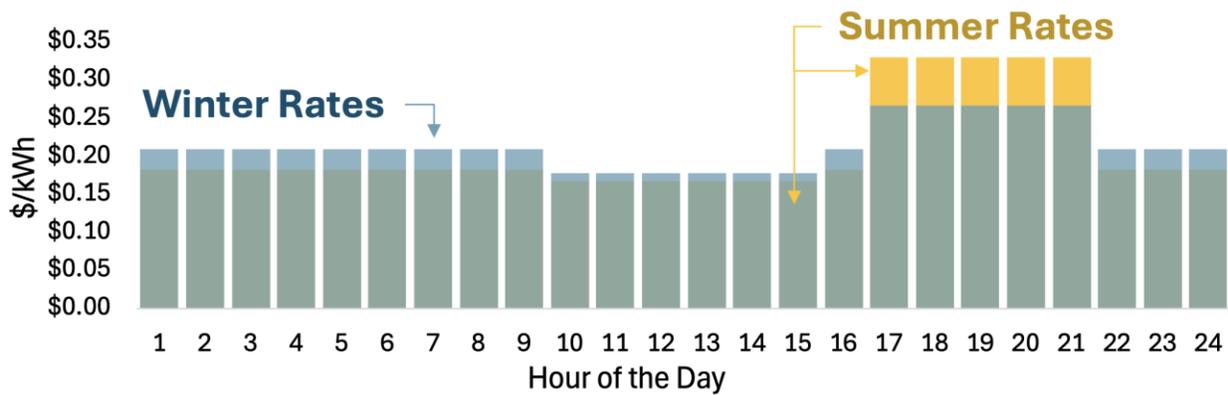
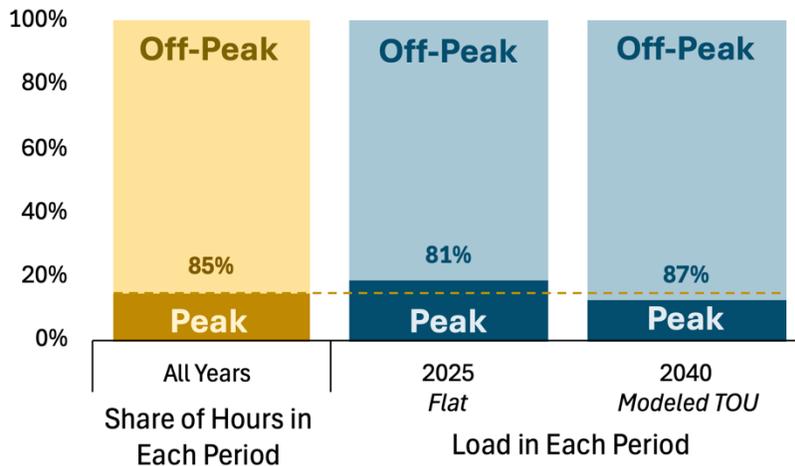


Figure 23: Annual EV Home Charging Load by Time-of-Use Period and Scenario

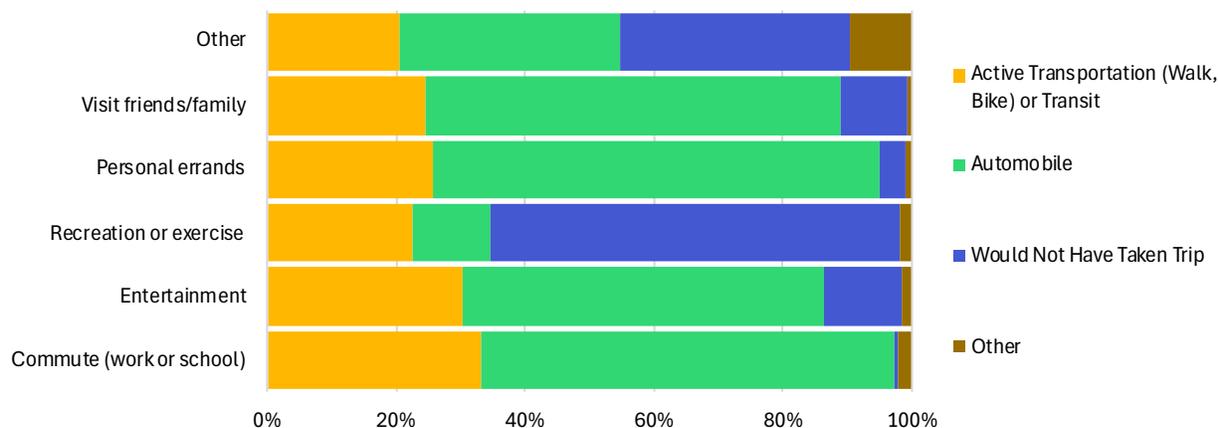


E-Bike Outcomes

As stated above, VMT reduction strategies are important in Palo Alto due to their emissions reduction potential and co-benefits, such as improved air quality, reduced congestion, and increased physical activity. One of the key strategies to reduce VMT and associated emissions is to increase bike and e-bike ridership. This analysis focused primarily on the impact of e-bike adoption on costs and VMT reduction, though increasing standard bicycle ridership will also reduce emissions and increase co-benefits.

Data from the Electric Bike Owners Report²⁶ shows that different e-bike trips have a different likelihood of offsetting emissions from automobiles. For example, using an e-bike to run personal errands has an almost 70% chance of offsetting vehicle miles, while a trip that was primarily for entertainment has a 55% chance of offsetting vehicle miles. As such, Palo Alto can maximize GHG reductions from e-bike adoption by targeting locations and corridors where trips would previously have been taken by car. Examples of this include infrastructure investment in common commute corridors, such as bike lanes, racks on transit, safe intersections, well-lit paths, charging stations, bike parking, and dedicated slow streets. E-bikes can also be used for first-mile and last-mile abatement when paired with public transportation. Targeted investment could lead to more than half of e-bike miles directly offsetting vehicle miles traveled. Note that these targeted investments should also support standard bicycle use as well.

Figure 24: Alternative Transit Mode if no E-Bike for Different Types of Trips



Data from Google Environmental Insights Explorer (EIE) and the 2022 Census American Community Survey (ACS) show that there are currently between 3,000 and 4,000 bikes in Palo Alto, with some share being e-bikes, and the others being conventional bikes.²⁷ In a scenario where bicycle adoption doubles in the future and avoided vehicle miles are

²⁶ <https://www.calbike.org/wp-content/uploads/2019/02/A-North-American-Survey-of-Electric-Bicycle-Owners.pdf>

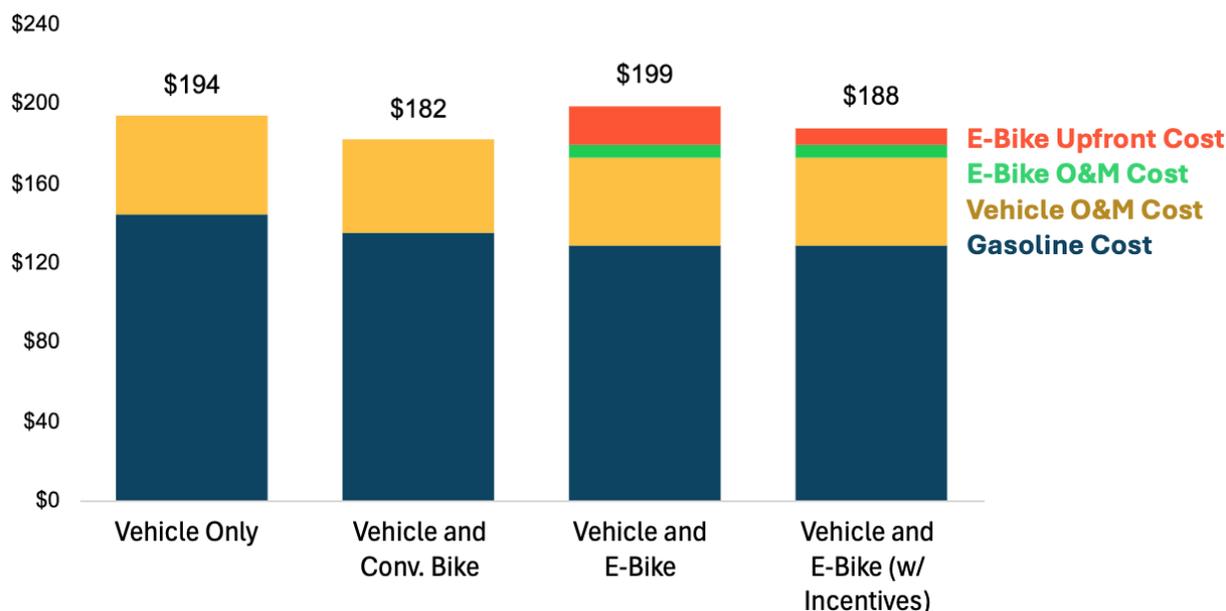
²⁷ 2022 ACS

maximized, there is the potential to reduce approximately 1,000 MT CO₂e of GHG emissions each year (about 0.1% of 1990 emissions, or about 0.4% of the remaining emissions reduction needed to achieve 80% reductions from 1990 levels).

In addition to the customer affordability net benefits of electric vehicles, as described earlier in the report, utilizing alternative mobility mediums, like bikes, can reduce vehicle and fuel costs. Reducing the number of miles traveled by a gasoline-powered car can reduce costs, both due to less wear and tear on the car and by reducing the amount of gasoline purchased. Figure 25 shows the levelized monthly cost of vehicle usage for a customer with no bike, with a non-electric bike, and with an e-bike. The introduction of the bike, which is assumed to already be owned by the customer, reduces monthly costs. However, the introduction of the costs of the e-bike brings the total cost for the customer back up to above the cost of no bike.

From a customer perspective, the cost-effectiveness of e-bikes is highly dependent on the avoided vehicle miles, and available incentive dollars. With the use of a conventional bike, overall operating costs can be reduced. This is due to the VMT reductions associated with bicycle ridership, which help to reduce the cost of gasoline, insurance, and vehicle wear and tear. In a scenario where the City provides incentives²⁸ to offset the upfront cost of an e-bike, owning and operating an ICE vehicle, paired with e-bike ridership, can potentially be more cost effective than relying only on car ownership.

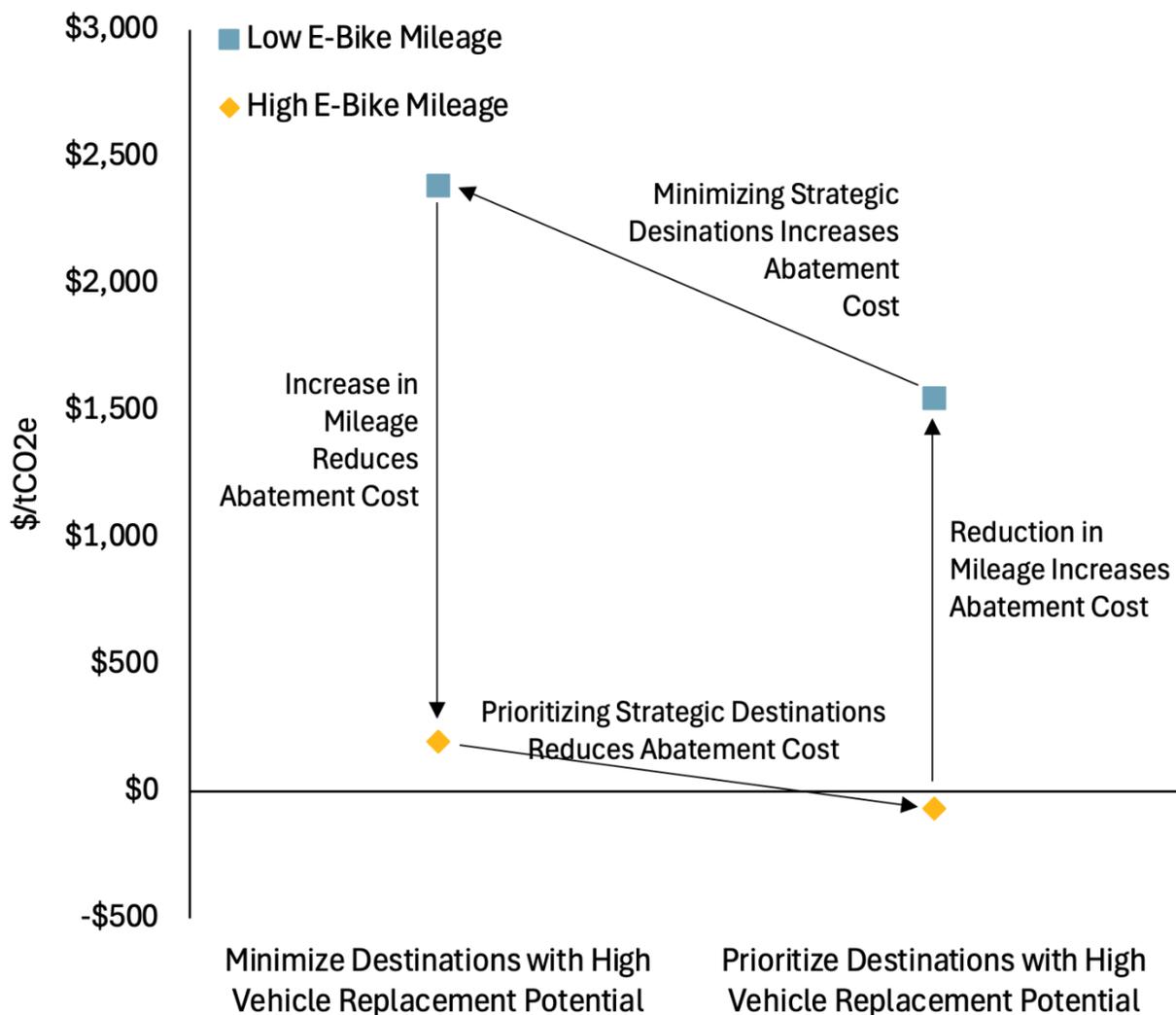
Figure 25: 10-Year Levelized Monthly Costs of Vehicle and Bike Ownership



²⁸ Incentives shown in the chart are based on results from the S/CAP Funding Model.

The cost effectiveness of emissions abatement via the use of e-bikes depends on the assumptions used in the calculation. Under the high scenario, bikers will use their e-bikes to offset high vehicle usage end uses: about 40% of biking would offset commuting and 25% would offset errands. Another assumption is that bikers would ride the e-bike for many miles, around 2,600 miles per year. If low usage is assumed instead (25% commute/15% errands, or 780 miles/year), the abatement cost would increase since the upfront cost is spread over fewer avoided vehicle miles. The results of these sensitivities can be seen in Figure 26. While the modeling does not currently explore cost sensitivities, increases in the cost of an e-bike (upfront or O&M) or in the cost of electricity would increase the marginal abatement cost.

Figure 26: E-Bike Abatement Costs with Sensitivities



Conclusion

Transportation electrification is a necessary step to reach Palo Alto’s ambitious climate goals and is a cost-effective option for both individual customers and the community, due to the significant operational cost savings from avoided gasoline and maintenance. To support widespread vehicle electrification over the coming decades, Palo Alto will need to develop comprehensive EV charging infrastructure. The number and types of chargers will depend on several factors, such as the total number of EVs adopted, public vs. home charging levels, public vs. private investment, and the level of support provided to visitor and commuter EVs. While this charging infrastructure is likely to incur significant upfront costs, it is a necessary component in unlocking the cost savings, emissions reduction, and other widespread benefits of transportation electrification.

Appendix A. Detailed Modeling Methodology

A.1 Inputs and Assumptions

A.1.1 Summary of Inputs and Outputs

A summary of all inputs and outputs of the transportation module are included in **Error! Reference source not found.** below.

Table 5: Major Modeling Inputs and Sources

Component	Description	Data Source(s)
Charger costs	Costs (\$/charger) to install an EV charger	E3 best practices and industry literature review ²⁹
Charger lifetime	Year that a charger lasts before retirement	E3 best practices and industry literature review
Electricity costs	Electricity costs to the customer to charge a vehicle	Provided by Palo Alto
Vehicle-to-charger ratios	Number of chargers needed per vehicle	EVI-Pro Lite ³⁰ , AB 2127 Infrastructure Assessment ³¹
Vehicle miles traveled (VMT)	Number of miles traveled by each vehicle per year	AECOM Impact Analysis modeling for Palo Alto S/CAP report
Charging load shapes	Times of day when EV charging occurs	E3 modeling using in-house E3 model EVGrid
Number of total vehicles	Total number of vehicles registered in Palo Alto	Department of Motor Vehicles (DMV) data
Number of electric vehicles	Number of electric vehicles registered in Palo Alto	Initial EV levels based on DMV data. Future projections are based on EV adoption scenario

²⁹ See A.1.3.5 Charger Costs for additional details

³⁰ <https://afdc.energy.gov/evi-x-toolbox#/evi-pro-ports>

³¹ <https://www.energy.ca.gov/publications/2024/assembly-bill-2127-second-electric-vehicle-charging-infrastructure-assessment>

Split of SFR/MFR EVs	Share of electric vehicles in Palo Alto that are owned by a single family resident	Provided by Palo Alto
Number of commuter and visitor vehicles	Total number of vehicles being used to commute into or visit Palo Alto	AECOM modeling for Palo Alto S/CAP report
EV and ICE Costs	Upfront cost per vehicle	ICCT and ACEEE industry reports ³²
Vehicle O&M Costs	Ongoing operations and maintenance costs per vehicle	ICCT, CARB, and AFDC reports ³³
Gasoline and diesel costs	Cost forecasts for gasoline and diesel fuels	EIA AEO 2023 Pacific Region fuel cost forecasts ³⁴
Vehicle lifetimes	Number of years before vehicles is replaced	E3 assumptions
Incentives for EVs and Chargers	Federal, state, and local incentives for EVs, EV chargers, and other EV-related projects	National Clean Investment Fund ³⁵ , Inflation Reduction Act ³⁶ , Infrastructure Investment and Jobs Act funding (NEVI ³⁷ , LowNo ³⁸ , CFI ³⁹ , CMAQ ⁴⁰), BAAQMD Programs (Climate Tech Finance ⁴¹ , Clean Cars for All ⁴² , Charge! ⁴³ , HDV Infrastructure ⁴⁴ , School

³² <https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf>, <https://www.aceee.org/sites/default/files/pdfs/t2102.pdf>

³³ <https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf>, <https://afdc.energy.gov/data/10310>, https://ww2.arb.ca.gov/sites/default/files/2021-08/210909costdoc_ADA.pdf

³⁴ <https://www.eia.gov/outlooks/aeo/data/browser/#/?id=70-AEO2023®ion=1-9&cases=ref2023~highprice~lowprice~highogs~lowogs&start=2021&end=2050&f=A&sourcekey=0>

³⁵ <https://www.grants.gov/search-results-detail/349234>

³⁶ <https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/>

³⁷ <https://www.fhwa.dot.gov/environment/nevi/>

³⁸ <https://www.transit.dot.gov/lowno>

³⁹ <https://www.fhwa.dot.gov/environment/cfi/>

⁴⁰ <https://www.fhwa.dot.gov/bipartisan-infrastructure-law/cmaq.cfm>

⁴¹ <https://ctf.baaqmd.gov/portfolio>

⁴² https://www.baaqmd.gov/~media/landing-pages/ccfa/homepage/ccfa-program-advisory-program-changes-20240105-pdf.pdf?rev=00676c608fcb4947a42fbd4767b2599&sc_lang=en

⁴³ <https://www.baaqmd.gov/funding-and-incentives/businesses-and-fleets/charge>

⁴⁴ <https://www.baaqmd.gov/funding-and-incentives/businesses-and-fleets/infrastructure>

		Buses ⁴⁵ , Fleet Funding ⁴⁶ , Carl Moyer ⁴⁷)
Population growth	Year-over-year change in number of people and vehicles in Palo Alto	AECOM modeling for Palo Alto S/CAP report
Share of Use Cases of E-Bikes	Determines what destinations or use-cases e-bikes serve. This is used to determine the share of e-bike miles that would offset vehicle miles. High represents a high share of e-bike uses being used to offset vehicle miles.	Mid values are from the North American Survey of Electric Bicycle Owners report ⁴⁸ . High and low are adjusted to increase/decrease avoided vehicle miles based on adjusting high-vehicle replacement uses (commute, errands) and low vehicle replacement uses (recreation and exercise).
Distance of E-Bike Ride	Number of miles the average e-biker rides per week.	Provided by Palo Alto
Number of customers with E-Bikes	Number of Palo Alto residents who are e-bike riders.	The City provided data on the total number of bikes and suggested 50% growth for High and 10% growth for Low. Mid is an average between the two.
E-bike efficiency	Energy consumed per mile of average e-biking.	Based on data collected as a part of the e-bike 1000 MPG project. ⁴⁹
ICE efficiency	Fuel consumed per mile of driving.	Calculated with a representative LDV (Nissan Versa) and AFDC data for MHDVs ⁵⁰

⁴⁵ <https://www.baaqmd.gov/funding-and-incentives/businesses-and-fleets/school-buses>

⁴⁶ <https://www.baaqmd.gov/funding-and-incentives/businesses-and-fleets/trucks>

⁴⁷ <https://www.baaqmd.gov/funding-and-incentives/funding-sources/carl-moyer-program>

⁴⁸ <https://www.calbike.org/wp-content/uploads/2019/02/A-North-American-Survey-of-Electric-Bicycle-Owners.pdf>

⁴⁹ <https://web.archive.org/web/20231203070602/https://sites.google.com/view/ebikestudy/results>

⁵⁰ <https://afdc.energy.gov/data/10310>

Gasoline Emissions	Emissions per gallon of fuel.	EPA standard emissions per gallon of gasoline. ⁵¹
EV Efficiency	Electricity consumed per mile of driving.	Industry data from ICCT (for LDV) and AFDC (for MHDV) ⁵²
E-Bike Costs and Characteristics	Costs to the customer of purchasing and owning the e-bike.	Industry survey, including data from RMI’s E-Bike Environment and Economics Impact Assessment Calculator. ⁵³

Table 6: Major Modeling Outputs

Component	Description	Data Source(s)
Number of EV chargers	Total number of chargers needed to support residents, visitors, and commuters in Palo Alto	Ratio of chargers to EV multiplied by the number of EVs in the active adoption scenario.
Total charger costs	Costs needed to build and maintain the necessary number of EV chargers in Palo Alto	Total number of chargers multiplied by the cost per charger to calculate the total charger costs.
Total EV load impact	Total amount of annual sales used for EV charging	Total electric load per vehicle multiplied by total number of EVs in active adoption scenario.
Total charging costs	Cost of charging, calculated using retail rates and load shapes	Palo Alto electricity rates times driver loads by charging location.
Individual customer benefit-cost impacts	Lifetime benefits and costs for an average customer in Palo Alto	Palo Alto Affordability Calculator model

⁵¹ <https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references>

⁵² <https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf>,
<https://afdc.energy.gov/data/10310>

⁵³ <https://rmi.org/insight/e-bike-environment-and-economics-impact-assessment-calculator/>

A.1.2 EV Adoption Scenarios

A.1.2.1 Light-Duty Vehicle (LDV) Adoption Scenarios

E3 developed three LDV EV adoption scenarios as inputs into the transportation model:

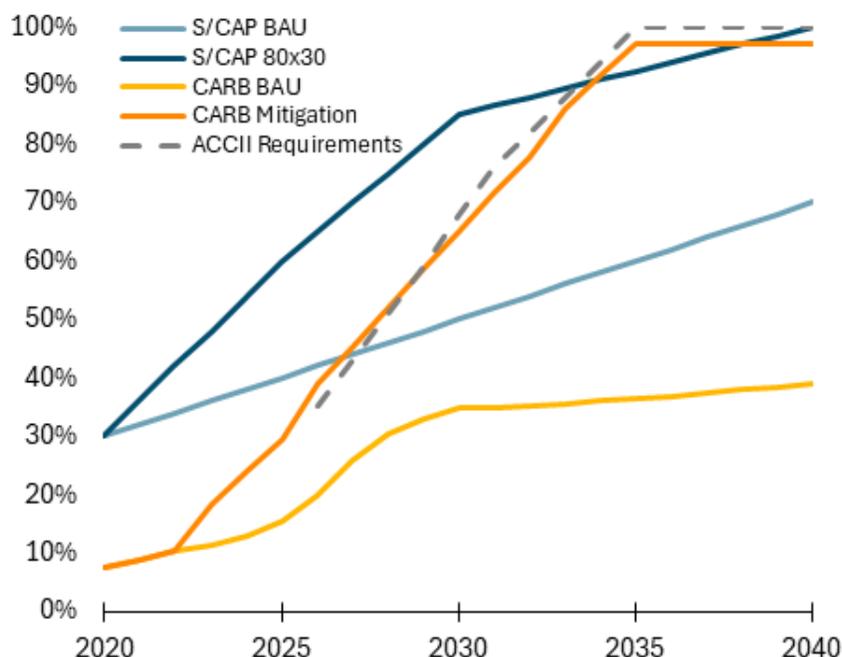
- 1) **BAU scenario:** BAU scenario is one that considers how EV adoption might look if the current conditions in Palo Alto remained the same. Therefore, it is important for a BAU scenario to incorporate all existing on-the-books policies in California and Palo Alto. The primary policy that is incorporated into the LDV BAU EV adoption scenario for Palo Alto is Advanced Clean Cars II (ACC II). ACCII was adopted in 2022 by CARB and requires 100% of new passenger vehicle sales in California to be zero-emission vehicles (ZEV) by 2035.
- 2) **Mid-scenario:** an average between the BAU and 80x30 S/CAP adoption scenarios
- 3) **A scenario that reaches 80x30 S/CAP goals:** The 80x30 scenario must reach the S/CAP emissions goals; as modeled in the S/CAP, reaching 65% emissions reduction from 1990 levels by 2030 necessitates 85% of new LDV sales to be EVs by 2030 and 44% of LDV stock to be EVs.

E3 utilized existing EV adoption scenarios from previous studies to develop adoption scenarios for the EV Charger Needs Assessment (Figure 27). The existing EV adoption scenarios that were considered for use include:

- + California Air Resources Board (CARB) Scoping Plan BAU (“CARB BAU”)
- + CARB Scoping Plan Mitigation (“CARB Mitigation”)
- + AECOM S/CAP BAU (“S/CAP BAU”)
- + AECOM S/CAP Policy 1 & 2 (“S/CAP 80x30”)

Neither of the existing LDV CARB BAU scenario nor the LDV S/CAP BAU scenario incorporate compliance with Advanced Clean Cars II (ACC II), as seen in Figure 27, while both the S/CAP 80x30 scenario and the CARB Mitigation scenario incorporate compliance with ACC II. Since E3 did not have access to the stock and sales assumptions that went into the S/CAP 80x30 stock rollover calculations, it was determined that Palo Alto’s LDV BAU scenario should be based upon the CARB Mitigation trajectory.

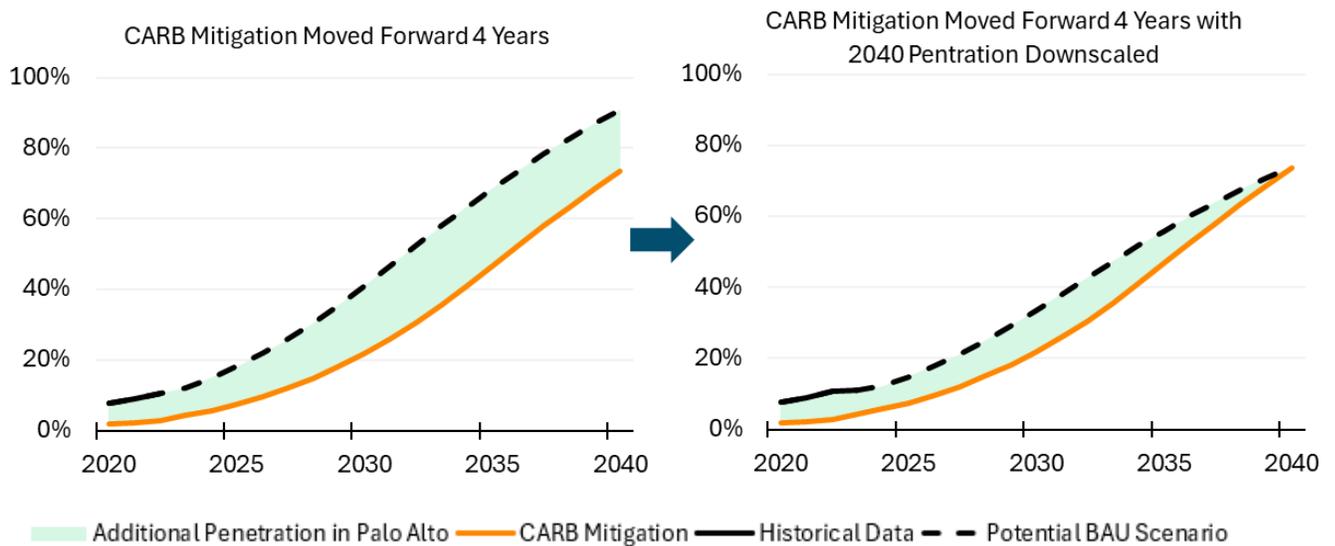
Figure 27: EV Adoption Scenarios in Existing Studies



E3 used the CARB Mitigation stock rollover “shape” for Palo Alto’s LDV BAU scenario and then benchmarked the curve to the current adoption of EV adoption in Palo Alto. Palo Alto’s EV adoption was at 11% in 2022 according to 2022 Department of Motor Vehicles (DMV) data⁵⁴, which is 7% higher than EV adoption statewide. Therefore, the CARB Mitigation shape was scaled to match Palo Alto’s current EV stock levels by moving the curve forward 4 years. By moving the CARB Mitigation scenario four years, the ending adoption of EVs in Palo Alto by 2040 would be 91%, which is likely not reflective of how adoption would slow down in later years. Therefore, E3 scaled the 2040 adoption down to match the CARB Mitigation 2040 stock levels (74%). This methodology accurately captures Palo Alto as higher on the adoption curve in early years while preserving the eventual slowdown of adoption in later years. Figure 28 visually demonstrates this methodology.

⁵⁴ <https://data.ca.gov/dataset/vehicle-fuel-type-count-by-zip-code>

Figure 28: LDV EV Adoption Scenario Scaling

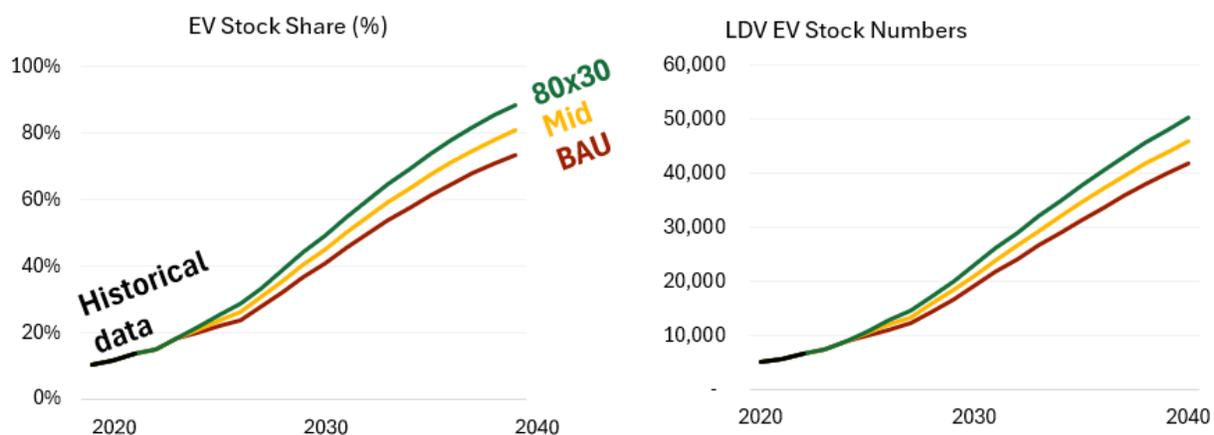


Once the LDV BAU method was determined, the LDV 80x30 scenario was built on top of the LDV BAU assumptions. The Palo Alto S/CAP report dictates that the LDV 80x30 scenario must reach a 65% emissions reduction from 1990 levels in the transportation sector. As modeled in the S/CAP, reaching 65% emissions reduction from 1990 levels by 2030 necessitates 85% of new LDV sales to be EVs by 2030 and 44% of LDV stock to be EVs. For the 80x30 scenario, E3 calculated the “shape” of the BAU trajectory in reference to the 2030 value. That is, the 2030 value is assigned a value of 1.00, and all other values in the EV adoption trajectory are calculated in relation to that 2030 value. To scale the BAU scenario up to a potential 80x30 scenario, E3 used the “shape” of the BAU trajectory (i.e., the ratio of all values compared to the 2030 values) but replaced the BAU 2030 value of 33% with the 80x30 value of 44% stock adoption.

The mid-scenario is an average between the BAU and 80x30.

Figure 29 shows the final LDV EV adoption scenarios.

Figure 29: LDV EV Adoption Scenarios



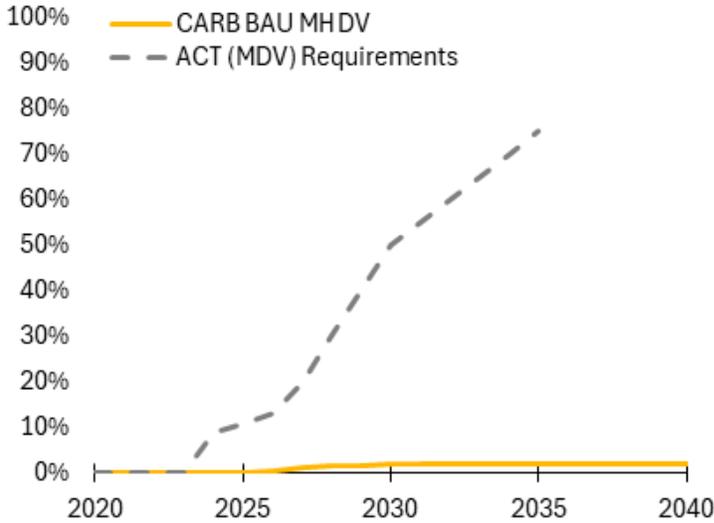
A.1.2.2 Medium-Duty Vehicle (MDV) Adoption Scenarios

Similar to LDVs, E3 developed three MDV EV adoption scenarios as inputs into the transportation model:

- 1) **Business-as-usual (BAU) scenario:** A business-as-usual (BAU) scenario is one that considers how EV adoption might look if the current conditions in Palo Alto remained the same. Therefore, it is important for a BAU scenario to incorporate all existing on-the-books policies in California and Palo Alto. Current policies that are incorporated into the MDV BAU EV adoption scenario for Palo Alto include Advanced Clean Trucks (ACT) and Advanced Clean Fleets (ACF). ACT was adopted in 2021 and requires that truck sales in California be increasingly made up by ZEVs, with the actual % determined by truck weight class. ACF was adopted in 2023 and requires medium- and heavy-duty (MHDV) fleets that are high priority, perform drayage, or belong to the State, local, or the federal government comply with certain ZEV requirements, with many required to be 100% ZEV by 2035.
- 2) **Mid-scenario:** an average between the BAU and 80x30 S/CAP adoption scenarios
- 3) **A scenario that reaches 80x30 S/CAP goals:** The 80x30 scenario must reach target stock levels by 2030 as determined by a user input in the model. The default user input is set to 20% MDV EV stock adoption by 2030.

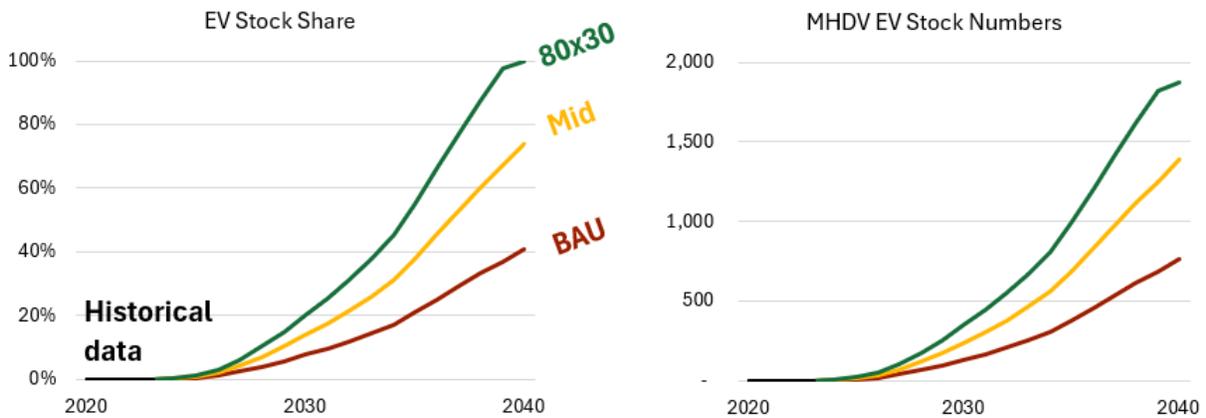
For developing MHDV scenarios, E3 again leveraged existing adoption trajectories from prior studies. The S/CAP model built by AECOM does not include a MHDV trajectory, and the CARB BAU scenario does not include compliance with ACT (Figure 30), so E3 used the CARB Mitigation trajectory for Palo Alto’s MHDV BAU scenario.

Figure 30: Estimated MHDV EV Sales Shares for CARB BAU vs. MDV Advanced Clean Trucks (ACT) Requirements



Unlike LDVs, Palo Alto does not have higher existing MHDV EV adoption compared to California as a whole, so no scaling was required for using the CARB Mitigation scenario as the Palo Alto BAU. Figure 35 below shows the MHDV scenarios for Palo Alto. The 80x30 scenario uses the same shape as the BAU trajectory but is scaled up to meet 2030 stock adoption goals.

Figure 31: MHDV EV Adoption Scenarios



For modeling purposes, it is assumed that all modeled medium- and heavy-duty vehicles in Palo Alto are medium-duty only,. 89% are privately owned and 11% belong to City-owned fleets.

A.1.3 Other Key Inputs and Assumptions

A.1.3.3 Charger Types and Locations

E3 modeled several different combinations of charging locations and charger types:

+ Home Charging:

- Level 1 (Home L1): Level 1 (L1) charging uses a standard 120-volt wall outlet. Home L1 charging can occur at single family or multifamily residences but is only modeled as an option for residents.
- Level 2 (Home L2): Level 2 (L2) charging uses a 240-volt outlet, which may require electrical upgrades at some homes but can charge vehicles significantly faster. Home L2 charging can occur at single family or multifamily residences but is only modeled as an option for residents.

+ Public Charging:

- Level 2 (Public L2): Level 2 (L2) charging uses a 240-volt outlet. Public L2 charging is modeled as an option for residents and commuters. The model user can also choose to allocate some public L2 charging to pole-mounted public L2 charging, rather than traditional ground mounted L2 charging. Pole-mounted Public L2 chargers have no TTM costs and 25% less BTM costs.
- Direct Current Fast Charging (Public DCFC): DCFC charging uses a 480-volt outlet. Public DCFC charging is modeled as an option for residents and commuters.

+ Workplace Charging:

- Level 2 (Work L2): Level 2 (L2) charging uses a 240-volt outlet. Work L2 charging may be modeled as an option for residents and commuters, depending on the selected user inputs.
- Direct Current Fast Charging (Work DCFC): DCFC charging uses a 480-volt outlet. Work DCFC charging is modeled as an option for medium-duty fleet vehicles only.

A.1.3.4 Charger-to-Vehicle Ratios

For home charging, E3 utilized NREL's EVI-Pro Lite to generate charger-to-vehicle ratios for EVs. EVI-Pro Lite is public model that calculates the number of chargers needed to serve light-duty personal vehicles a region, in this case, the San Jose-Sunnyvale-Santa Clara Metro Area, given a specific number of EVs. E3 used Palo Alto-specific inputs to EVI-Pro Lite, including the breakdown of battery electric versus plug-in hybrid electric vehicles and the share of vehicles type (sedans, SUVs, pickups, vans). Studies show that EV chargers do not scale linearly with EV adoption, therefore the ratio of charger to EVs will change as adoption

increases in Palo Alto. As such, E3 modeled four representative cases comprising of a combination of two levels of EV adoption and two levels of access to home charging. Under the low adoption case, which represents 2024 levels of adoption, the model was run with the minimum number of vehicles allowed in the region since this is still greater than the current number of EVs in Palo Alto. For the high adoption cases, this value is then scaled to reflect the 2024 to 2040 increase from 19% to 81% forecasted EV stock share in Palo Alto. For both stock levels, there is a case with low levels of home charging access (40%, minimum required for model to serve all load) and high levels of home charging access (86%, current level of home charging access). These four options represent the minimum number of cases needed to model flexible access to home charging and results in each year. For public charging and medium-duty vehicles, different methodology and sources were used, discussed below.

EVI-Pro Lite is an online tool created by the National Renewable Energy Laboratory (NREL) in collaboration with the Alternative Fuels Data Center (AFDC) within the US Department of Energy. The tool takes user inputs (Table 7) to determine the number of chargers needed within a metropolitan area to support light-duty vehicle daily travel needs. E3 ran four representative light-duty cases in EVI-Pro Lite to understand high and low levels of EV stock adoption and high and low levels of home charging (Table 8).

Table 7: EVI-Pro Lite Inputs

Input	Value	Source
BEV Share of EVs	64%	Palo Alto-Provided 2022 Vehicle Registration Data
PHEV Share of EVs	36%	
Sedan Share of Total Vehicles	47%	
C/SUV Share of Total Vehicles	43%	
Pickup Share of Total Vehicles	4%	
Van Share of Total Vehicles	6%	

Table 8: EVI-Pro Lite Representative Cases Run

Year	Home Access	Charging	% Elec. LDV Palo Alto	Proxy Regional EV Stock
2025	40%		19%	15,800
2040	40%		81%	77,387
2025	86%		19%	15,800

2040	86%	81%	77,387
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These cases represent different combinations of two key variables, high vs. low home access to home charging and high vs. low adoption levels. Currently, access to home charging among EV drivers is very high. About 86% of EV drivers can currently charge at home, but as more public and work charging infrastructure is built, drivers without home charger are expecting to increase adoption. The low case, 40%, represents the share of drivers that would need to have access to home charging for EVI-Pro Lite to create scenarios that are able to serve all necessary driving load. The high and low EV adoption levels are represented with different modeled years. The model assumed that the 2025 model year will be a low adoption case and that by 2040 there will be higher adoption. These adoption numbers come from the scenario design detailed above. Charger-to-EV ratios are not linear, so the number of chargers needed per EV will be different in high adoption scenarios when compared to low adoption scenarios. The raw results from EVI-Pro Lite were then aggregated to align with the charger types used in other E3 modeling processes. These resulting number of chargers were divided by the EV stock within that case to create an EV-to-Charger ratio for home L1 and L2 chargers and each representative case. These representative ratios are blended in the S/CAP funding model to reflect the user inputs.

For public L2 and DCFC, E3 derived charger-to-vehicle ratios from CEC’s “Implementation of AB 2127 Electric Vehicle Charging Infrastructure Assessments.”⁵⁵ CEC reports 2030 charger counts for high and low home charging access scenarios, and charger counts for all model years for the baseline scenario (66% home charging access in 2030 and 60% in 2035). The high and low home charging access scenarios modify the access by +/-10%, respectively. CEC does not report charger counts for the high and low home charging access scenarios for more than 1 year. Since we are modeling one near term and one future year for high and low home charging access, E3 adjusts the report’s charger-to-vehicle ratios. To do this, we apply the increase or decrease in public chargers from the +/-10% home charging access increase to the baseline scenario charger counts for a near term year (2030) and a future year (2035). In the model, work charging is aggregated into public charging to allow additional user input flexibility in later modeling stages.

For medium-duty vehicles, E3 created EV-to-charger ratios based on the number of charges needed to sustain statewide medium- and heavy-duty EV adoption in forecasted years. This data is from table H-1 in the California Energy Commission’s Assembly Bill 2127 Second Electric Vehicle Charging Infrastructure Second Assessment Revised Staff Report⁵⁶.

Charger-to-EV Ratios in Each Representative Case

⁵⁵ <https://efiling.energy.ca.gov/GetDocument.aspx?tn=254869>

⁵⁶ <https://www.energy.ca.gov/publications/2024/assembly-bill-2127-second-electric-vehicle-charging-infrastructure-assessment>

		2025 - 40% home charging access	2040 - 40% home charging access	2025 - 86% home charging access	2040 - 86% home charging access
Light-Duty	Home L1	0.128	0.125	0.274	0.268
Light-Duty	Home L2	0.266	0.260	0.573	0.558
Light-Duty	Public L2	0.122	0.179	0.082	0.087
Light-Duty	Public DCFC	0.006	0.007	0.004	0.004
Light-Duty	Work L2	0.000	0.000	0.000	0.000
		2025		2040	
Medium-Duty	Work L2	0.895		0.702	

Resulting Post-Processed EV-to-Charger Ratios

		2025 - 40% home charging access	2040 - 40% home charging access	2025 - 86% home charging access	2040 - 86% home charging access
Light-Duty	Home L1	7.8	8.0	3.6	3.7
Light-Duty	Home L2	3.8	3.8	1.7	1.8
Light-Duty	Public L2	8.2	5.6	12.2	11.6
Light-Duty	Public DCFC	178.4	138.6	278.9	258.1
Light-Duty	Work L2	0	0	0	0
		2025		2040	
Medium-Duty	Work DCFC	1.1		1.4	

A.1.3.5 Charger Costs

EV charger costs are divided into four cost components, with all inclusive of labor and materials:

- 1) To-the-meter (TTM) infrastructure:** TTM costs include costs borne to the utility for maintaining or upgrading electrical infrastructure, including the distribution system and transformers. Home L1 charging for single family installations incur no TTM costs.
- 2) Behind-the-meter (BTM) infrastructure:** BTM costs include infrastructure costs that occur on the customer’s side of the meter. This may include a panel upgrade, wiring upgrades, trenching, repaving, and other landscaping costs.
- 3) EV supply equipment (EVSE):** EVSE costs are the costs of the actual charger. E3 assumed that L1 chargers are included in the price to purchase an electric vehicle, and therefore incur no additional cost.
- 4) Operations & maintenance (O&M):** O&M costs refer to ongoing annual costs to keep chargers online and operational. All Home L2 chargers and single family Home L2 chargers are assumed to have no O&M costs.

Costs across all categories are assumed to grow 3% per year, based on the ICCT 2023 Home Charging Report.⁵⁷ This can be edited by cost component in the user inputs section of the model. All chargers are assumed to have a lifetime of 10 years, after which the user can determine if the chargers should retire or be assumed to last forever.

Charger cost inputs are shown in Table 9 below.

Table 9: EV Charger Cost Sources by Charger Type

Charger Type	Resident Type	Cost Component	2024	Source
Home L1	Single family	Behind-the-Meter Infrastructure	\$0	E3 Estimate
Home L1	Multifamily	Behind-the-Meter Infrastructure	\$1,587	Peninsula Clean Energy, EV Technical Resources
Home L2	Single family	Behind-the-Meter Infrastructure	\$800	E3 Estimate
Home L2	Multifamily	Behind-the-Meter Infrastructure	\$3,500	ICCT, 2019, national analysis
Work L2	Work	Behind-the-Meter Infrastructure	\$3,500	ICCT, 2019, national analysis
Public L2	Public	Behind-the-Meter Infrastructure	\$3,500	ICCT, 2019, national analysis
Work DCFC	Work	Behind-the-Meter Infrastructure	\$56,928	IOU SRP, 2023, PG&E/SCE programmatic costs
Public DCFC	Public	Behind-the-Meter Infrastructure	\$56,928	IOU SRP, 2023, PG&E/SCE programmatic costs
Home L1	Single family	EV Supply Equipment	\$0	E3 Estimate
Home L1	Multifamily	EV Supply Equipment	\$0	E3 Estimate
Home L2	Single family	EV Supply Equipment	\$635	ICCT, 2023, national analysis
Home L2	Multifamily	EV Supply Equipment	\$2,100	PG&E EVCN, 2021, PG&E programmatic costs
Work L2	Work	EV Supply Equipment	\$2,748	CALeVIP, statewide data
Public L2	Public	EV Supply Equipment	\$3,715	ICCT, 2023, national analysis
Work DCFC	Work	EV Supply Equipment	\$47,400	CALeVIP, statewide data

⁵⁷ <https://theicct.org/wp-content/uploads/2023/03/home-charging-infrastructure-costs-mar23.pdf>

Public DCFC	Public	EV Supply Equipment	\$47,400	CALeVIP, statewide data
Home L1	Single family	To-the-Meter Infrastructure	\$0	E3 Estimate
Home L1	Multifamily	To-the-Meter Infrastructure	\$700	Peninsula Clean Energy, regional transformer costs
Home L2	Single family	To-the-Meter Infrastructure	\$1,000	E3 Estimate
Home L2	Multifamily	To-the-Meter Infrastructure	\$5,181	IOU SRP, 2023, SDG&E programmatic data
Work L2	Work	To-the-Meter Infrastructure	\$5,181	CALeVIP, Accessed via archive, statewide data
Public L2	Public	To-the-Meter Infrastructure	\$5,181	IOU SRP, 2023, SDG&E programmatic data
Work DCFC	Work	To-the-Meter Infrastructure	\$24,398	CALeVIP, Accessed via archive, statewide data
Public DCFC	Public	To-the-Meter Infrastructure	\$24,398	CALeVIP, Accessed via archive, statewide data
Home L1	Single family	O&M	\$0	E3 Estimate
Home L1	Multifamily	O&M	\$0	E3 Estimate
Home L2	Single family	O&M	\$0	E3 Estimate
Home L2	Multifamily	O&M	\$100	E3 Estimate
Work L2	Work	O&M	\$100	NY DPS
Public L2	Public	O&M	\$300	NY DPS
Work DCFC	Work	O&M	\$2,500	NY DPS
Public DCFC	Public	O&M	\$2,500	NY DPS

A.1.3.6 EV Charging Loads

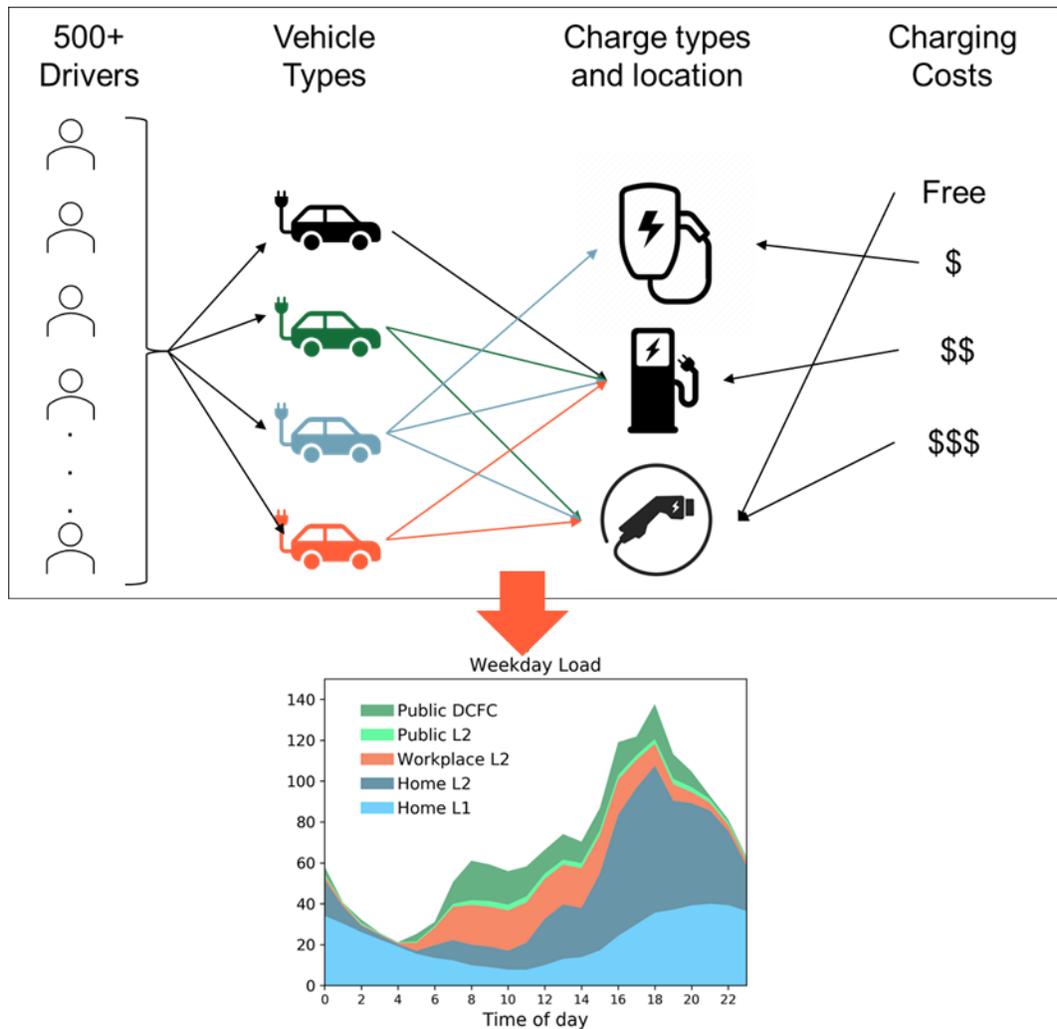
E3's EVGrid tool uses various data inputs to model EV charging load profiles. Driving profiles are sampled probabilistically from NHTS vehicle trip data. The driving profiles along with vehicle and charger characteristics from market research, charging tariffs from the relevant utility, and EV charger network size from NREL EVI-Pro Lite are used to simulate EV charging. The tariffs can be flat or TOU rates, and the drivers can do unmanaged or managed charging. The output is an 8760-population average EV charging load, normalized per vehicle. These

8760 load shapes were then aggregated into TOU periods in an external pre-processing step. These TOU periods represent the periods in Palo Alto's rate with the highest number of TOU periods. For rates with less than 3 TOU periods, including flat rates, the multiple periods may have the same cost of electricity to model electric rates correctly. Workplace charging is treated as a post-processing step for LDVs to increase flexibility in later user inputs. Additional inputs to the external modeling can be found within the model.

E3's EVGrid Model employs a bottom-up modeling approach that simulates the driving and charging behavior of thousands of EV drivers. Driving behavior is captured using travel survey data for drivers in California from Replica. A statistical process using a Markov-Chain Monte Carlo algorithm is used to simulate driving profiles from vehicle trip data. This process simulates the probability that a driver is parked at possible destinations (home, work, public location) or is driving between two of the locations based on the vehicle trip data. The Markov-Chain Monte Carlo algorithm selects 500 sample drivers to balance computational time and sample diversity.

Multiple driver types are modeled based on varying access to home and public chargers. Normalized load shapes for each driver type are generated through linear optimization subject to various constraints. Load shapes are then scaled by the portion of drivers with each charging access type. The final load shape therefore captures the diversity of driving behavior and charging access across the driving population. The resulting charging profile reflects a per vehicle average across the entire personal LDV population and is used with the EV adoption forecast in each year to create a population-level charging profile. See Figure 32 for a visual representation.

Figure 32: Overview of EVGrid



Due to the computational intensity of simulating driving and charging behavior, a representative winter and summer week was simulated. The resulting weekly load shapes are adjusted for each week of the year based on temperature data for California and empirical vehicle efficiency data.

Separate charging profiles were developed for unmanaged and managed charging, such that the results could be blended into the user-input ratio in the S/CAP model. In unmanaged charging scenarios, drivers charge at different locations (residential, public L2, and public DCFC) based on their driving patterns and charging access. Under an unmanaged charging scenario, drivers are not exposed to time-varying charging rates and charge immediately upon arrival at a charging location. While the unmanaged charging scenario does not expose drivers to time-varying price signals, the unmanaged charging scenario does consider that customers may have the choice between multiple charging options. If given driving requirements, drivers can select charging locations based on the cost of charging at each location and are assumed to charge using the least expensive option. For example, public

charging is typically more expensive than residential, and this price comparison is incorporated into unmanaged drivers’ decisions on where to charge if given the choice based on their driving patterns.

In managed charging scenarios, in addition to charging based on driving patterns, charging access, and relative prices across charging locations, drivers are exposed to time-varying charging rates and manage their charging at each location to minimize their cost of charging. This means that drivers may not charge as soon as they arrive at a charging location but may instead wait until lower-priced hours to charge. Under managed charging, drivers still charge the amount needed to satisfy driving patterns. Separate managed charging profiles are generated using the City of Palo Alto Utility’s electric rates, which are described in greater detail in the next section.

A.1.3.7 Charging costs

Driver choice in EVGrid is based on the cost to charge at different locations and at different times. For all unmanaged charging cases, EVGrid uses flat (non-time differentiated) rates. For managed charging cases, EVGrid uses time-of-use rates. Home charging uses E-1, the default residential rate. E-1 is a tiered rate, so load from EV charging is assumed to always fall into tier 2 since it’s incremental to existing home load. Public charging rates are based on existing public charging costs provided by the City. These were time-differentiated to match the hours distribution and shape of existing time-of-use rates. Fleet charging is assumed to be using the E-7 commercial rate. Additional details about the differences between the modeled residential TOU rate and the Staff Report E-1 TOU rate can be seen in Figure 21 and Figure 22.

Rate Name	Rate Class	Energy (\$/kWh) - Peak		Energy (\$/kWh) - Mid Peak		Energy (\$/kWh) - Off Peak	
		Summer	Winter	Summer	Winter	Summer	Winter
E-1 Tier 2	Res.	\$0.247	\$0.247	#N/A	#N/A	#N/A	#N/A
Modeled TOU	Res.	\$0.250	\$0.222	#N/A	#N/A	\$0.206	\$0.192
CPAU_L2	Public	\$0.350	\$0.350	#N/A	#N/A	#N/A	#N/A
CPAU_DCFC	Public	\$0.400	\$0.400	#N/A	#N/A	#N/A	#N/A
CPAU_L2_TOU	Public	\$ 0.545	\$ 0.407	\$ 0.463	\$ 0.338	\$ 0.369	\$ 0.259
CPAU_DCFC_TOU	Public	\$ 0.622	\$ 0.465	\$ 0.530	\$ 0.387	\$ 0.422	\$ 0.296
E-7	Commercial	\$ 0.136	\$ 0.088	#N/A	#N/A	#N/A	#N/A
E-7 TOU	Commercial	\$ 0.250	\$ 0.222	#N/A	#N/A	\$ 0.206	\$ 0.192

Charging Management	Home	Home	Public	Public	Work
Managed	E-1 TOU	E-1 TOU	CPAU_L2_TOU	CPAU_DCFC_TOU	E-7 TOU

Unmanaged	E-1 Tier 2	E-1 Tier 2	CPAU_L2	CPAU_DCFC	E-7
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A.1.3.8 E-Bike Assumptions

Avoided Vehicle Miles Traveled

Research from the North American Survey of Electric Bicycle Owners⁵⁸ provides data on the share of trips, by destination or reason for the trip, that would use alternate modes of transportation if an e-bike had not been present. This data gives E3 the ability to calculate the primary trips that e-bikes are used for, as well as the number of vehicle miles that e-bikes offset.

Table 10: End Use Share of Alternate Mode of Transit

	Active Transportation (Walk, Bike) or Transit	Automobile	Would Not Have Taken Trip	Other
Commute (work or school)	33%	64%	1%	2%
Entertainment	30%	56%	12%	1%
Recreation or exercise	23%	12%	63%	2%
Personal errands	26%	69%	4%	1%
Visit friends/family	24%	65%	10%	1%
Other	20%	34%	36%	10%

Energy Consumption and Emissions Reductions

Using the total passenger miles ridden and the e-bike efficiency, the model calculates the total e-bike electricity usage. Similarly, using the avoided vehicle miles traveled, the annual EV/ICE LDV split, and EV/ICE efficiencies, the model calculates the electricity and gasoline savings from VMT reduction. From this, the model calculates emissions savings from avoided VMT.

Costs

E-bike costs are derived from cross-industry insights, including the Rocky Mountain Institute’s (RMI) E-Bike Calculator.⁵⁹ E-bikes have three cost components, as seen in . The upfront cost is paid once, when the bike is purchased, and accounts for the cost of the bike. The annual fixed O&M is incurred each year and accounts for an annual bike checkup. This increases with inflation. The final e-bike cost is the cost of battery replacement. This occurs every four years but is levelized so that there is an equal payment in each year. Battery costs decline over time using data from the RMI calculator. Additional information about avoided LDV costs can be found in Figure 6.

⁵⁸ <https://www.calbike.org/wp-content/uploads/2019/02/A-North-American-Survey-of-Electric-Bicycle-Owners.pdf>

⁵⁹ <https://rmi.org/insight/e-bike-environment-and-economics-impact-assessment-calculator/>

Table 11: E-Bike Cost Assumptions

Cost Component	Value (2024)	Source
Upfront E-Bike Cost	\$2,000	Industry literature review, including the RMI E-Bike Calculator ⁶⁰
Annual Fixed O&M	\$75	
E-Bike Battery Replacement	\$714	

A.1.4 User Inputs

Most user inputs in the load and total cost component of the EV model are dependent on the selected scenario. Scenario assumptions that are linked to scenario choice are shown below in Table 12. Specific scenario inputs for High Local Action, Medium Local Action, and Low Local Action were provided by Palo Alto.

Table 12: EV Modeling Inputs by Scenario

EV Model Input	Robust EV Charging	Light EV Charging
Overall EV Adoption	80x30 Scenario	BAU Scenario
Multifamily Resident EV Adoption	High	Low
Commuter Public Charging in Palo Alto	High	Low
Level of Resident Access to Home Charging	Low	High
Level of Resident Workplace Charging	High	Low
Level of Commuter/Visitor Workplace Charging	High	Low
Level of Resident Charge Management	Medium	Medium
Level of Commuter Charge Management	Medium	Medium
Level of Medium and Heavy-Duty Fleet Charge Management	Medium	Medium
Share of Public L2 Chargers that are Pole-Mounted	10%	0%

Each scenario also had different financing options to represent the level of local action. All scenarios have private investment with public incentives for all chargers allocated to multifamily residents and commuters and public investment only for medium and heavy-duty vehicles. High Local Action and Medium Local Action have private investment with

⁶⁰ <https://rmi.org/insight/e-bike-environment-and-economics-impact-assessment-calculator/>

public incentives for single family residents while Low Local Action has private investment only.

A.1.4.9 Charger Retirement

If the user selects to include EV charger retirements, the transportation model will assume that chargers are retired 10 years after they are built. For existing chargers, 1/10th of the chargers are retired in each year until no chargers remain after 10 years. When a charger is retired at the end of its life, if a new charger of the same type is needed in the same year, the model assumes that the new charger can be built to directly replace the retiring charger. These rebuilt chargers require EVSE and O&M costs, but have no BTM or TTM costs since the infrastructure remains from the retired charger, and therefore are cheaper than building chargers in new locations.

A.1.4.10 Additional User Inputs

The model also includes additional inputs that are based solely on user preference. These inputs are not based on E3 findings or assumptions. These include:

- + **Charge Management:** Users can select the level of charge management for residents, commuters, and medium duty fleets separately.
- + **Multifamily Resident EV Adoption:** Users can select a level of EV adoption among multifamily residents, as opposed to single family residents. This does not impact the total level of adoption.
- + **Resident Access to Home Charging:** Users can select a share of residential customers who have access to home charging. This may be linked to the share of EV customers who live in multifamily units.
- + **Resident and Commuter Workplace Charging:** Users can choose to reallocate some level of public charging to workplace charging for light-duty vehicles. All medium duty vehicles charge exclusively at work.
- + **Pole-Mounted Public L2 Chargers:** Users can select the share of public L2 chargers that should be built as utility pole-mounted in each year.

A.1.5 Representative Cases Run

Based on high level scenario design assumptions, E3 created six representative cases that span vehicle size (light-duty and medium-duty), level of EV adoption, and level of access to home charging. See Appendix Table 1 for a detailed list of all six cases. These representative cases were run through EVI-Pro Lite to generate EV-to-charger ratios and EVGrid to generate representative load shapes for each case. The results were then fed into the S/CAP Funding Model. The S/CAP Funding Model then uses user selections and inputs to calculate specific scenarios using representative cases.

Appendix Table 1: Details for six representative cases

Case	Vehicle Type	EV Saturation	Home Access	Charging
Representative Case #1	Light-Duty	Low	Low	
Representative Case #2	Light-Duty	Low	High	
Representative Case #3	Light-Duty	High	Low	
Representative Case #4	Light-Duty	High	High	
Representative Case #5	Medium-Duty	Low	n/a	
Representative Case #6	Medium-Duty	High	n/a	

A.2 Business Model Methodology

A.2.1 Business-as-Usual (BAU)

E3 designed one business model that is meant to serve as a representation of business-as-usual, i.e., it shows how EV charger costs would be distributed under normal conditions. Under the BAU business model, it is assumed that Palo Alto would pay for all TTM infrastructure, recovering costs only for public and work chargers. It is assumed that third party private companies, such as ChargePoint, would cover the BTM infrastructure, EV supply equipment, and non-energy O&M costs for all workplace and public charging, recovering costs for all components. For residential home charging, customers would pay for their own behind the meter, EV supply equipment, and non-energy O&M costs. Additionally, customers would pay 100% of electricity costs.

The components covered by Palo Alto include:

- + TTM infrastructure (cost recovery for public and workplace chargers only)

The components covered by the building owner or driver include:

- + Residential BTM infrastructure
- + Residential EV supply equipment
- + Residential non-energy O&M
- + Electricity costs

The components covered by a private third-party company include:

- + Public and workplace charging BTM infrastructure (costs are fully recovered through driver usage)
- + Public and workplace charging EV supply equipment (costs are fully recovered through driver usage)

- + Public and workplace charging non-energy O&M (costs are fully recovered through driver usage)

A.2.2 Public Investment Only

The Public Investment Only business model assumes that Palo Alto would bear all upfront and non-energy O&M costs for the EV charging infrastructure. Under this business model, Palo Alto would be covering the entirety of the costs, and not recovering the costs over time through a mechanism like charging-as-a-service.

The components covered by Palo Alto include:

- + TTM infrastructure
- + B TM infrastructure
- + EV supply equipment
- + O&M (non-electricity)

The components covered by the building owner or driver include:

- + Electricity costs

In this business model, it is not assumed that a private third-party company would cover any of the cost components.

A.2.3 Private Investment with Public Incentives (Current Model)

The Private Investment with Public Incentives business model is set up exactly like the BAU business model, except that a portion of the funding raised by Palo Alto will be allocated toward incentives for EV chargers. That portion is dictated by a user input.

A.2.4 Charging-as-a-Service (offered by the City)

Under the Charging-as-a-Service (offered by the City) business model, it is assumed that Palo Alto will bear all infrastructure costs for public and workplace charging, but will recover the costs over time through a \$/kWh price at the chargers. Customers would continue to cover the costs of residential home charging and electricity. The cost recovery is calculated by adding up the total costs for chargers at a certain charging location (\$) and dividing by the utilization at that charging location (kWh), then multiplying by an interest rate (a user input).

The components covered by Palo Alto include:

- + TTM infrastructure (cost recovery for public and workplace chargers only)
- + If MFR CaaS is employed, residential BTM infrastructure, EV supply equipment, and non-energy O&M (costs would be fully recovered through driver usage)

- + Public and workplace charging BTM infrastructure (costs are fully recovered through driver usage)
- + Public and workplace charging EV supply equipment (costs are fully recovered through driver usage)
- + Public and workplace charging non-energy O&M (costs are fully recovered through driver usage)

The components covered by the building owner or driver include:

- + Residential BTM infrastructure
- + Residential EV supply equipment
- + Residential non-energy O&M
- + Electricity costs

In this business model, it is not assumed that a private third-party company would cover any of the cost components.

A.2.5 Charging-as-a-Service (offered by a Third Party)

Under the Charging-as-a-Service (offered by the a Third Party) business model, it is assumed that private third party EV charger companies will bear all infrastructure costs for public and workplace charging (except TTM infrastructure), but will recover the costs over time through a \$/kWh price at the chargers. Residential drivers would continue to cover the costs of residential home charging and electricity. The cost recovery is calculated by adding up the total costs for chargers at a certain charging location (\$) and dividing by the utilization at that charging location (kWh), then multiplying by an interest rate (a user input).

Charging-as-a-service (offered by a third party) is already an active business model in California. For example, Shell Recharge is a program that lowers upfront capital costs but that requires a type of lease agreement whereby drivers pay Shell Recharge for the use of the chargers over time.⁶¹ ChargePoint as a Service (CPaaS) is also active in California, which similarly means ChargePoint owns the chargers, thus lowering upfront costs, and drivers pay over time for the cost and use of the chargers, including operating expenses like electricity, charge management services, and maintenance.⁶²

The components covered by Palo Alto include:

- + TTM infrastructure (cost recovery for public and workplace chargers only)

The components covered by the building owner or driver include:

- + Residential BTM infrastructure

⁶¹ <https://a.storyblok.com/f/85281/x/74527c9ef3/charging-as-a-service-solution-guide.pdf>

⁶² <https://www.chargepoint.com/en-ca/products/cpaas>

- + Residential EV supply equipment
- + Residential non-energy O&M
- + Electricity costs

The components covered by a private third-party company include:

- + If MFR CaaS is employed, residential BTM infrastructure, EV supply equipment, and non-energy O&M (costs would be fully recovered through driver usage)
- + Public and workplace charging BTM infrastructure (costs are fully recovered through driver usage)
- + Public and workplace charging EV supply equipment (costs are fully recovered through driver usage)
- + Public and workplace charging non-energy O&M (costs are fully recovered through driver usage)

A.2.6 Private Investment Only

Under the Private Investment Only business model, cost allocations are set up like the BAU business model.

The components covered by Palo Alto include:

- + TTM infrastructure (cost recovery for public and workplace chargers only)

The components covered by the building owner or driver include:

- + Residential BTM infrastructure
- + Residential EV supply equipment
- + Residential non-energy O&M
- + Electricity costs

The components covered by a private third-party company include:

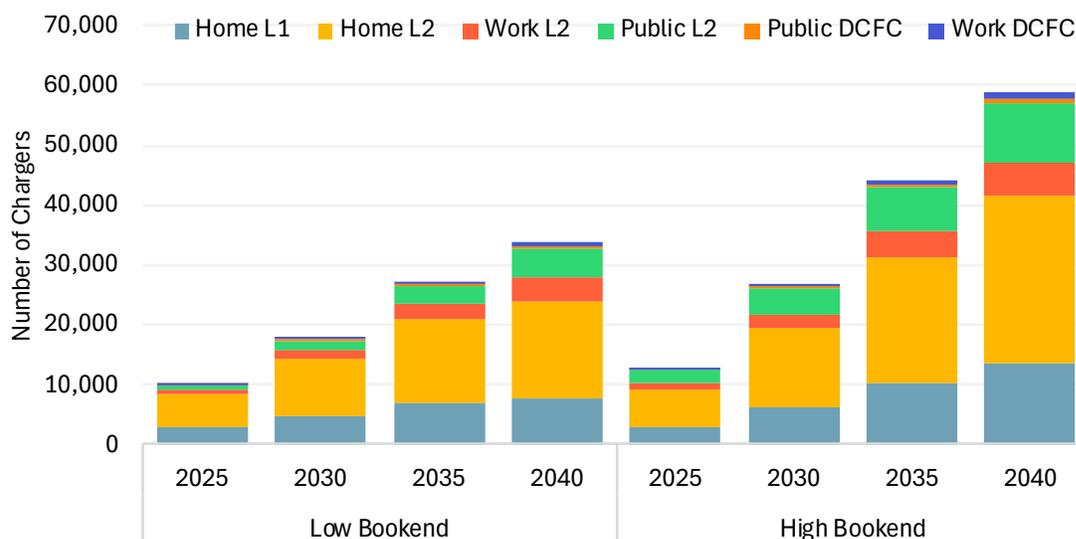
- + Public and workplace charging BTM infrastructure (costs are fully recovered through driver usage)
- + Public and workplace charging EV supply equipment (costs are fully recovered through driver usage)
- + Public and workplace charging non-energy O&M (costs are fully recovered through driver usage)

Appendix B. Detailed Results

B.1 Total Number of Chargers by Scenario

All three scenarios show significant EV charger growth through mid-century. There are three main differences between the scenarios. First is the number of EVs that they are serving. Depending on the scenario, EV adoption may happen faster or earlier. Second is the share of home and public charging. Assumptions around reduced access to home charging may lead to the need to build more public chargers. Finally, the assumption on the amount of workplace LDV charging changes by scenario. The differences in these scenarios can be seen in Figure 33.

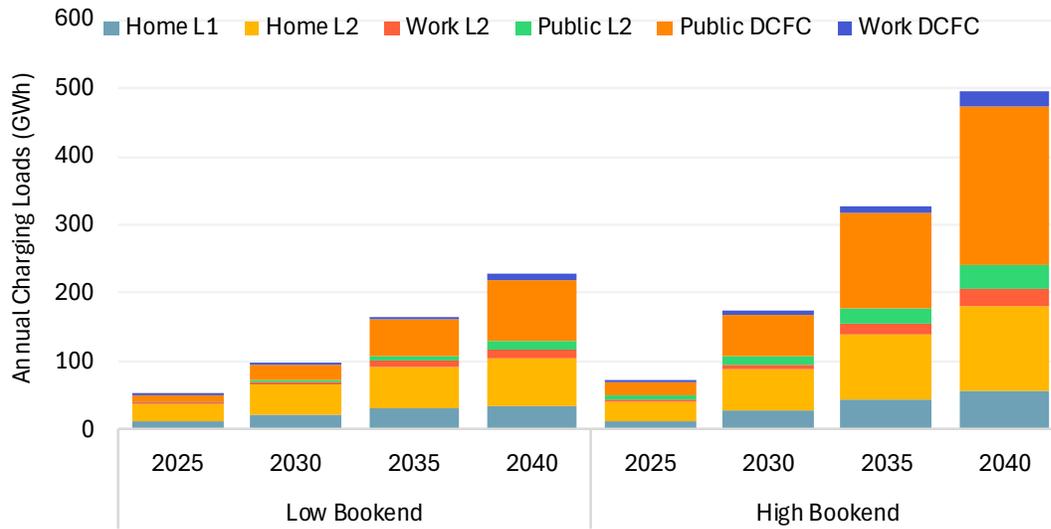
Figure 33: Number of Chargers by Location and Scenario



B.2 EV Charging Loads by Scenario and Business Model

EV charging loads vary by scenario since they are closely linked to EV adoption, which varies by scenario. The High Local Action case has the highest levels of adoption, and therefore the most load, and the Low Local Action scenario has the lowest adoption, and therefore lowest load, as seen in Figure 34.

Figure 34: Annual Loads by Location and Scenario (GWh)



B.3 Cost of Charging by Scenario and Business Model

Figure 35: Cost of Charging for Drivers by Location and Scenario

