Palo Alto Electrification Funding & Financing Study

FINAL DRAFT Report

December 2025

Energy+Environmental Economics

This study by Energy and Environmental Economics was funded by the City of Palo Alto Utilities. Any errors or omissions are the responsibility of the authors.

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Table of Contents

Table of Figures

Table of Tables

Acronym Definitions

ACCII	Advanced Clean Cars II
ACT	Advanced Clean Trucks
ASHP	Air Source Heat Pump
BAAQMD	Bay Area Air Quality Management District
BAU	Business-as-Usual
CaaS	Charging-as-a-Service
CARB	California Air Resources Board
CO_2e	Carbon Dioxide Equivalent
EV	Electric Vehicle
GHG	Greenhouse Gas
HPWH	Heat Pump Water Heater
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
LCFS	Low Carbon Fuel Standard
LDV	Light Duty Vehicle
MAC	Marginal Abatement Cost
MDV	Medium Duty Vehicle
MF	Multifamily
MHDV	Medium-and-Heavy Duty Vehicles
MT	Metric Ton
NOx	Nitrous Oxide
O&M	Operations and Maintenance
S/CAP	Sustainability and Climate Action Plan
SF	Single Family
TE	Transportation Electrification
VMT	Vehicle Miles Traveled

Executive Summary

The City of Palo Alto has committed to an ambitious climate target of reducing community-wide emissions 80% below 1990 levels by 2030 ("80x30"). Both building electrification and transportation electrification will play a significant role in meeting this target. The Sustainability and Climate Action Plan (S/CAP) Funding Model was developed to quantify the costs and benefits associated with communitywide electrification from the perspective of the community as a whole (encompassing individual community members and participating businesses - who are also utility ratepayers- and the City, both in its role as a municipality and its role as a utility) as well as the perspectives of the City (as municipality, as utility, and combined) and individual illustrative community members who would be electrifying their homes, businesses, and vehicles. This study evaluates three scenarios, each assuming a different speed of electrification, and each relying on different degrees of City involvement and funding provided to community members to encourage electrification. The three scenarios are:

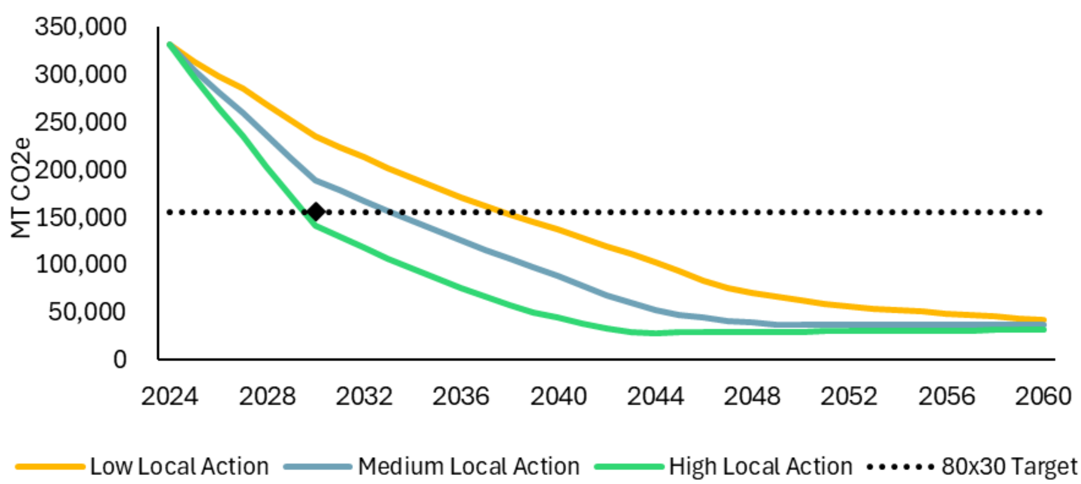
- **Low Local Action**: assumes a lower speed of both building electrification and transportation electrification, and a lower level of City investment in incentives and public infrastructure compared to the other scenarios
- **Medium Local Action**: assumes a medium speed of building and transportation electrification, and a moderate level of City investment
- **High Local Action**: assumes a higher speed of building and transportation electrification, and a higher level of City investment compared to the other scenarios

Based on specified assumptions outlined in the report, electrification provides a net financial benefit to the community, meaning that the savings generated by electrification in the form of financial outflows from the community (e.g. natural gas purchases, gasoline) exceed the increased costs associated with electrification (e.g. additional electricity purchases) on an annual basis over the entire period modeled (2024-2060), based on the assumptions in the illustrative scenarios modeled. This net benefit is primarily driven by a reduction in fossil fuel costs, particularly reduced gasoline and diesel costs driven by transportation electrification. Although electrification also provides non-financial benefits such as reduced local air pollution and greenhouse gas abatement, this report focuses on the direct monetary costs and benefits of electrification to different segments of the community. It is worth noting that a net financial benefit at the community level does not necessarily mean every household or business in the community will see a net benefit. For example, those who keep their ICE vehicles would not see the benefits associated with transportation electrification, but those who adopt EVs would. The phrase "direct monetary costs and benefits of electrification" highlights an important concept, since its meaning in this study differs from how this phrase is used in the context of utility ratemaking. Specifically, this study's presentation of costs and benefits to distinct segments of the Palo Alto community is not an electric rate cost of service study. Palo Alto's electric rates are governed by Proposition 26 (Cal. Const. art. XIII C, sec. Thus, while costs and benefits to "the community as a whole" are offered here to assist policymakers in evaluating various electrification scenarios, these are not the same costs and benefits legally relevant to setting constitutionally compliant electric rates. In depth cost of service studies and legal review would be necessary to determine whether and how individual programs may be validly supported by electric ratepayer funds if the City were to pursue that funding source, as well as any resulting rate impacts from these illustrative scenarios or other scenarios modeled using the S/CAP Funding Model.

It should be noted that all modeling assumptions around Federal incentives in these illustrative scenarios were made in 2024, prior to the repeal of the Inflation Reduction Act (IRA). Therefore, the level of Federal incentives included in results may not be currently available, but represent the point in time at which the model was created.

Achieving 80% reductions by 2030 is feasible but requires high upfront investments in equipment and infrastructure. Reaching emissions reductions at this pace also will require the early retirement of building equipment, meaning fossil fuel heaters and appliances would need to be replaced with all-electric equipment before the end of their useful life. Retiring equipment early increases costs due to the loss of remaining value on the equipment that was not yet at its end of life. As shown below in Figure ES 1, the High Local Action scenario achieves the 80% emission reduction goal by 2030. In the Low Local Action scenario, 80% emission reduction is achieved by approximately 2040. Emissions reductions under this scenario are driven primarily by transportation electrification; under this scenario, early retirements of building equipment are not required.

Figure ES 1. Annual greenhouse gas emissions (MT CO_2e)



Electrification generally requires a high upfront investment to cover electric equipment capital costs, but then provides operational savings over time. Whether there is a lifecycle net cost or benefit depends on the technology type, as discussed in the following chapters. The overall costs and benefits for electrifying community members within Palo Alto are discussed in detail in the Sectoral and Community Member Outcomes section of the report.

Buildings

The three building types modeled for this report are single family residential buildings, multifamily residential buildings, and commercial buildings. Across each building type efficient electric devices were considered to replace traditional space heating, water heating, cooking, clothes drying, and pool heating technologies.

Of the building electrification technologies, space heating tends to have more favorable economics than water heating, but electrification of both is needed to achieve 80% reductions by 2030.

Vehicles

In general, light-duty vehicle (LDV) electrification saves money on a lifecycle basis. The avoided gasoline and diesel costs outweigh any incremental capital expenditures or electricity costs associated with purchasing an electric vehicle.

Cost Types

In examining the relative costs and benefits of electrification, costs and benefits can be split into two primary categories:

- **Ongoing costs and benefits**: this category captures operating costs, energy (e.g., fuel, electricity) costs, debt expense, or any ongoing cashflow that would occur over the lifetime of a specific device purchase
- **Upfront costs and benefits**: this category captures any cost or incentive associated with the capital costs necessary for electrification

These costs are examined from three perspectives throughout the report: the community, the City of Palo Alto, and individual homeowners or business owners residing in Palo Alto.

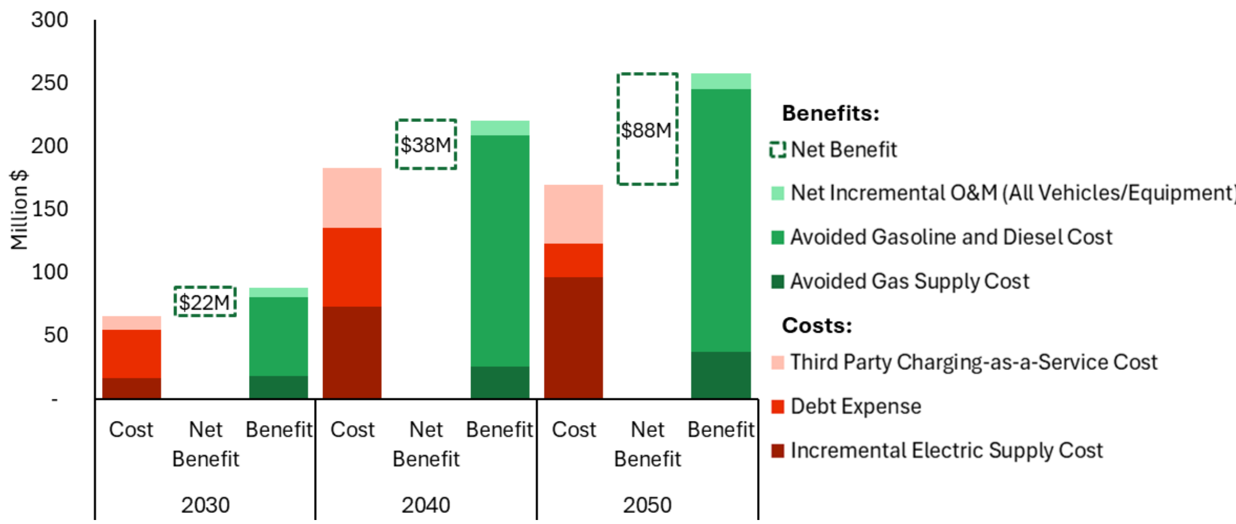
Results

Below are the ongoing (variable) and upfront costs from the community perspective for the High Local Action scenario (Figure ES 2 and 3, respectively). While electrification yields ongoing benefits for the community, the community must first incur the upfront capital cost for electrification. For simplicity this report assumes that all the incremental upfront cost (the amount by which the capital cost of electric equipment exceeds the cost of a like-for-like gas replacement) is legally able to be financed by the City's debt issuance or provision of charging-as-a-service (CaaS)[1]. The total amount of incremental upfront cost is shown in Figure ES 3 for several snapshot years, and the incremental up-front cost of electrified equipment is offset by the avoided cost of the gas equipment that no longer needs to be installed (for example, as shown in Figure ES3, the community is estimated to need to pay about $304 million in like for like gas equipment replacements in 2030, but could replace with electric equipment instead for an additional $155 million). The community member's repayment of that incremental upfront cost is shown in Figure ES 2 below under "Third Party Charging-as-a-Service Cost" and "Debt Expense." Even with the

[1] In depth legal analysis, distinct from this report, will be necessary to determine whether and to what extent such programs can legally be debt funded or funded through Charging as a Service.

need to repay the financing of this incremental upfront capital investment, the High Local Action scenario shows an ongoing net community benefit in 2030, 2040, and 2050.

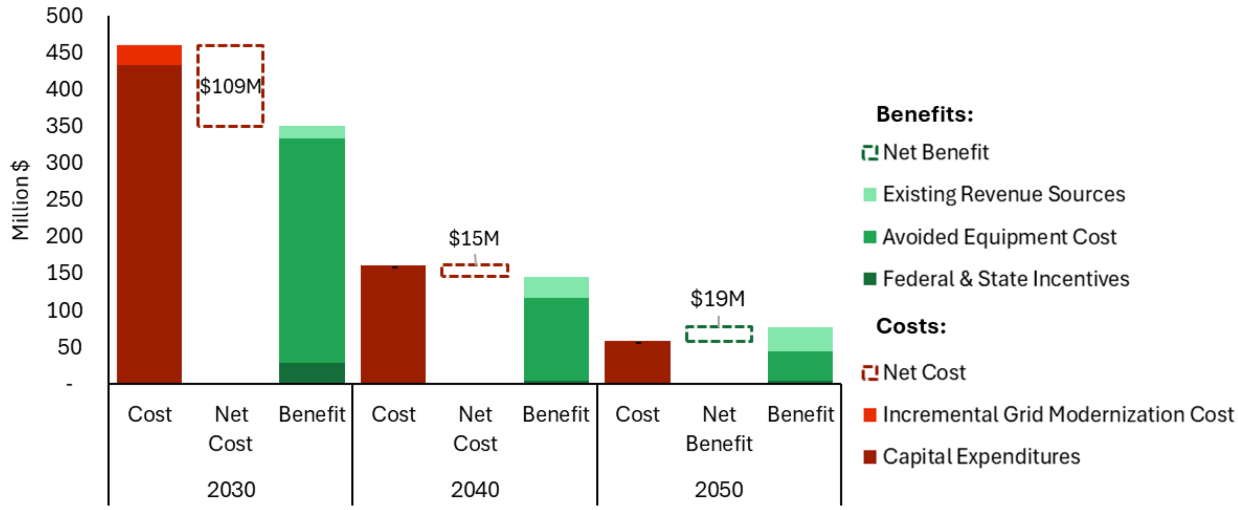
Figure ES 2. Annual community ongoing (variable) costs and benefits in key years, High Local Action scenario[2]



[2] Footnote to Chart ES2 with additional detail on legend categories;

- "Net Benefit" means all savings in the chart net of all costs in the chart
- "Net Incremental O&M (Vehicles / Equipment)" means net savings in operations and maintenance from electrifying vehicles and equipment, a benefit which accrues to the owners of those vehicles and equipment
- "Avoided Gasoline and Diesel Cost" is a savings that accrues to the owners of electrified vehicles
- "Avoided Gas Supply Cost" is a savings that accrues to current or previous natural gas customers who convert gas equipment to electric and only includes gas supply and transportation to Palo Alto, not distribution cost (so not the full retail rate). The net savings at an individual level is displayed separately in this report and does not take into account the full retail rates.
- "Third Part Charging-as-a-Service Cost" is a charge (often per kWh) that is paid by drivers (or also by the City if charging incentives are offered) to the EV charging provider to repay the up-front cost of the charging equipment
- "Debt Expense" is debt service paid to lenders by the City for new infrastructure and by electrifying community members (or the City via incentives) for electrified equipment and vehicles
- "Incremental Electric Supply Cost" represents the increased electric supply cost (excluding distribution costs, so not the full retail rate) and is paid by electrifying community members. The net impact at an individual level is displayed separately in this report and does take into account the full retail utility rates.
- Note that the beneficiaries and payors noted above can change based on the funding strategy chosen. For example, under a system of incentives funded by a tax, the design of the tax and incentive programs could change who is receiving the benefits and who is paying the costs.

Figure ES 3. Annual community upfront costs and benefits in key years, High Local Action scenario [3]



Electrification also yields costs and benefits for the City of Palo Alto, both as a municipality and a utility. The net costs and benefits depend heavily on the strategy chosen for assisting community members with electrification. The strategy modeled for this study was incentive-focused, which is the simplest approach, but incurs an ongoing net cost to the City until 2040 that would need to be funded through new revenue sources such as taxes or increased utility rates. This is primarily due to the debt issued to cover the upfront cost of incentives for electrification, as well as lost revenue from gas sales (Figure ES 4). The scenario shown in Figure ES 4 also involves the City take the legal and policy steps (such as a ballot measure) needed to use the additional electricity sales revenue generated by electrification to offset the increased ongoing costs. If the City did not do this the amount of new revenue needed would be higher, as described in the "City Outcomes" section of this

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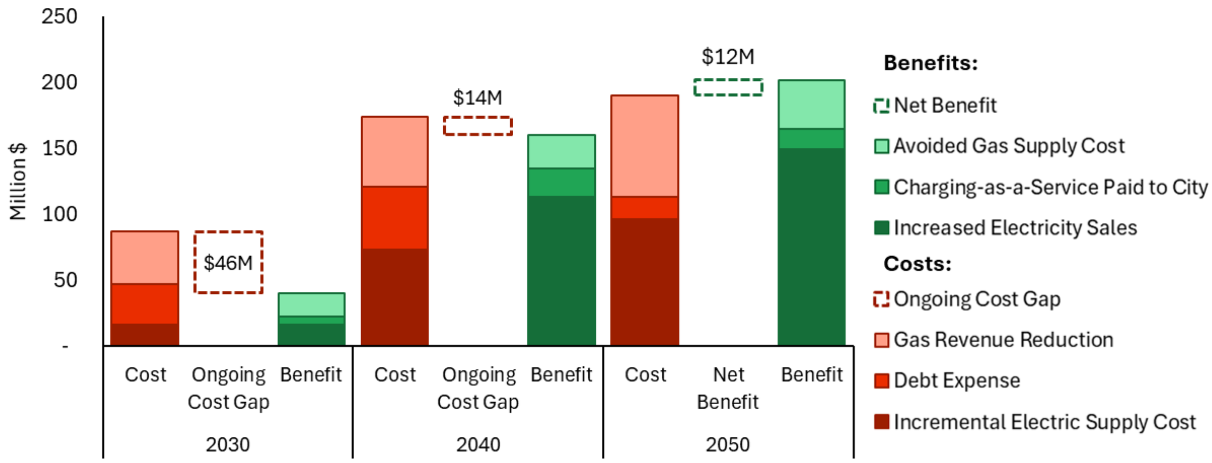
[3] Footnote to Chart ES3 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Avoided Equipment Cost" is the cost that would have been incurred if gas equipment were replaced by other gas equipment rather than electric equipment. This benefit accrues to the equipment owner.
- "Federal and State Incentives" represent available Federal and State incentive and tax credit funds. These illustrative scenarios were created prior to changes in Federal policy that occurred in 2025, so include Federal incentives and tax credits that may not be available anymore.
- "Incremental Grid Mod Cost" represents the up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- "Capital Expenditures" represents the up-front costs of the electric equipment to replace gas equipment and is assumed to be borne by lenders in this illustrative scenario, with later repayment by a mix of residential and non-residential building owners and the City via incentives.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

report. There is value to additional modeling by City staff of other strategies that are attractive to community members but do not require as much new revenue. Examples include strategies that rely more on financing than incentives, which would result in lower City new revenue needs.

Figure ES 4. Ongoing (variable) City costs and benefits, including unused upfront benefits, High Local Action scenario[4]



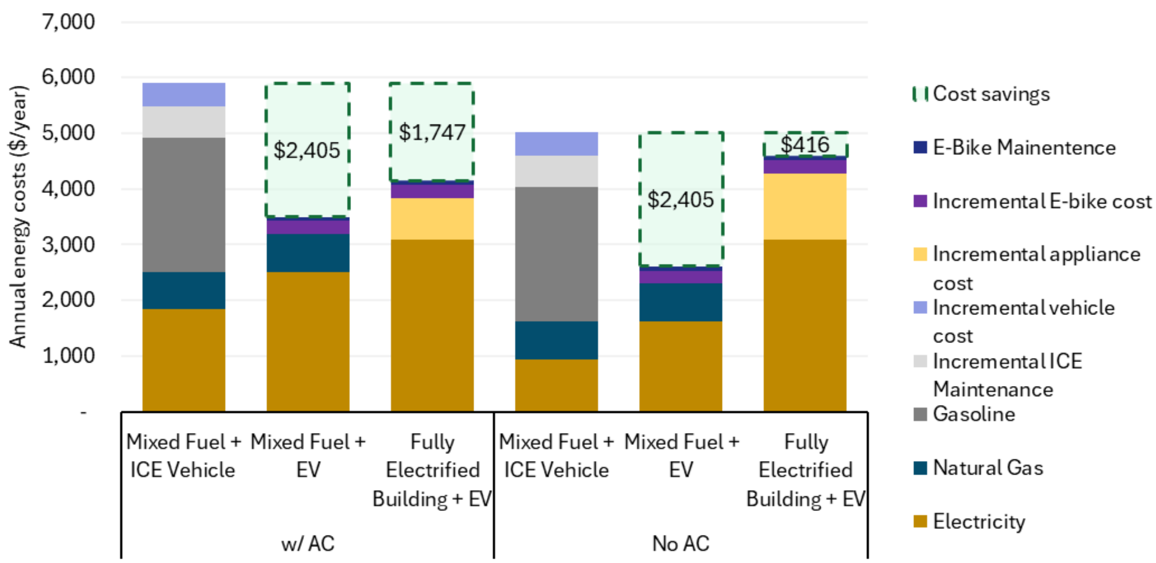
From the perspective of households and community members, this analysis found that individual households that are purchasing new equipment can experience cost savings from purchasing an EV in 2025, even without City-provided incentives. This is primarily due to the significant cost savings from avoided gasoline consumption. Before considering any City-wide incentives, the addition of building electrification will increase costs for households. These cost increases are more significant for homes that do not have air conditioning (estimated at 22% of households in Palo Alto), since households with air conditioning are likely to already have the infrastructure in place to install a heat pump and already pay for the electricity needed for cooling. Figure ES 5 shows that for a

[4] Footnote to Chart ES2 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Avoided Gas Supply Cost" is a savings that accrues to the gas utility from no longer having to serve electrified customers natural gas, and reflects the gas supply and transportation to Palo Alto, not distribution cost savings.
- "Charging-as-a-Service Cost Paid to City" represents a charge (likely per kWh) paid by drivers to the City to repay the up-front cost of City-provided infrastructure for EV charging
- "Increased Electricity Sales" represents the additional electric sales revenue for new electrified equipment based on the full electric retail rate.
- "Gas Revenue Reduction" represents lost gas sales revenue for retired gas equipment replaced by new electrified equipment based on the full gas retail rates
- "Debt Expense" is debt service paid to lenders by the City for new infrastructure (e.g. upgraded electric distribution equipment), retiring gas infrastructure, and customer incentives
- "Incremental Electric Supply Cost" represents the increased cost to procure electricity and transport it to Palo Alto. It does not include distribution costs.
- Note that the contents of these categories can change based on the funding strategy chosen. For example, paying incentives over time rather than up-front would change the debt expense category.

representative single family mixed-fuel household in 2025, purchasing an EV leads to $2,405/year in cost savings (from fuel and maintenance savings). However, if that community member were to fully electrify their home, those cost savings (avoided gasoline, natural gas, and maintenance costs) are estimated at $1,747/year for a household with air conditioning, and $416/year for a household that does not already have air conditioning. The illustrative individual perspective chosen here also includes an e-bike for part of the vehicle miles traveled and represents approximately $250 of the total fuel savings by increasing electricity use and reducing gasoline.

Figure ES 5. Annual household expenses for single family household under different levels of electrification in 2025 (no City-provided incentives)



City-provided incentives can help increase cost savings for building electrification by defraying upfront costs for households and community members. However, to provide incentives at this scale, the City will need to generate new revenue streams, such as issuing new taxes, which would also affect household and business annual expenses. Additional incentives are likely to be necessary to promote early retirement of building appliances needed to meet Palo Alto's GHG reduction targets.

Introduction

Context and Motivation

The City of Palo Alto ("the City") is a part of the fight against climate change within California, the world's 5th largest economy. The City adopted a Carbon Neutral Electricity plan in 2013 and achieved carbon neutrality in the electric sector using hydroelectric power and new California renewables in 2017. In 2016, the City Council adopted an ambitious community-wide emissions reduction goal of 80% below 1990 levels by 2030 ("80x30") and created implementation plans to begin meeting these ambitious targets. In June 2023, the City Council formally adopted the

Sustainability and Climate Action Plan (S/CAP), a comprehensive roadmap to reaching Palo Alto's 2030 climate targets and ensuring a resilient community for all community members in the years to come.

The City is not alone. In 2015, Governor Brown signed Executive Order B-30-15, which set the goal for California to reduce emissions by 40% below 1990 levels by 2030. California Senate Bill 32 (SB 32) turned this Executive Order into state law. The California Air Resources Board (CARB) has laid out a plan to reach carbon neutrality by 2045,[5] and the Bay Area Air Quality Management District (BAAQMD) has set appliance rules to reduce the nitrous oxide (NOx) emissions from furnaces and water heaters, which effectively prohibits the purchase of natural gas fired devices after specified years.[6]

A primary focus of Palo Alto's S/CAP climate goals is accelerating building and transportation electrification. This means increasing the speed with which consumers, businesses, and governments purchase electric vehicles (EV) and electric building equipment, such as air source heat pumps (ASHP) and heat pump water heaters (HPWH). This study provides the City of Palo Alto with insight into the costs associated with different levels of transportation and building electrification, an overview of the funding that already exists to cover those costs, and the magnitude of the funding gap that needs to be closed through new revenue sources. Additionally, this study explores the impact of electrification on customer costs, energy demand, and progress toward Palo Alto's 80x30 greenhouse gas (GHG) emissions targets.

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 citywide electrification and cover the associated costs:

+ **Adoption rates and energy demand:** what are the annual equipment changes needed to reach electrification goals? What are the lowest cost measures to achieve the goals? What is the total energy demand impact of citywide electrification?
+ **GHG emissions:** what are the emissions reductions associated with different levels of electrification in Palo Alto? What levels of building and transportation electrification are needed in Palo Alto to reach the 80x30 S/CAP target?
+ **Total community cost to electrify:** what are the costs associated with electrification in Palo Alto and what is the upfront investment funding gap (investment needs net of upfront savings) and ongoing cost gap (ongoing benefits net of ongoing costs plus repayment of investment)?
+ **Total City cost to electrify:** what are the City's costs associated with electrification in Palo Alto and how much revenue is required to provide varying levels of support for electrification? How do those costs and revenue affect the City's municipal operations as opposed to its utility operations?

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[5] CARB
[6] BAAQMD

- **Community member costs:** what are the upfront costs for community members (residents, businesses and other non-residential community members) associated with electrification and what are the impacts on household expenses?
- **Equity considerations:** how do different electrification investment strategies impact low- and moderate-income customers?
- **Funding Sources:** How do different funding sources affect different parts of the community?

Additional Studies

As part of the S/CAP the City commissioned multiple parallel studies to gather an understanding of the different facets of electrification and their impacts. Data from these studies was used to develop the funding model and the results in this report. The additional studies are:

- **Funding Source Survey:** This study focused on the existing and prospective funding and financing sources available to the City as a municipality, the City as a utility, and community members within Palo Alto looking to electrify. Existing sources included Federal, State, and regional incentives applied to the upfront cost of electric vehicles and appliances, State programs such as the Low Carbon Fuel Standard (LCFS) or Cap-and-Trade that provide funding to the utility to incentivize clean energy, and preestablished funding sources within the City of Palo Alto. Prospective sources included different types of taxes, third party lenders, and other sources that the City could consider utilizing to fund electrification.
- **EV Charger Needs Assessment Analysis:** This study examined the number of EV chargers needed to support different levels of transportation electrification in Palo Alto. The annual cost of charger installation depends on the number of chargers installed, as well as the type of chargers installed both at residents' homes and for public access. 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 drivers (mainly relevant for single family households), provided by taxpayers and ratepayers (e.g., the City provides incentives or directly owns the equipment), or recovered on a $/kWh basis upon utilization (e.g., Charging-as-a-Service run by a third-party EV charging company).
- **Building Subsector Studies:** The building subsector study developed datasets characterizing residential, commercial, and industrial buildings in Palo Alto for analysis in the S/CAP funding model. Specifically, the study categorized representative building types and end-use technologies (both fossil fuel and electric), identified the existing stock of buildings and end-use technologies used in each building type, and estimated annual consumption, upfront cost, and annual operations and maintenance (O&M) costs by building and end-use (including electrified technologies). These data provided the foundation for evaluating the evolution of buildings and end-use technologies in Palo Alto under various electrification pathways.

Funding & Financing Modeling Approach

E3 has developed a funding and financing model, using data from the additional studies referenced above, along with the funding and financing source survey, to calculate the total cost of communitywide electrification in Palo Alto, under different scenarios of adoption and levels of investment.

The model first estimates device stocks, adoption rates, and energy demand by sector and community member type. Next, the **Total Community Cost to Electrify** is calculated, consisting of total community-wide upfront costs, which are calculated by multiplying device capital costs and incremental adoption in each year. Once these costs are determined, the **Total Investment Gap** is calculated. This is the total upfront cost less the avoided upfront cost of like-for-like replacements of existing vehicles and appliances, and available Federal, State, and regional incentives. It should be noted that all modeling assumptions around Federal incentives were made in 2024, prior to the repeal of the Inflation Reduction Act (IRA). Therefore, the level of Federal incentives included in results may not be currently available, but represent the point in time at which the model was created. The Total Investment Gap captures the remaining incremental cost of electrification after existing funding sources and the savings from avoided capital cost is used up. The model then calculates the **City Capital Needs** to deliver incentives and/or loans to community members across sectors to close a desired portion of the Total Investment Gap. The remaining portion of the Total Investment Gap not closed by the City is assumed to be closed by private loans taken out by community members. This was a simplifying modeling assumption based on the idea that many households are unlikely to have sufficient capital to cover the upfront costs of electric technologies and would instead need to finance these upgrades over time. If needed, the model assumes the issuance of municipal or utility debt to generate the City Capital Needs to deliver incentives and/or loans. **Debt Expense** to repay both private and City debt is then calculated as combined interest and principal payments due in each year.

From the community members' perspective, any capital expense less avoided capital costs, Federal and State incentives, and Palo Alto City incentives are assumed to be covered via third party loans. Community members' Debt Expense to these external lenders is calculated and reported in the model.

More details on the modeling approach are available in the appendix.

Adoption Scenarios & Policy Alternatives

This study explores several possible scenarios for transportation and building electrification in Palo Alto, as well as different policy alternatives that the City could adopt to support that electrification. These electrification scenarios do not represent adoption forecasts. Instead, they are meant to highlight different plausible futures for climate action in Palo Alto and what they would cost given different assumptions about the level of local action. Each policy alternative attempts to address the most cost-effective technologies first, but this report does not guarantee that these policy alternatives are the optimal pathways. Instead, they showcase the cost and emissions implications associated with three example scenarios under varying levels of local policy support.[7] The City can use the models generated for this study to continue to refine and optimize the scenarios and levels of local policy support to reflect community preferences. The following section outlines the example building and transportation electrification scenarios that were modeled and the policy alternatives that were explored in this analysis.

Electrification Adoption Scenarios

Building Electrification

The built environment is a large source of greenhouse gas emissions. Traditional space heating, water heating, and cooking devices run on natural gas, which emits carbon dioxide when combusted. An alternative to gas-powered appliances are electric devices, such as air source heat pumps (ASHPs), heat pump water heaters (HPWHs), and electric induction stoves and ovens. These devices are more efficient and reduce greenhouse gas emissions and indoor air pollutants. The adoption of these types of devices is referred to as building electrification. Building electrification is a crucial piece of Palo Alto's goal of hitting the stated emissions targets.

California is already a national leader with regards to building electrification. The state has approved aggressive energy codes for new construction, and many jurisdictions are instituting building electrification incentives or policies. A key policy mandate that is set to go into effect in the next five years is the BAAQMD Zero NOx standards, which requires that only zero-NOx residential water heaters can be sold and installed in the Bay Area on or after January 1, 2027 and only zero NOx furnaces can be sold or installed in the Bay Area after 2029.[8] Despite these actions taken in California to accelerate building electrification, the actual pace of the transition away from fossil

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[7] The modeling team did not run an optimization model to identify the optimal pace of electrification or funding mechanisms. However, the technologies prioritized across each policy alternative are generally the most cost-effective ones.

[8] The BAAQMD zero NOx standards limit the allowed emissions from nitrogen oxides from small space and water heating systems. The purpose of limiting these emissions is to improve local air quality and public health. Currently, the only commercially available space and water heating devices that can comply with the nitrogen oxides emissions standards are electric appliances, such as all-electric heat pumps and heat pump water heaters. More details on the rule can be found here.

fuels for existing buildings is still largely uncertain.

Thus, the S/CAP funding model includes three hypothetical building electrification adoption scenarios, which represent three different possible futures with varying pace and ambition of building electrification: a High, Medium, and Low Electrification future. While actual electrification adoption will depend on multiple factors including mandate compliance, ease of adoption, and the community's commitment to hitting emissions targets, these scenarios allow policymakers to contemplate the level of investment needed for different paces of building electrification.

The High Electrification scenario assumes that Palo Alto will achieve 100% space and water heating electrification in residential buildings by 2030 in order to meet the ambitious 80x30 goals as laid out in the S/CAP. This level of electrification will require early retirement of existing space and water heating equipment and will go above and beyond compliance with the BAAQMD Zero NOx standards.[9] Retiring equipment early increases costs due to the loss of remaining value on the equipment that was not yet at its end of life.

In the Low Electrification scenario, it is assumed that building owners will use their existing equipment until burnout (i.e., the end of its useful life), at which point a specified portion of those building owners will replace the existing appliances with the all-electric alternative to comply with BAAQMD's Zero NOx standards. The Low Electrification scenario does not represent a future in which Palo Alto reaches its emissions reduction targets by 2030. The Medium Electrification scenario is between the high and low and can be adjusted to reflect any pace of adoption between the high and low scenarios.

The residential and non-residential space heating building equipment stock changes under all three scenarios are shown in

Figure 1 and

Figure 2 below.

Figure 1: Residential space heating equipment stock over time by scenario

[9] https://www.baaqmd.gov/~/media/dotgov/files/rules/reg-9-rule-4-nitrogen-oxides-from-fan-type-residential-central-furnaces/2021-amendments/documents/20230127_factsheet_rg09040906-pdf.pdf?rev=d9742b53163040889754f9dd0744351a&sc_lang=en

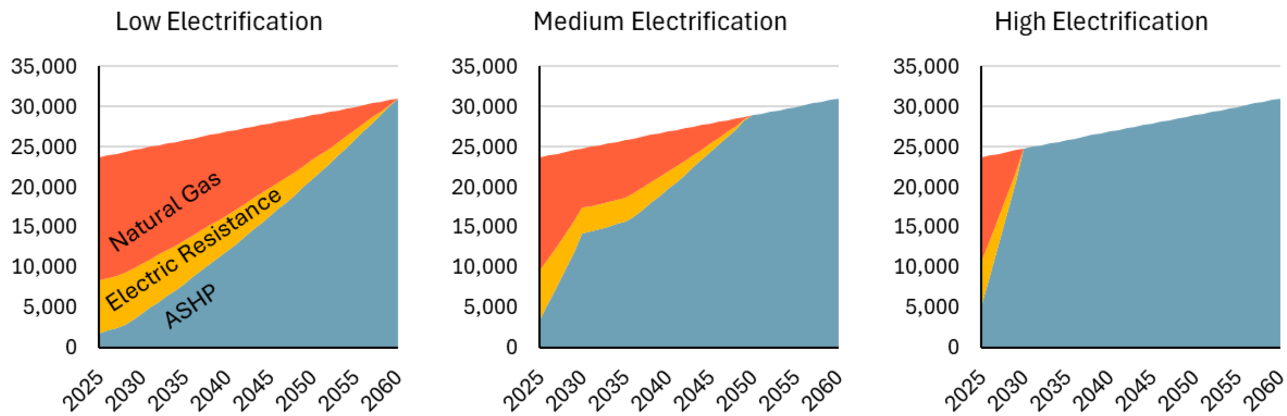
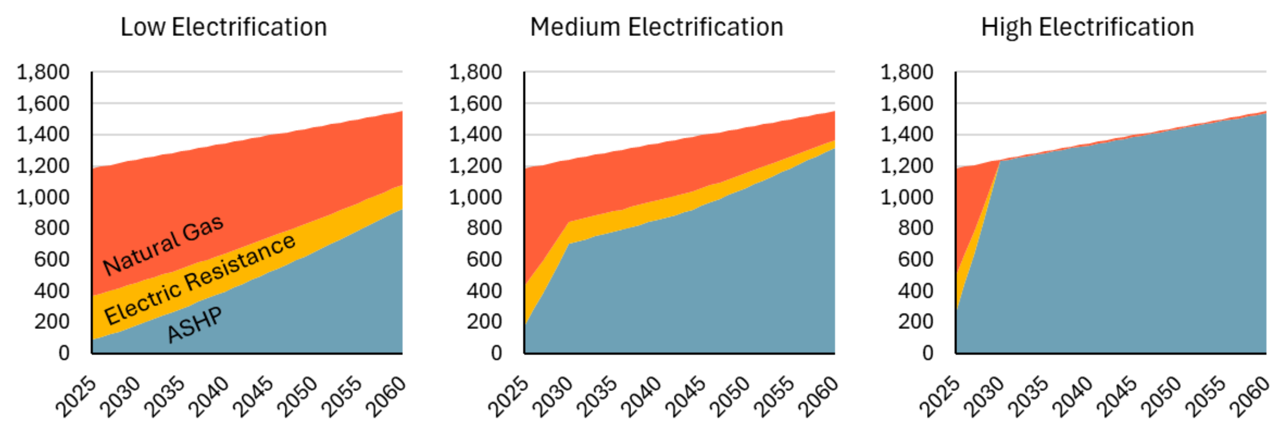


Figure 2: Non-residential space heating equipment stock over time by scenario



Transportation Electrification

Another primary driver of greenhouse gas emissions in Palo Alto is the transportation sector. Traditional internal combustion engine (ICE) vehicles that run on gasoline or diesel emit carbon dioxide and have negative effects on local air quality. To reduce emissions, Palo Alto will need to both reduce vehicle miles traveled (VMT) by increasing alternative transportation (public transit, carpooling, walking, biking, etc.) and by widespread electrification in the transportation sector.[10] Transportation electrification means that Palo Alto residents and businesses must convert from ICE vehicles to EVs. Within the light duty vehicle (LDV) market segment, EVs are already gaining popularity; however, adoption would need to continue at a rapid pace in order to hit emissions targets. The medium duty vehicle (MDV) market segment comes with additional challenges, given increased energy demand per vehicle and higher vehicle costs. The S/CAP funding model includes analysis within the transportation sector to examine the costs, energy demand shifts, and emissions

[10] The S/CAP Funding Model does not include detailed costs associated with the investments needed to reduce VMT. These costs can be added to the model as needed in the future.

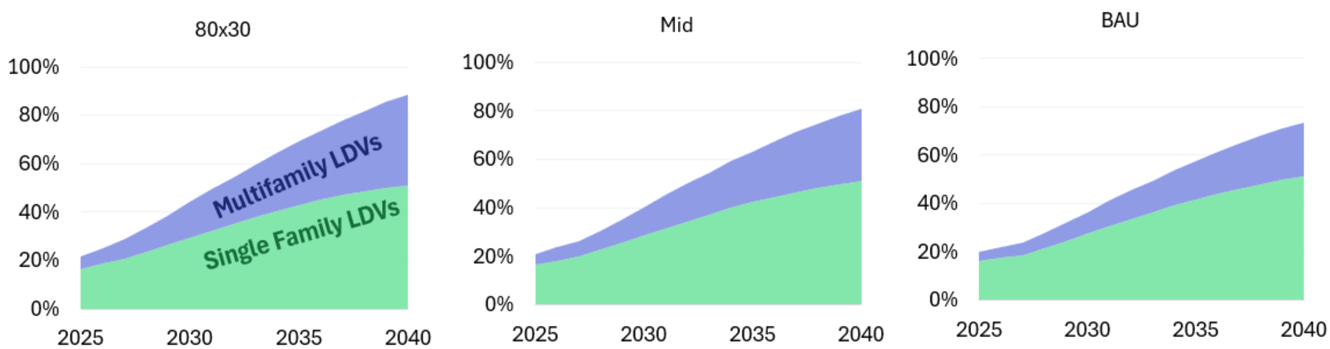
reduction associated with different levels of transportation electrification.

E3 developed three LDV EV adoption scenarios and three MDV EV adoption scenarios for use in the EV Charger Needs Assessment and S/CAP Funding Model. The most ambitious scenario represents the additional transportation electrification that would be needed in order to meet Palo Alto's 80x30 climate goals, on top of the current on-the-books policies. The business-as-usual EV adoption scenario represents EV adoption under a business-as-usual (BAU) future, which incorporates the impact of all current on-the-books policies. The primary policy drivers of EV adoption in the BAU scenario are Advanced Clean Cars II (ACCII) [11,12] and Advanced Clean Trucks (ACT).[13,14] ACCII is a California emissions standard that requires 100% of new passenger vehicles sold in California be zero-emissions (e.g., battery-electric, hydrogen fuel cell electric, etc.) by 2035. ACT requires that medium- and heavy-duty vehicle (MHDV) manufacturers increase their sales of zero-emission MHDVs over time – with specific sales targets set by vehicle weight class. The 80x30 scenario also complies with ACCII and ACT, but requires additional EV adoption on top of those policies to meet the emissions reduction targets by 2030. Because of the stringency of ACCII and ACT that all scenarios comply with, however, there is not significant variation in LDV adoption across the three scenarios.

The LDV EV adoption scenarios are shown in

Figure 3 below and additional details can be found in the EV Charger Needs Assessment report.

Figure 3. LDV EV Adoption Scenarios (% Stock)



[11] Advanced Clean Cars II

[12] 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. The ACCII is the source of ongoing litigation.

[13] Advanced Clean Trucks see: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks

[14] It should be noted that ACT 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 ACT. The federal action is currently being litigated. All modeling assumptions for this project were made in 2024, prior to the repeal of the CA waiver.

Policy Alternatives

The future of electrification in Palo Alto will look very different based on the types of strategies and policies that the City chooses to adopt. The S/CAP Funding model explored three potential policy alternatives to help answer “what if” questions about the future of Palo Alto’s climate strategy: High Local Action, Medium Local Action, and Low Local Action. These policy alternatives showcase what the cost implications in Palo Alto could look like under different levels of policy implementation, local action, and targeted investment. It should be noted that each policy alternative that was explored for this study was modeled with one of the building and transportation electrification adoption scenarios described above. High Local Action was modeled with the high building electrification scenario and 80x30 EV adoption scenario under the assumption that it would require high levels of local action to produce those adoption rates. Low Local Action was modeled with the low building electrification scenario and the BAU EV adoption scenario, assuming a strategy where electrification in Palo Alto proceeds at a similar pace to the rest of the region. The Medium Local Action scenario was modeled with the two moderate electrification scenarios. However, there is no guarantee that these policy strategies will produce the adoption rates that have been modeled. The cost results for each alternative are shown in the

Policy Scenario Outcomes and Key Insights section below.

Low Local Action

The Low Local Action scenario represents a policy pathway that involves minimal intervention from Palo Alto to support electrification. This policy alternative relies most heavily on state policy, like ACCII and BAAQMD mandates, to drive electrification, rather than adopting local mandates to encourage adoption. Under the Low Local Action policy scenario, it is assumed that adoption of EVs, e-bikes, and electric appliances in buildings will be slower, and that there will be less investment in supportive infrastructure. This policy alternative also puts the majority of the costs associated with electrification on community members as opposed to the City. Some capital is extended to community members under this package in the form of incentives. This policy alternative has the lowest overall costs due to the slower pace of adoption, but it would not reach the 80x30 or carbon neutrality goals.

High Local Action

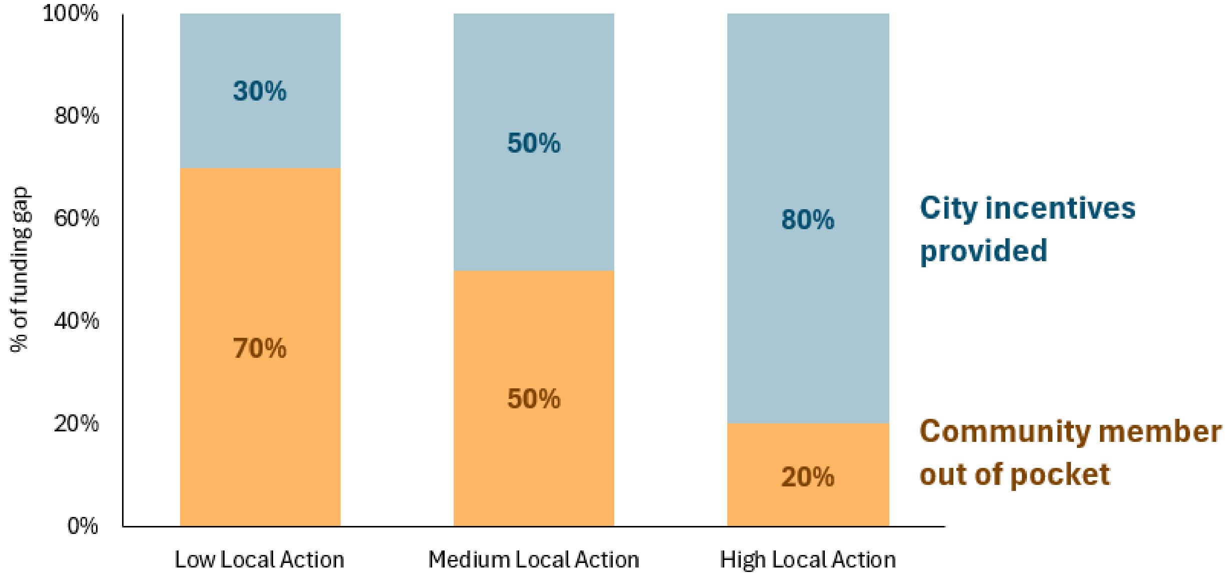
The High Local Action scenario represents a policy alternative that incorporates many drivers of electrification, such as mandates, and high incentives from Palo Alto, in addition to existing State and regional policies. This policy alternative also assumes that the City will provide incentives equal to the incremental up-front cost of electrifying (the amount by which the up-front cost of new electrified equipment exceeds the up-front cost of gas replacements) to further encourage adoption, and that these incentives, combined with regional and State mandates and possible additional local mandates if feasible, are sufficient to drive electric technology adoption in the transportation and building sectors at a rapid pace. Overall, the High Local Action scenario represents a pathway that is more likely than the other policy scenarios to meet the 80x30 GHG reduction targets through rapid electrification and VMT reductions. At the same time, this policy scenario represents the highest cost scenario due to accelerated adoption from early equipment retirements. In order for the City to provide high levels of incentives, significant new revenue sources – such as new taxes – would be required.

Medium Local Action

The Medium Local Action package represents a moderate level of local action and investment, with the City providing more incentives than in the low scenario, but less than in the high scenario. There are assumed to be some level of local mandates, and incentives driving adoption, but less so than in the High Local Action scenario. EV and building electrification move at a moderate pace, and total costs are somewhere between those seen in the High and Low scenario, with some new revenue sources likely to be required. It is possible that this scenario would reach the 80x30 targets as laid out in the S/CAP, but not as likely as in the High Local Action scenario.

Figure 4 shows the cost allocation directly funded by customers versus funding from the City of Palo Alto (which may include indirect customer funding via taxes or rates) across the three policy alternatives.

Figure 4: Percentage of incremental costs funded by City incentives across scenarios



Policy Scenario Outcomes and Key Insights

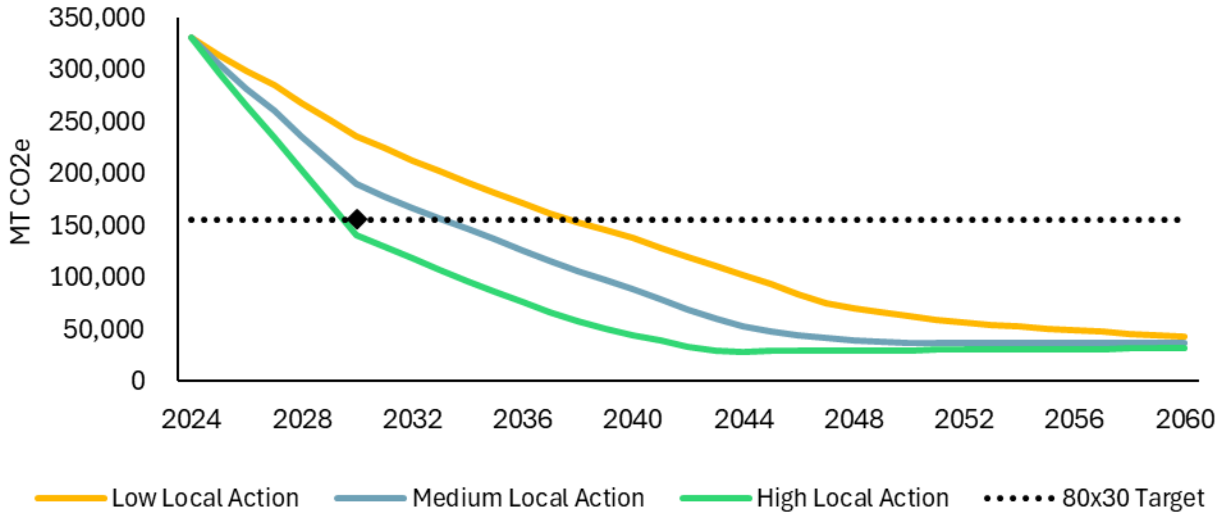
Emissions Outcomes

Emissions Trajectories

Each local impact scenario yields a different emissions trajectory for the city of Palo Alto, which has implications on the City's progress toward its 80x30 GHG reduction target. This is largely influenced by electric device adoption rates; if Palo Alto ratepayers purchase EVs and electrify their homes and businesses quickly, near-term emissions will decrease at a faster pace relative to a scenario with more gradual adoption. The number of ICE vehicles and gas building appliances remaining in Palo Alto in later years will determine the trajectory of long-term emissions. It is assumed that electricity is emissions-free due to Palo Alto's carbon neutral electricity commitment, meaning that heat pumps, EVs, and other all-electric devices do not emit greenhouse gases when in use. Figure 5 below shows the emissions trajectory from 2024-2060 across scenarios, compared to a baseline scenario that exhibits no additional transportation or building electrification. Baseline emissions are expected to grow slightly due to population growth. Note that all three scenarios reach a very low "floor" level in later years but do not reach zero. Some uses (mainly in industrial, research, and medical facilities) are assumed to be too expensive to electrify; emissions from these buildings would need to be offset with biogas or other strategies to achieve carbon neutrality. However, these uses should continue to be investigated for electrification as technology improves.

Figure 5. Annual greenhouse gas emissions (CO_2e)[15]

[15] Annual GHG emissions account for carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O), using AR5 100-year Global Warming Potential (GWP)



As shown above, the different adoption rates assumed for each scenario have a significant impact on when Palo Alto will hit the 80x30 target. The emissions abatement relative to 2024 across scenarios is:

- **Low Local Action:** 95 thousand metric tons (MT) of carbon dioxide equivalent (CO_2e) (70% reduction relative to 1990 emissions) in 2030; 80% reduction achieved in 2038. Gas use declines gradually over time, and scenario does not reach lowest levels of gas use until 2060 due to a much slower pace of building electrification
- **Medium Local Action:** 142 thousand MT CO_2e (76% reduction relative to 1990 emissions) by 2030, 80% reduction achieved in 2034. Reaches lowest levels of gas use in 2050
- **High Local Action:** 190 thousand MT CO_2e (82% reduction relative to 1990 emissions) in 2030, reaching 80x30 goal. Reaches lowest levels of gas use by 2030

Although each scenario exhibits emissions reductions, **only the High Local action scenario achieves an 80% reduction in greenhouse gas emissions relative to 1990 by 2030**. The High Local Action scenario included an assumption of a high level of building electrification, which utilizes the following stock projections:

- **Single family buildings:** 100% of single-family home end-uses electrified by 2030
- **Multifamily buildings:** 100% of heating, ventilation, and air conditioning (HVAC) and water heating, 76% of cooking, 77% of clothes drying electrified by 2030
- **Small commercial buildings:** 100% of HVAC and water heating, and 20% of cooking, clothes drying, and pool heating electrified by 2030
- **Large commercial buildings (excluding medical and industrial facilities):** 100% of HVAC and water heating, 33% of cooking, and 20% of clothes drying and pool heating electrified by 2030
- **Medical and industrial facilities:** Not assumed to electrify due to high estimated cost. This assumption should be examined in more detail through direct partnerships and studies of these facilities.

The High Local Adoption scenario also includes a high level of transportation electrification, which assumes:

- EVs make up 57% of the LDV stock share for residents in single-family homes, 30% for residents in multifamily homes, and 44% for commuters by 2030
- EVs make up 20% of the MHDV stock share by 2030

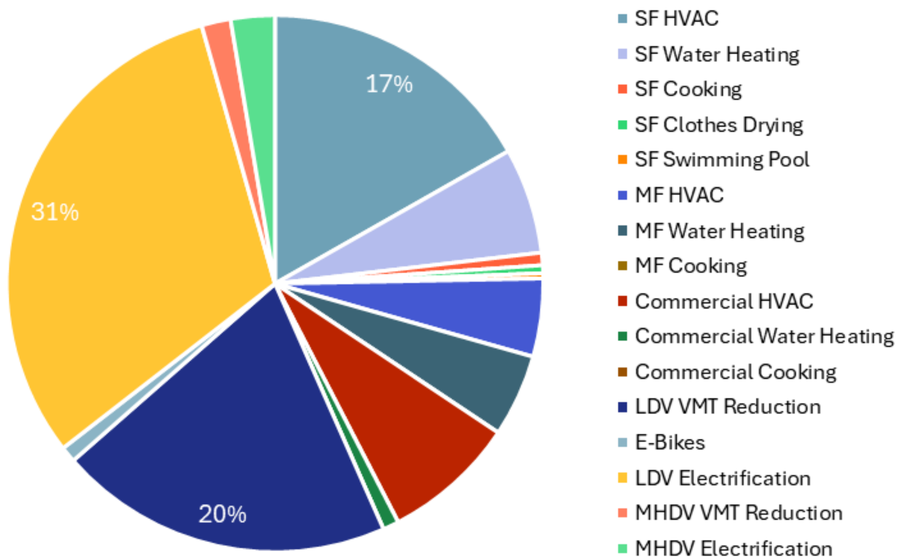
Increased e-bike purchases (4,156 e-bikes in Palo Alto by 2030), and usage in lieu of LDV driving (5.6M vehicle miles traveled).

- Figure 6

Figure 7 below show the percentage of total annual abatement by device in the year that each scenario achieves the 80% emissions reduction target (2030 for High Local Action, 2038 for Low Local Action).

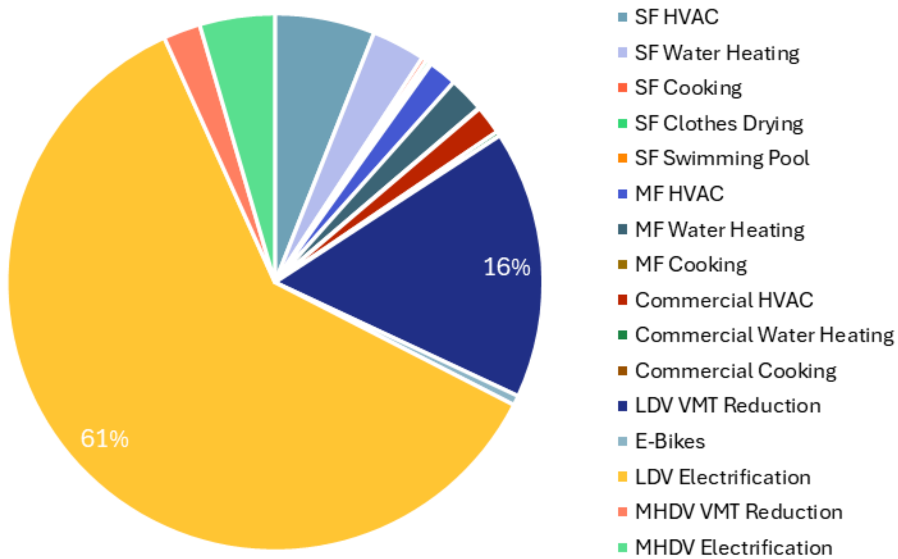
Figure 6 illustrates the High Local Action scenario's reliance on multiple facets of electrification to reduce emissions. Although transportation electrification measures account for 34% of abatement in 2030, residential HVAC electrification accounts for 21%, and commercial HVAC accounts for another 8% of abatement. On the other hand, the Low Local Action scenario, shown in Figure 7, is much more dependent on transportation electrification. Transportation electrification accounts for 65% of abatement in 2038, whereas residential and commercial HVAC electrification accounts for only 9% of abatement. This reflects the lower pace of building electrification in the Low Local Action scenario, which also means electrifying over 50% of the residential building stock HVAC equipment takes until 2042, as opposed to 2027 in the High Local Action scenario.

Figure 6. Annual emissions abatement by technology type (High Local Action, 2030)[16]



[16] Acronyms: SF (single family), MF (multifamily), HVAC (heating, ventilation, and air conditioning), LDV (light duty vehicle), MHDV (medium-heavy duty vehicle)

Figure 7. Annual emissions abatement by technology type (Low Local Action, 2038)



Marginal Abatement Costs

To understand the least-cost strategies towards decarbonization, one can use a Marginal Abatement Cost (MAC) curve. The MAC curves provide insight into how each device contributes to emissions abatement, as well as the relative cost effectiveness of each measure on a dollar per metric ton of CO_2e abated ($/t$CO_2e$) basis. The relative cost effectiveness (abatement cost) is shown on the y-axis and reflected in the height of the bars, with negative costs representing savings. The width of the bars reflects that technology's contribution to achieving the 80% emissions reduction goal (in the year 2038 for the Low Local Action Scenario and 2030 for the High Local Action Scenario).

In the S/CAP Funding Model, the abatement cost shown on the y-axis is calculated as the incremental total cost of ownership of the mitigation technology relative to its traditional counterpart, divided by the device's lifetime abatement potential. Total cost of ownership captures all costs and benefits from a community perspective, including, when applicable, incremental device or vehicle upfront cost less Federal and State incentives, O&M, gasoline and diesel costs, electric supply cost, gas commodity cost, and charging-as-a-service (CaaS) cost. Negative costs represent savings, and negative abatement costs signify that the mitigation technology in question is both less costly from a community perspective and reduces emissions compared to a like for like replacement of gas or gasoline technology. Figure 8 and

Figure 9 below illustrate what technologies contribute most heavily to abatement in each scenario, while also demonstrating the estimated cost associated with each abatement measure. It should be noted that, for simplicity, the cost of panel and service upgrades has been included in the HVAC electrification costs. VMT reduction, while included as a decarbonization strategy, is not included in the MAC curve because there is no capital cost associated with VMT reduction in the model. The numeric values shown in the below figures are included in table form in the 'Results' section of the appendix.

Figure 8. Low Local Action scenario MAC curve for electric equipment

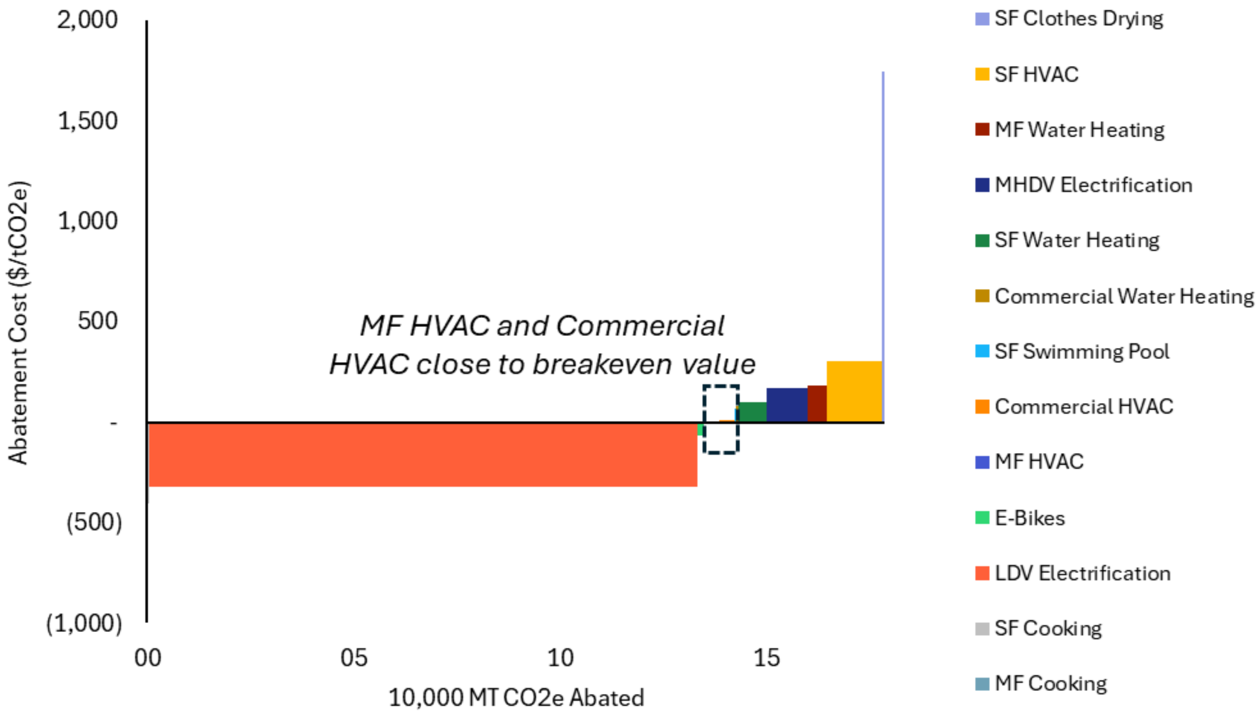
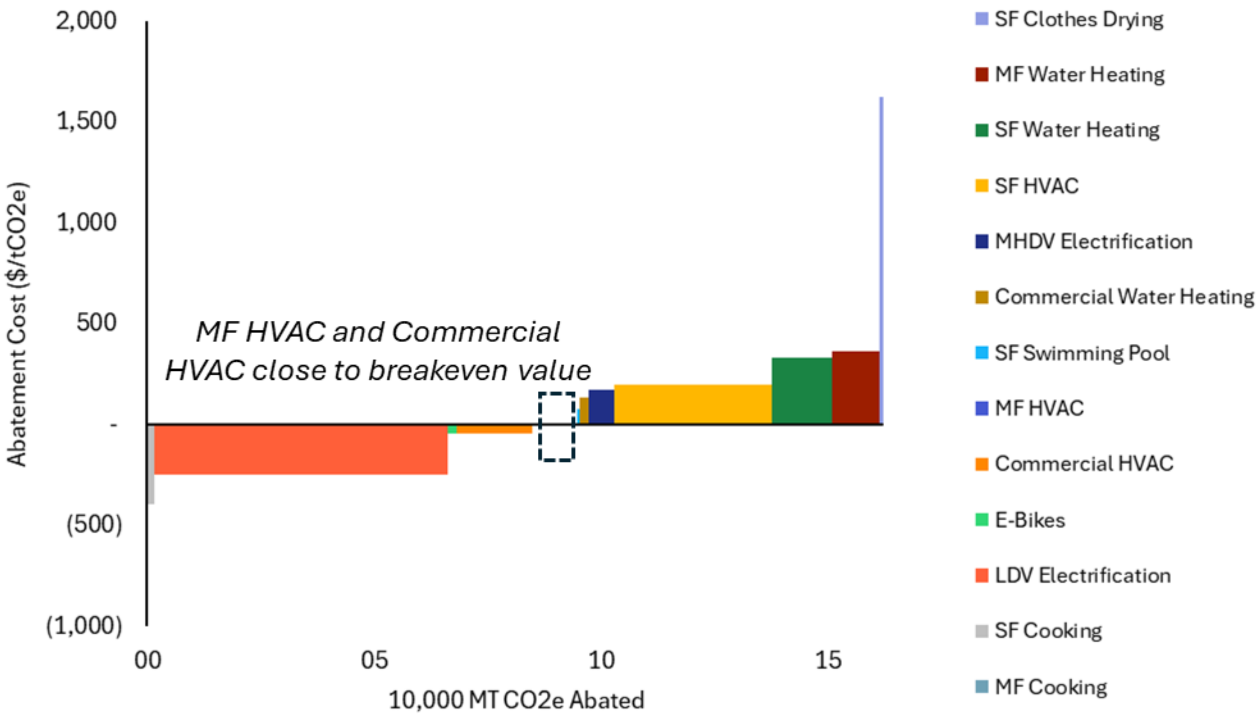


Figure 9. High Local Action scenario MAC curve for electric equipment



The marginal abatement costs for these technologies vary depending on the level of adoption, due to two key parameters: 1) regional funding sources, such as BAAQMD and TECH Clean CA incentives, have a spending cap, which allows for more regional incentive dollars per customer in a lower adoption scenario, and 2) higher adoption in key customer segments (i.e., customers with air conditioning, customers in earlier-vintage homes) has implications on the upfront cost. Housing units with air conditioning will have higher avoided equipment costs associated with electrification, given that both heating and cooling equipment like for like replacement costs will be avoided in the event that the unit has an ASHP installed to cover both heating and cooling. This higher avoided cost will reduce the calculated abatement cost.

Overall, the technology with the lowest marginal abatement cost and largest emissions reduction is light duty EVs ($200-$300/tCO_2e cost savings). On the other hand, clothes drying electrification is the least cost effective as an emissions abatement measure.[17] Although installing an electric clothes dryer is relatively inexpensive compared to other devices and may contribute to communitywide gas system savings by allowing whole homes to disconnect from the gas system, electric clothes driers are expensive on a $/tCO2e basis. The technologies with the largest marginal abatement costs are those associated with the hard-to-electrify building end-uses, space heating and water heating. These types of end-uses would require more home renovations and possibly electric panel upgrades, making them “hard to electrify.” Generally speaking, single-family ASHPs are likely to have higher marginal abatement costs due to higher incremental costs and the included cost of panel & service

[17] The electric clothes dryer is assumed to be an electric resistance dryer, not a heat pump dryer.

upgrades.[18] However, the cost will vary significantly depending on whether the home has AC already installed. Homes with AC already installed will generally have lower incremental costs to electrify. Additionally, HPWHs are seen to generally have higher marginal abatement costs than ASHPs, and MDVs are shown to have higher marginal abatement costs than LDVs.

Community Outcomes

The community perspective represents the cost or benefit or the electrification transition to Palo Alto as a whole, encompassing individual community members and participating businesses (who are also customers of the City's utilities), and the City (both in its role as a municipality and its role as a utility). To achieve higher levels of electrification, the community of Palo Alto as a whole will incur new costs such as EV and heat pump capital costs, increased electric system costs, and higher electric supply costs. There will be benefits as well, including Federal and State incentives, reduced natural gas commodity costs, and any reduction in operating costs associated with electric device adoption (e.g., reduced gasoline costs from adopting EVs). Reductions in gas distribution costs will occur if sections of the gas system are retired, and though those cost savings, as well as any additional costs associated with decommissioning components of the gas system, are beyond the scope of this study, the Funding Model is flexible enough to incorporate them in the future. The net upfront cost to the community is described as the upfront investment gap, or the amount of capital that must be raised either from external sources of capital or within Palo Alto. If the upfront costs exceeds the upfront benefits accumulated through electrification, there is an upfront investment cost gap; if benefits exceed costs, there is a net benefit to the community. If there is an upfront investment cost gap it is assumed to be financed over time through public and/or private debt, and repayment of that debt is included in the ongoing cost of electrification.

Below, the ongoing and upfront costs and benefits of electrification for the community are provided for the Low and High Local Action scenarios. It should be noted that any cashflows that remain within the community would not be expressed as a cost or benefit from the community perspective. For example, changes in utility rate revenues are not included as they are a cost to community members and a benefit to the utility; the two sides of this component cancel each other out and are not considered as a cost or benefit when examining the community as a whole.

Ongoing costs and benefits

Although electrification will require an upfront investment, this investment results in additional benefits for the community. The model estimates the ongoing costs and benefits of electrification and compares the net change to the community's annual expenses that results from electrification. Note that any ongoing cashflows happening between entities within the community are excluded. Ongoing costs and benefits include:

- **Operating costs:** this category captures any increase in O&M costs paid by the community

[18] The cost of service and panel upgrades are assigned to ASHPs for the purpose of the MAC curve.

as a whole, including repairs and maintenance of vehicles and equipment

+ **Third Party CaaS costs** paid by the community for public EV charging
+ **Debt repayment:** this includes the principal and interest paid by Palo Alto community members to third party lenders and the principal and interest paid by the City on issued debt. Note that the repayment of City-provided loans to Palo Alto residents would be considered a cost to the community members and a benefit to the City, and therefore is excluded from the community perspective
+ **Energy costs:** ongoing energy costs and benefits for the community include avoided gasoline and diesel costs, avoided gas supply costs, and increased electric supply costs. Remaining energy expenditures are excluded from the community perspective as they are a cost for one entity and a benefit for another; for example, the portion of electric bills comprised of distribution costs and public benefits charges would be a cost to ratepayers and a benefit to the utility, and therefore should not be included in the community perspective

As adoption increases, both ongoing costs and benefits associated with electrification escalate. Figure 10 and

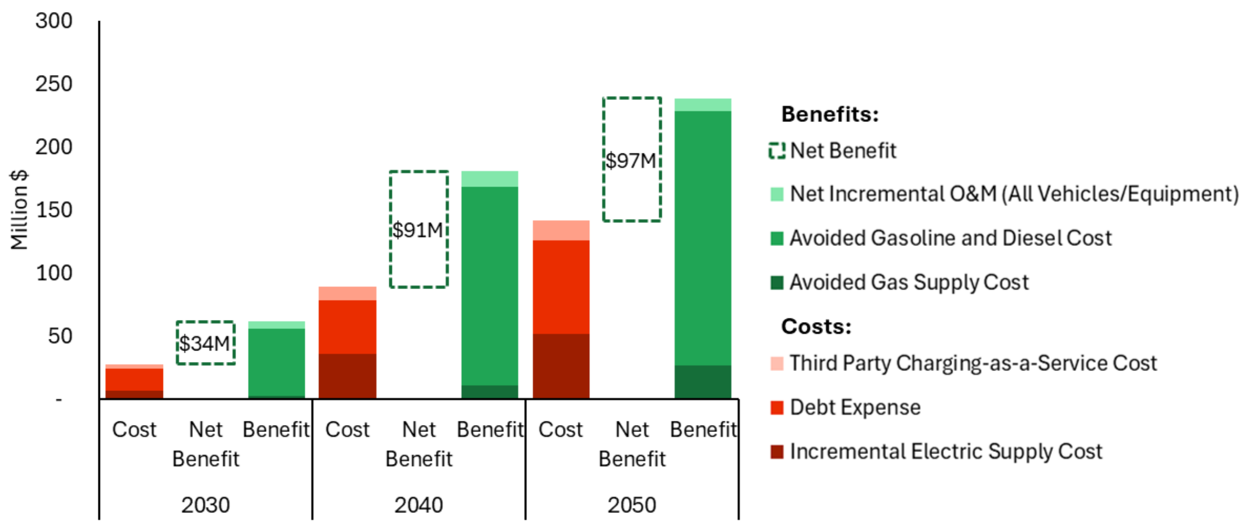
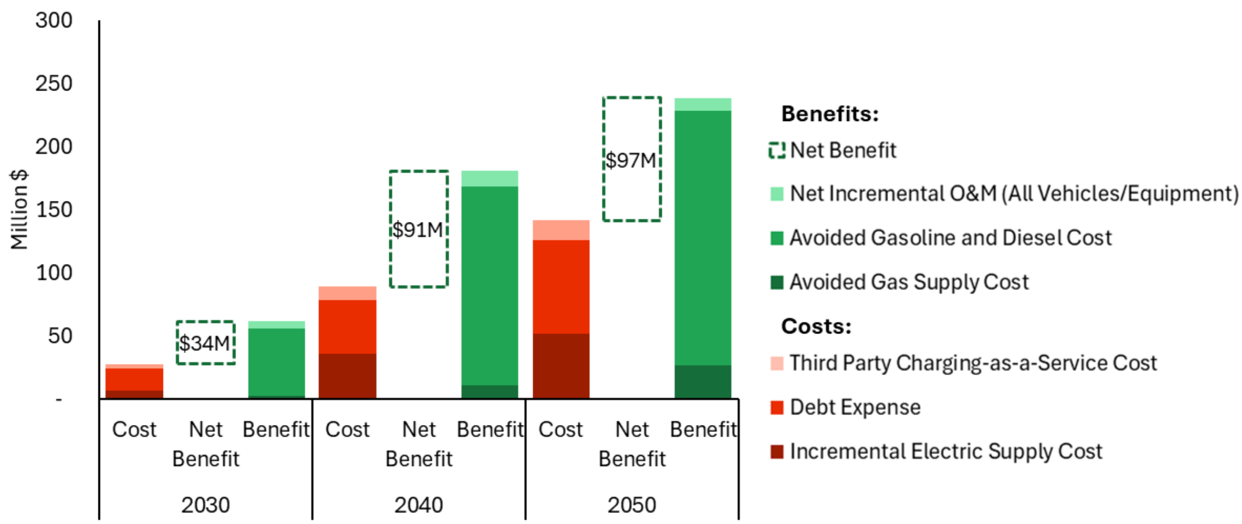


Figure 11 show that in both the Low and High Local Action scenarios, ongoing benefits for the community as a whole outweigh costs. Across scenarios, benefits are primarily driven by transportation electrification. Specifically, avoided gasoline and diesel costs provide about $200 million in benefits to the segment of the community with EVs in 2050.

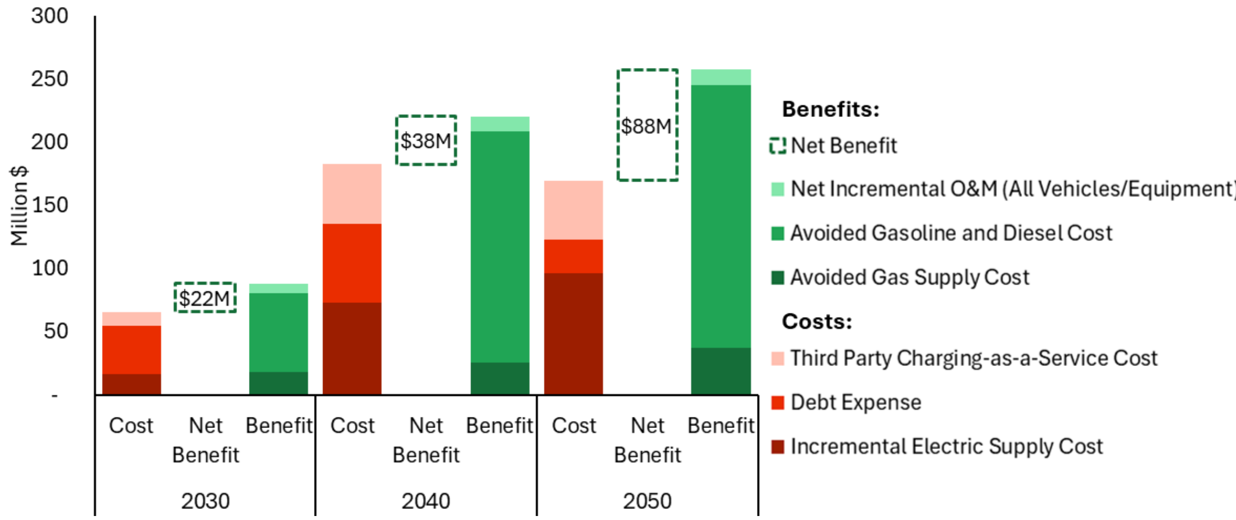
Figure 10. Community ongoing costs and benefits in key years, Low Local Action scenario[19]



[19] Footnote to Figure 10 with additional detail on legend categories;

- "Net Benefit" means all savings in the chart net of all costs in the chart
- "Net Incremental O&M (Vehicles / Equipment)" means net savings in operations and maintenance from electrifying vehicles and equipment, a benefit which accrues to the owners of those vehicles and equipment
- "Avoided Gasoline and Diesel Cost" is a savings that accrues to the owners of electrified vehicles
- "Avoided Gas Supply Cost" is a savings that accrues to current or previous natural gas customers who convert gas equipment to electric and only includes gas supply and transportation to Palo Alto, not distribution cost (so not the full retail rate). The net savings at an individual level is displayed separately in this report and does not take into account the full retail rates.
- "Third Part Charging-as-a-Service Cost" is a charge (often per kWh) that is paid by drivers (or also by the City if charging incentives are offered) to the EV charging provider to repay the up-front cost of the charging equipment
- "Debt Expense" is debt service paid to lenders by the City for new infrastructure and by electrifying community members (or the City via incentives) for electrified equipment and vehicles
- "Incremental Electric Supply Cost" represents the increased electric supply cost (excluding distribution costs, so not the full retail rate) and is paid by electrifying community members. The net impact at an individual level is displayed separately in this report and does take into account the full retail utility rates.
- Note that the beneficiaries and payors noted above can change based on the funding strategy chosen. For example, under a system of incentives funded by a tax, the design of the tax and incentive programs could change who is receiving the benefits and who is paying the costs.

Figure 11. Community ongoing costs and benefits in key years, High Local Action scenario[20]

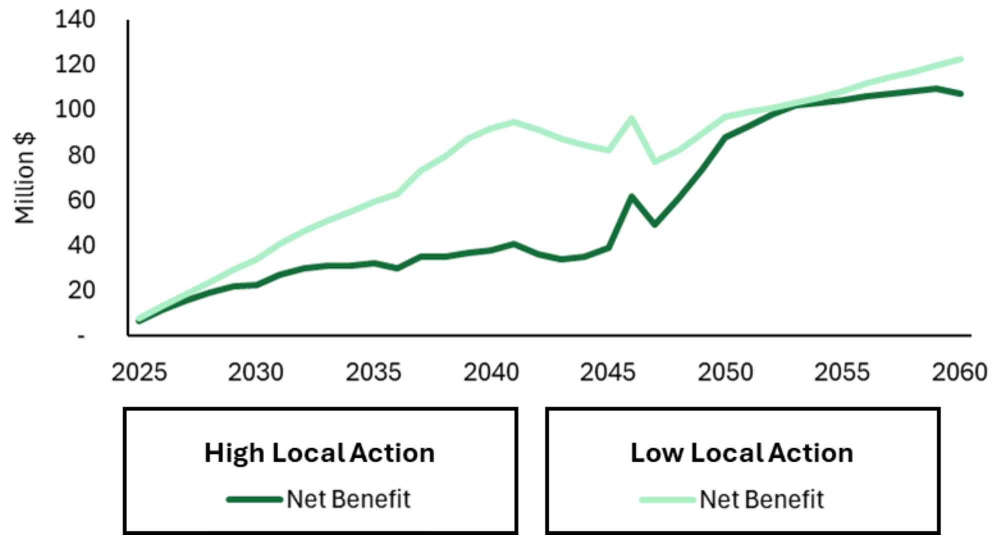


As shown in Figure 12, the community receives an ongoing net benefit for the entirety of the analysis period in both the Low and High Local Action scenarios (although results for different individual community members and groups of community members will vary). Across scenarios, these net benefits generally increase over time as ongoing benefits continue to further outweigh ongoing costs.

[20] Footnote to Figure 11 with additional detail on legend categories;

- "Net Benefit" means all savings in the chart net of all costs in the chart
- "Net Incremental O&M (Vehicles / Equipment)" means net savings in operations and maintenance from electrifying vehicles and equipment, a benefit which accrues to the owners of those vehicles and equipment
- "Avoided Gasoline and Diesel Cost" is a savings that accrues to the owners of electrified vehicles
- "Avoided Gas Supply Cost" is a savings that accrues to current or previous natural gas customers who convert gas equipment to electric and only includes gas supply and transportation to Palo Alto, not distribution cost (so not the full retail rate). The net savings at an individual level is displayed separately in this report and does not take into account the full retail rates.
- "Third Part Charging-as-a-Service Cost" is a charge (often per kWh) that is paid by drivers (or also by the City if charging incentives are offered) to the EV charging provider to repay the up-front cost of the charging equipment
- "Debt Expense" is debt service paid to lenders by the City for new infrastructure and by electrifying community members (or the City via incentives) for electrified equipment and vehicles
- "Incremental Electric Supply Cost" represents the increased electric supply cost (excluding distribution costs, so not the full retail rate) and is paid by electrifying community members. The net impact at an individual level is displayed separately in this report and does take into account the full retail utility rates.
- Note that the beneficiaries and payors noted above can change based on the funding strategy chosen. For example, under a system of incentives funded by a tax, the design of the tax and incentive programs could change who is receiving the benefits and who is paying the costs.

Figure 12. Community ongoing net benefit over time[21]



Upfront costs and benefits

In order for Palo Alto to reap the ongoing benefits of electrification, the community will first have to invest in the necessary upfront costs of electrification. Upfront costs capture the initial investment needed to electrify Palo Alto's buildings and transportation system. These costs are essentially the financial hurdles needed in order for the community to receive the ongoing benefits outlined above.

The primary upfront cost of electrification is the capital expenditure required to purchase EVs, EV chargers, E-bikes, electric appliances across building types, and any electric panel or service upgrades needed to support building electrification. Additionally, the upfront cost captures the incremental electric system cost, or the additional investment needed in electrical infrastructure to support increased electricity demand.

Upfront benefits capture any external funding or financing source that covers these upfront costs as well as any avoided costs Upfront costs and benefits include:

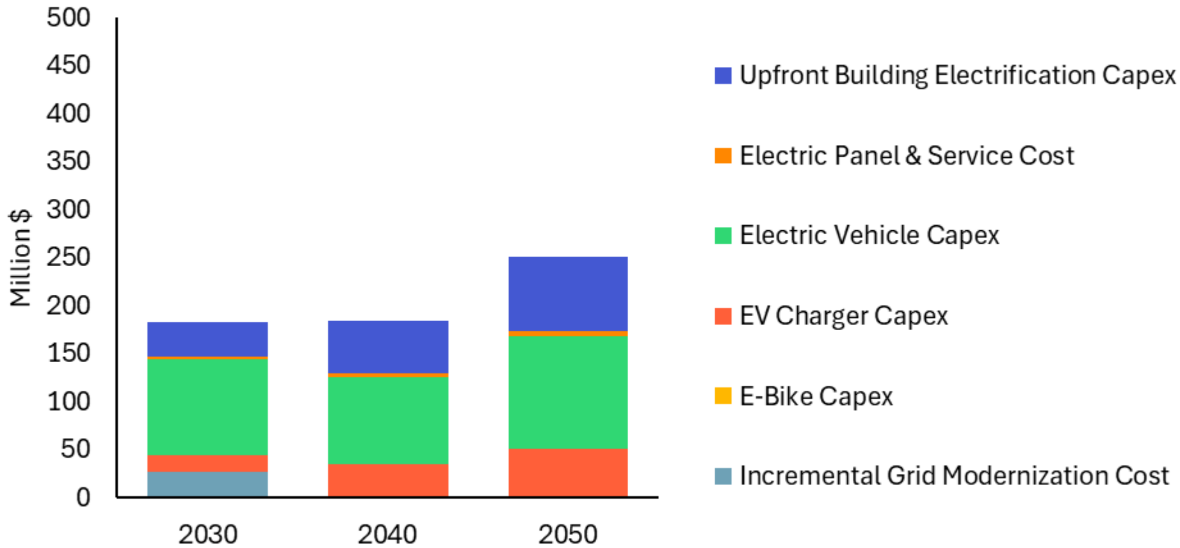
- **Upfront equipment costs:** these include any capital expenditure costs involved with building electrification, electric panel and service upgrade costs, EV purchases, EV charger installations, and E-bike purchases.
- **Avoided costs:** These include avoided like-for-like replacement costs of ICE vehicles and traditional building appliances.
- **System costs:** these capture the incremental infrastructure costs needed for the electric system to support higher electricity demand.
- **Existing funding and financing sources:** this includes sources like federal and State

[21] Spike in ongoing net benefits in 2046 is caused by a temporary increase in gasoline prices, causing an increase in avoided gasoline expense; the increase in gasoline prices is caused by multiple factors affecting the different components of the total $/gallon price used in the model.

incentives and existing revenue sources.

The annual upfront cost of communitywide building and transportation electrification is significant, but as shown in Figures 15 and 16, is mostly offset by significant avoided costs of like for like equipment replacement; in the High Local Action scenario, which exhibits a highly accelerated electrification timeline, the total investment needed is about $459 million in 2030 (Figure 14), offset by about $304 million avoided costs of like for like replacements. With most investments taking place before 2030 in the High Local Action scenario the upfront cost of electrification investments falls to around $58 million in 2050. The Low Local Action scenario, on the other hand, has a slower adoption trajectory, causing higher investments in later years; this scenario has an upfront cost of electrification around $182 million in 2030 (offset by $107 million in avoided costs), and increases to about $250 million in 2050 (Figure 13).

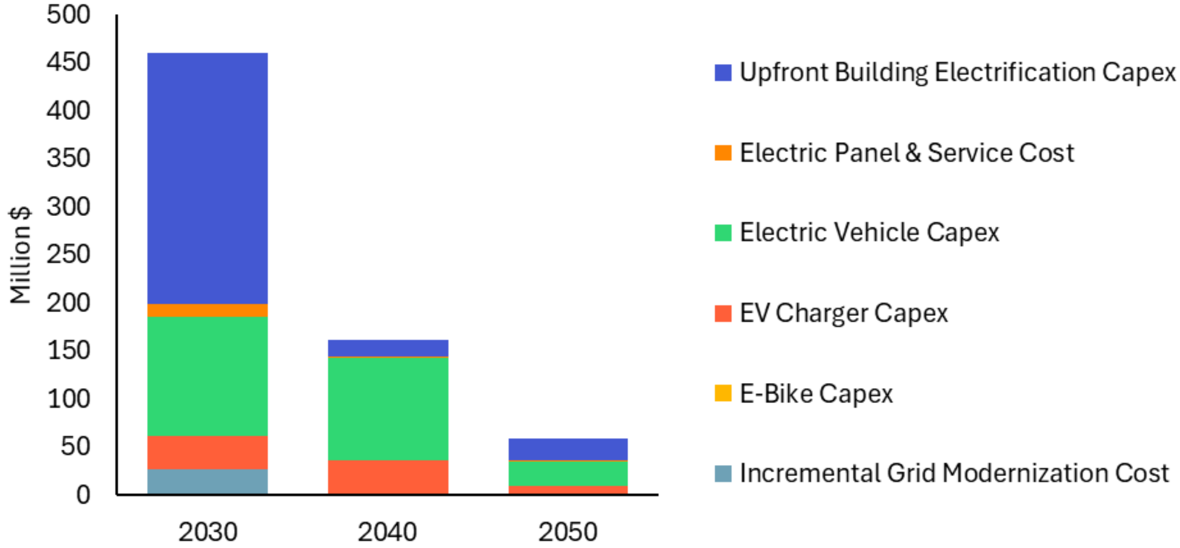
Figure 13. Community upfront costs in key years, Low Local Action scenario[22]



[22] Footnote to Figure 13 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Avoided Equipment Cost" is the cost that would have been incurred if gas equipment were replaced by other gas equipment rather than electric equipment. This benefit accrues to the equipment owner.
- "Federal and State Incentives" represent available Federal and State incentive and tax credit funds. These illustrative scenarios were created prior to changes in Federal policy that occurred in 2025, so include Federal incentives and tax credits that may not be available anymore.
- "Incremental Grid Mod Cost" represents the up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- "Capital Expenditures" represents the up-front costs of the electric equipment to replace gas equipment and is assumed to be borne by lenders in this illustrative scenario, with later repayment by a mix of residential and non-residential building owners and the City via incentives.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

Figure 14. Community upfront cost in key years, High Local Action scenario[23]



Because all scenarios comply with the aggressive targets of ACCII and ACT, the S/CAP Funding Model assumes a relatively consistent rate of EV adoption across scenarios, causing costs to be similar for electric vehicle purchases.[24] Overall, it is estimated that EV capital costs are between $99-123 million and EV charger costs are between $18-34 million in 2030, under all adoption scenarios. Although the high local action scenario requires more public charger buildout, a large

[23] Footnote to Figure 14 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Avoided Equipment Cost" is the cost that would have been incurred if gas equipment were replaced by other gas equipment rather than electric equipment. This benefit accrues to the equipment owner.
- "Federal and State Incentives" represent available Federal and State incentive and tax credit funds. These illustrative scenarios were created prior to changes in Federal policy that occurred in 2025, so include Federal incentives and tax credits that may not be available anymore.
- "Incremental Grid Mod Cost" represents the up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- "Capital Expenditures" represents the up-front costs of the electric equipment to replace gas equipment and is assumed to be borne by lenders in this illustrative scenario, with later repayment by a mix of residential and non-residential building owners and the City via incentives.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

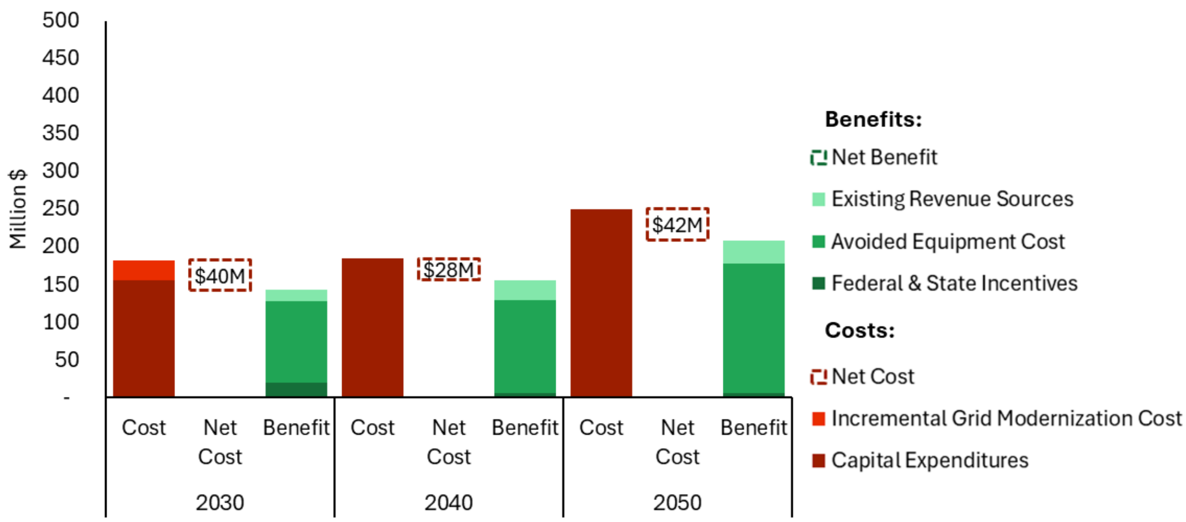
[24] It should be noted that ACCII and ACT are enabled by the Environmental Protection Agency's Clean Air Act federal preemption waiver to California to set their own vehicle emissions standards. As of June 2025, the current Federal administration has rescinded the EPA's waiver, thus terminating the ability for CA to set vehicle emissions standards such as ACCII and ACT. 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.

portion of these costs are borne by a third-party and paid back over time through CaaS, which is seen in the ongoing costs section. Building electrification rates, on the other hand, vary significantly between these scenarios depending on the level of local action and incentives provided for community members.

As mentioned in the Funding & Financing Modeling Approach section, once upfront costs are calculated, any avoided costs, existing revenue sources available to the City, and Federal, State, or Local incentives are subtracted out to calculate the Total Investment Gap. The Total Investment Gap will be filled by debt; if the cost falls to community members it is assumed they will take out loans from third-party lenders, and if the cost falls to the City it is assumed that municipal or utility bonds (described in more detail in a separate Funding Source Survey report) will be issued.

As shown in Figure 15 and Figure 16, the annual Investment Gap can be significant. In the High Local Action scenario, the Investment Gap peaks in 2030 at $109 million, when capital expenditures are highest. If the community incurs investment gap, it does not need to be paid off in one year. The annual repayment cost of the debt issued to finance the investment gap is significantly smaller, and as shown in the Ongoing Costs and Benefits section above, is offset by the benefits of electrification (for the purpose of calculating the net benefits at a community level; this is not meant to indicate that any particular benefit of electrification can automatically be used to directly pay debt service, since additional legal and business analysis would be needed to determine the suitability of any benefit to generate a revenue source).

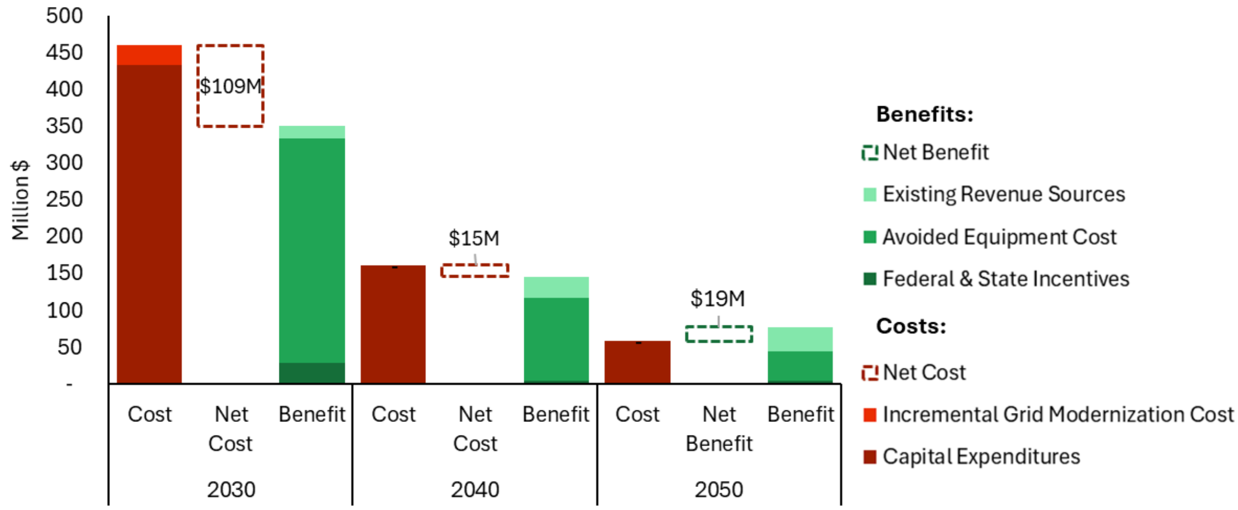
Figure 15. Community upfront costs and benefits in key years, Low Local Action scenario[25]



[25] Footnote to Figure 15 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Avoided Equipment Cost" is the cost that would have been incurred if gas equipment were replaced by other gas equipment rather than electric equipment. This benefit accrues to the equipment owner.
- "Federal and State Incentives" represent available Federal and State incentive and tax credit funds. These illustrative scenarios were created prior to changes in Federal policy that occurred in 2025, so include Federal incentives and tax credits that may not be available anymore.
- "Incremental Grid Mod Cost" represents the up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- "Capital Expenditures" represents the up-front costs of the electric equipment to replace gas equipment and is assumed to be borne by lenders in this illustrative scenario, with later repayment by a mix of residential and non-residential building owners and the City via incentives.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

Figure 16. Community upfront costs and benefits in key years, High Local Action scenario[26]



In Figure 17, both the Low and High Local Action community upfront cost and benefit results are shown. In the Low Local Action case, the community incurs an investment gap from 2026-2052, which peaks in 2047, the year that capital expenditures are highest from the community perspective; the investment gap in this year is $102 million, driven by higher EV and EV charging infrastructure capital costs. Capital expenditures decrease significantly by 2054, and largely level off in the remaining years of the analysis, leading to the community receiving a net benefit from 2054 onwards.

In the High Local Action scenario, the community investment gap peaks in 2030 at $109 million, also when capital expenditures are highest. Since the High Local Action scenario assumes that significant investment in building electrification occurs by 2030 in order to achieve the 80x30 target,

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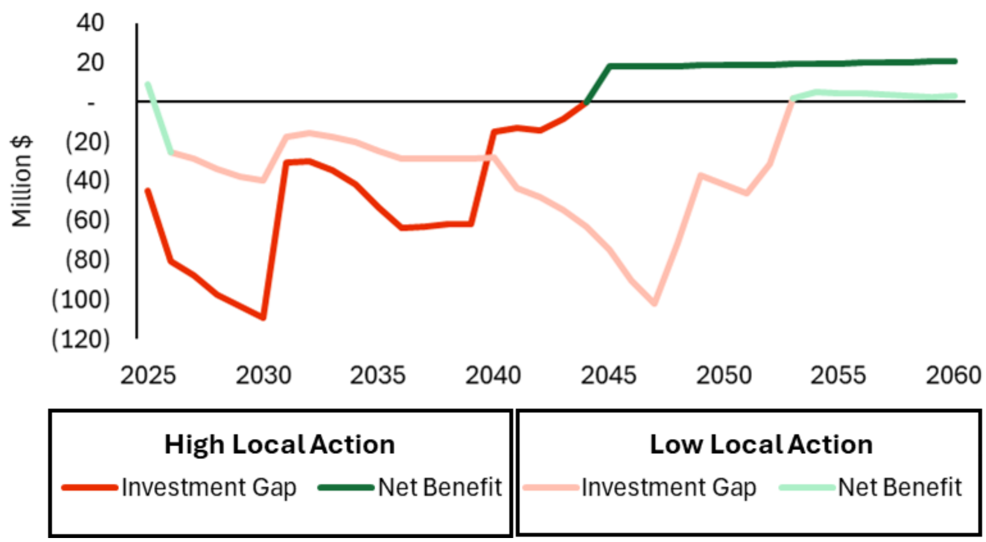
[26] Footnote to Figure 16 with additional detail on legend categories;

- "Net Benefit" or "Net Cost" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Avoided Equipment Cost" is the cost that would have been incurred if gas equipment were replaced by other gas equipment rather than electric equipment. This benefit accrues to the equipment owner.
- "Federal and State Incentives" represent available Federal and State incentive and tax credit funds. These illustrative scenarios were created prior to changes in Federal policy that occurred in 2025, so include Federal incentives and tax credits that may not be available anymore.
- "Incremental Grid Mod Cost" represents the up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- "Capital Expenditures" represents the up-front costs of the electric equipment to replace gas equipment and is assumed to be borne by lenders in this illustrative scenario, with later repayment by a mix of residential and non-residential building owners and the City via incentives.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

building electrification capital expenditure drops off significantly in 2031, causing a brief decrease in the investment gap. However, the gap once again widens from 2032-2039 due to higher EV and EV charger capital expenditures. From 2040 onward, as existing revenue sources increase and capital expenditures decrease, the investment gap shrinks, and the community begins to receive a net benefit in 2044.

Figure 17. Community investment gap/net benefit over time [27]



After accounting for existing revenue sources and customer contributions, the remaining cost gap is assumed to be met by external loans to customers and loans to the city in the form of bonds. The extent to which community members must take out loans to cover the cost of electrification depends on the percentage of the investment gap covered by the City, which is scenario-specific (see Figure 4). The amount of debt the City must issue is largely dependent on the level of investment in public infrastructure, City-owned vehicles, and incentives or loans provided to community members.

Figure 18 and Figure 19 below show communitywide borrowing annually in the Low and High Local Action scenarios, respectively, $1.4 billion in both scenarios, but over two different time periods. In the High Local Action scenario, investment in electrification ramps up quickly and is largely covered by the City, hence the high bond issuance in early years. There is another increase in bond issuance in the late 2030s as the capital requirement for electrification incentives, particularly those covering medium- and heavy-duty EVs and EV chargers, increase; the High Local Action scenario assumes 100% of the MHDV stock will be electric by 2040, which causes MHDV EV purchases, and therefore capital costs, to peak in this time period. The Low Local Action scenario,

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[27] Note that in the up-front cost chart, later year net benefits do not offset earlier net costs. Instead, the annual investment needs in this chart (the “investment gap”) represents up-front costs that are assumed to be funded by issued debt, becoming the “Debt Expense” cost in the Ongoing Cost charts (Figures 10, 11)

on the other hand, exhibits more gradual investment that relies more heavily on community members taking out loans from external lenders.

The amount of borrowing has impacts on ongoing costs from the community perspective. Both the City and individual community members must repay debt, as well as interest expense. This is shown in the ongoing cost figures (Figure 10 and) as 'Debt Expense.'

Figure 18. Communitywide borrowing, Low Local Action

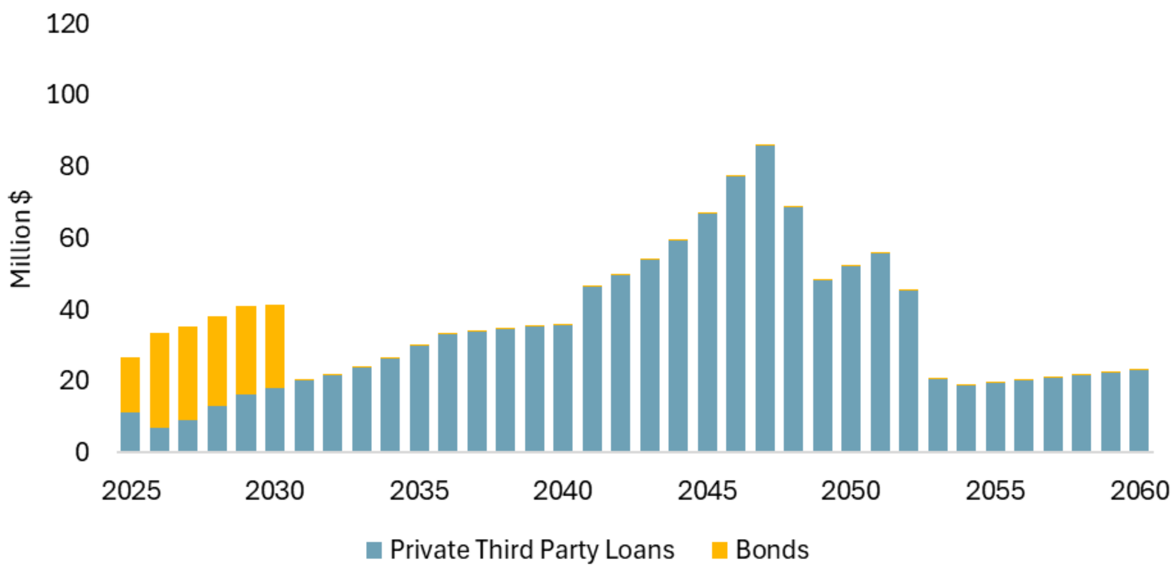
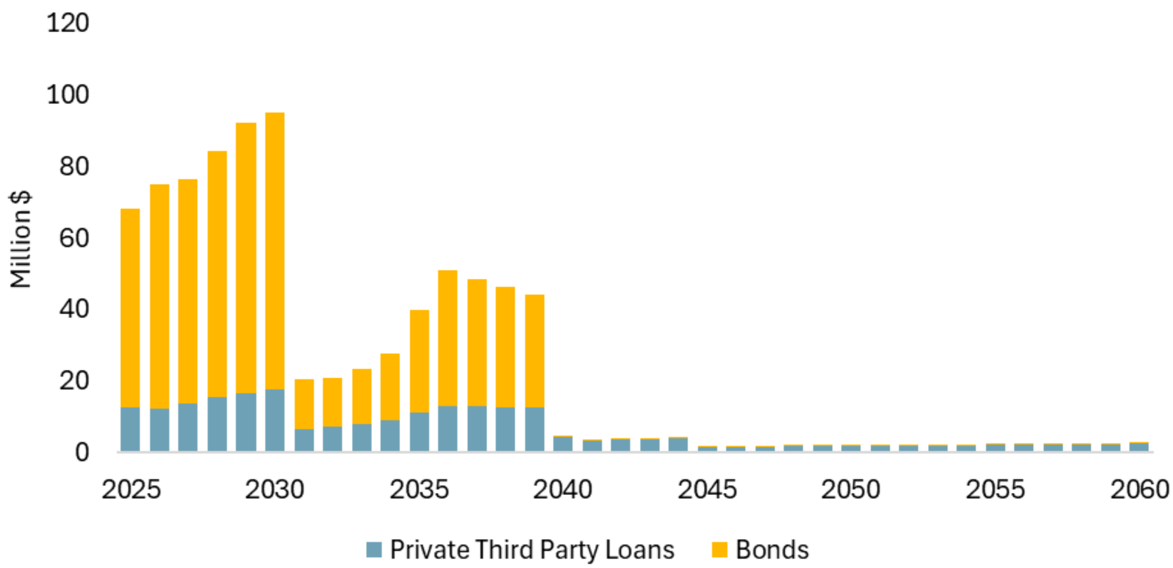


Figure 19. Communitywide borrowing, High Local Action



City Outcomes

The City perspective captures any costs incurred or benefits received by the City of Palo Alto, both as a municipality and a utility. Although there is a distinction between municipal and utility funds and costs within the model, some of the results shown below capture the combined municipality and utility costs.

Ongoing costs and benefits capture anything unrelated to the upfront cost of equipment or the electric system infrastructure. From the City's perspective, ongoing costs and benefits include:

- **Debt repayment:** an ongoing cost to the City is the payment of both interest and principal based on the amount of debt issued.
- **Energy costs:** building and transportation electrification causes a change in Palo Alto residents' energy expenditures, and therefore causes a change in the energy-related costs and benefits associated with the City's perspective. Benefits include increased electricity sales and an avoided gas supply cost, while costs capture reduced gas revenue and increased electric supply costs. These charts do not include operational savings from removing parts of the gas system, which can be added following the Gas Utility Transition Study.[28]

The upfront costs and benefits associated with the City perspective include the following:

- **System costs and benefits:** this captures any incremental costs needed to build out the electric system to support building and transportation electrification.
- **Program costs:** this covers the City's spending on loans and incentives provided to community members, and the purchase of City-owned EVs, EV chargers, and E-bikes
- **Existing City revenue sources:** this captures any City revenue sources that can be used as a funding source to support electrification, such as Cap-and-Trade credits or Low Carbon Fuel Standard (LCFS) credits; it also includes any funding from Public Benefits assumed to be allocated towards electrification programs. Note that these revenue sources have various compliance obligations established by State law. This analysis assumes a scenario in which all revenues are allocated toward emissions reduction actions, but this may or may not be feasible, or may not reflect the policy choices of the City.
- **Federal and State incentives** available to the City[29]
- **Increased electricity sales** in excess of incremental electric supply costs are assumed to contribute to the upfront costs associated with grid modernization, as well as loans and incentives provided to community members for electric devices and vehicles

Ongoing costs and benefits

[28] Preliminary analysis from the early phases of the Gas Transition Study were presented to the City's Climate Action and Sustainability Committee on October 17, 2025, and showed that the approximately 40% of gas utility costs related to the physical gas distribution system would likely require widespread electrification to be completed before significant operational savings could be achieved. https://cityofpaloalto.primegov.com/meetings/ItemWithTemplateType?id=9481&meetingTemplateType=2&compiledMeetingDocumentId=17155

[29] It should be noted that all modeling assumptions around Federal incentives were made in 2024, prior to the repeal of the Inflation Reduction Act. Therefore, the level of Federal incentives included in results may not be currently available, but represent the point in time at which the model was created.

Both ongoing costs and benefits from the City's perspective become more significant as local action increases, as seen in

Figure 20 and Figure 21 below. Ongoing costs incurred and benefits received by the City are influenced by electrification adoption rates and the level of City support for electrification provided. The three sources of ongoing costs for the City are incremental electric supply cost, decreased gas revenue, and debt expense; electric supply cost is derived from an increase in electricity demand, both from transportation and building electrification, and decreased gas revenue is driven by the reduction in gas demand from building electrification. It should be noted that the model assumes that the gas utility continues to operate as it does currently, without cost reductions regardless of electrification, which is why reduced gas revenue is treated as a cost; this is a maximally conservative assumption. Debt expense is driven by the size of the municipal and utility debt issuances necessary to cover up front incentives or loans to community members, as discussed below. Ongoing benefits are also driven by electrification. This model assumes that the City would fund public charging or multi-family charging and receive revenue in return (Charging as a Service revenue), electric sales revenue, and a reduced gas commodity cost as a result of increased electrification.

Figure 20 shows that the Low Local Action scenario yields an ongoing cost gap in 2030; this is largely due to a high debt expense. The utility is expected to issue debt in early years to cover electrical grid modernization costs (covered in upfront costs), which results in a high debt expense that causes a net ongoing cost.

Figure 20. Ongoing City costs and benefits, Low Local Action

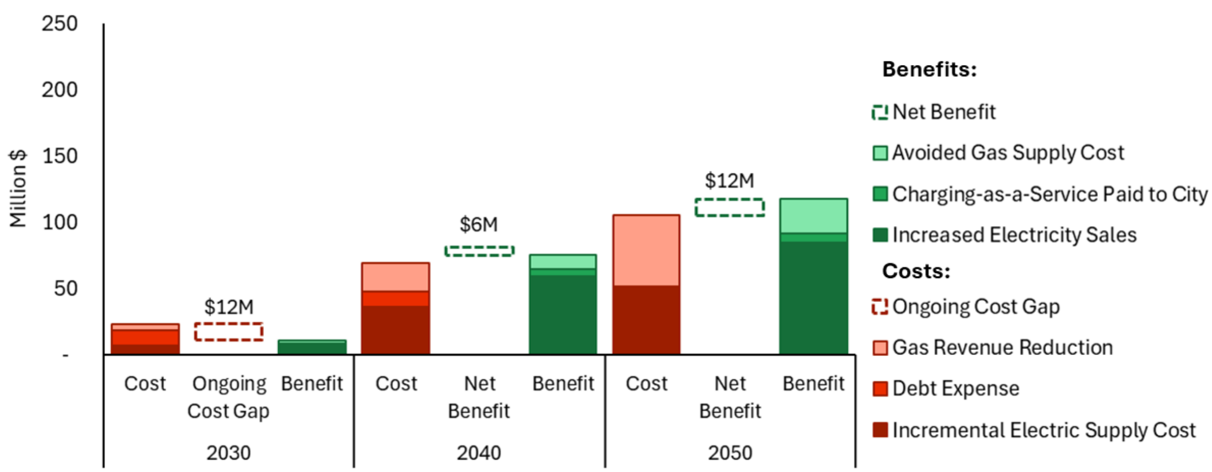


Figure 21 shows that the High Local Action scenario also yields an ongoing cost gap in both 2030 and 2040; similarly to the Low Local Action scenario, this is due to high debt expense in early years caused by debt issued for electrical grid modernization investments.

These ongoing cost gaps would need to be closed by new ongoing revenue sources for the City, most likely taxes. In addition, this model assumes that the City is able to take advantage of increased revenue from increased electricity sales to offset other costs, such as debt service or lost gas utility revenue. Since these funds are theoretically being used to cover electrification costs, it is implied the money will be attributed to this use through the ratemaking process. This requires active policy choices by the City and legal and risk management analysis on how to execute. Without these policy choices this increased revenue would likely be returned to consumers through lower electric rate increases, and the ongoing cost gap shown in Figure 21 would be significantly larger.

Figure 21. Ongoing City costs and benefits, High Local Action

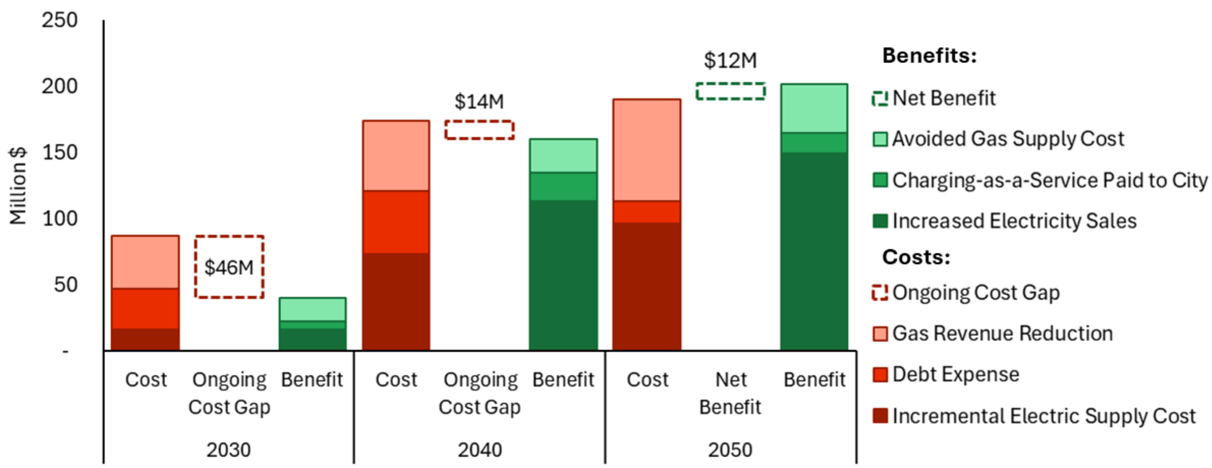
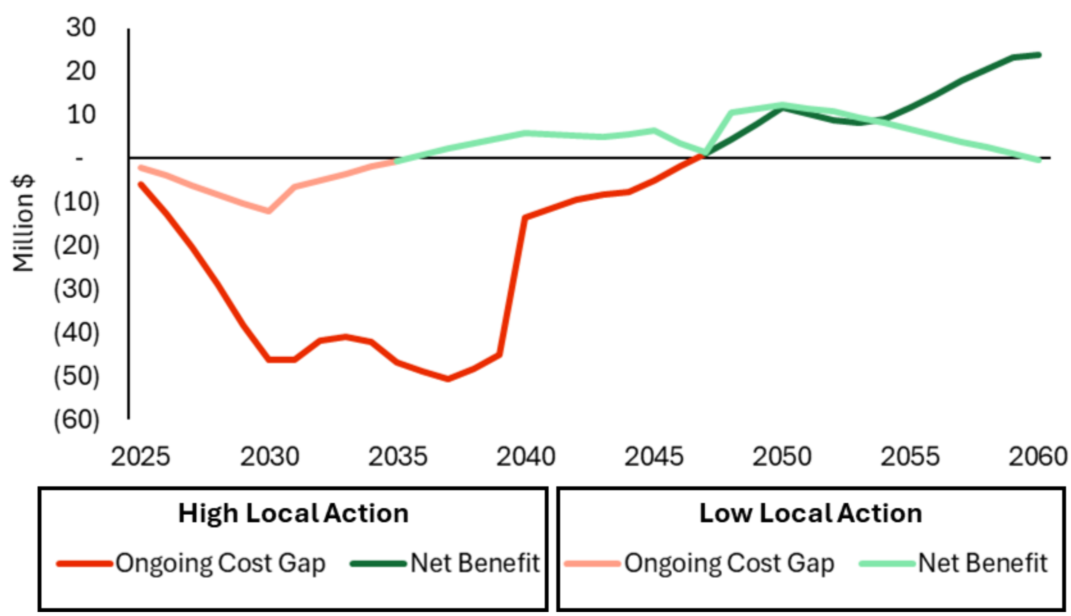


Figure 22 shows the result of the City's ongoing costs and benefits over the lifetime of the analysis for both the Low and High Local Action cases. It includes the net result of all of the costs and benefits from Figures 20 and 21, but the detail is omitted for chart clarity. As shown, in the Low Local Action scenario the City earns an ongoing net benefit from 2036-onward. In the High Local Action scenario, the City earns an ongoing net benefit from 2047-onward.

Figure 22. City ongoing cost gap/net benefit over time



Below are the ongoing costs and benefits incurred by the City, split between those allocated to the utility versus those allocated to the municipality. The majority of ongoing costs and benefits are attributed to the utility, given that they are largely derived from costs and benefits associated with energy use. The CaaS revenue from City-owned public chargers is solely attributed to the municipality. Debt expense is allocated in the model to the City's municipal and utility operations in proportion to the amount of debt issued by either the utility (e.g. for infrastructure or incentive payments) or the municipality (e.g. for EV charger infrastructure).

As shown below in Figure 23 and Figure 24, in both scenarios the utility has an ongoing cost gap across key years. This ongoing cost gap would require additional revenues, likely utility rate revenues, to recover.

Figure 23. Ongoing City costs and benefits, Utility only, Low Local Action scenario

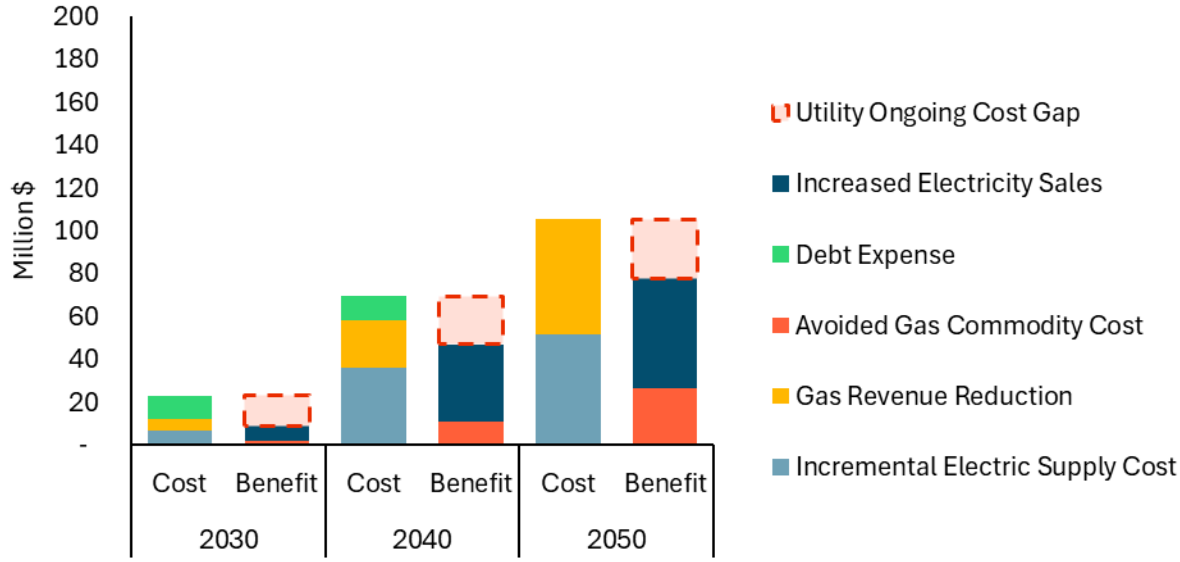


Figure 24. Ongoing City costs and benefits, utility only, High Local Action scenario

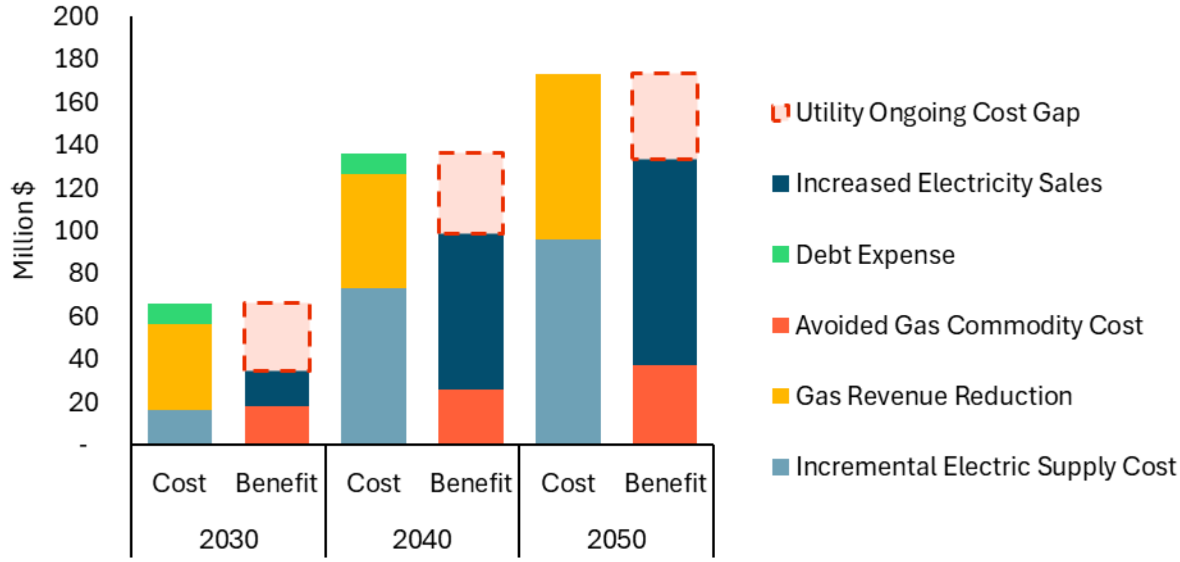


Figure 25 and Figure 26 show the ongoing costs and benefits of the municipality. In the High Local Action scenario the municipality yields an ongoing cost gap in all key years. This is due to the scenario definition, which assigns the debt issuance associated with electrification incentives to the municipal side of the City's operations and involves the City building large amounts of public EV charging to attract multifamily, commuter, and visitor charging, which combined ends up generating a high debt expense relative to CaaS revenue as modeled. In this scenario, CaaS revenue also drops as more community members are assumed to have access to home charging. In 2050, the municipality incurs an ongoing investment gap of $2 million. These would be scenario features to adjust in future City staff model runs to ensure better matching between revenues and expenses assigned to the municipal and utility operations, subject to any applicable legal restrictions. In the Low Local Action scenario, municipal debt issuance is extremely low because much less EV charging is built and the City does not provide many incentives; this causes a low debt expense which allows the municipality to earn an ongoing net benefit across key years.

Figure 25. Ongoing City costs & benefits, municipality only, Low Local Action scenario

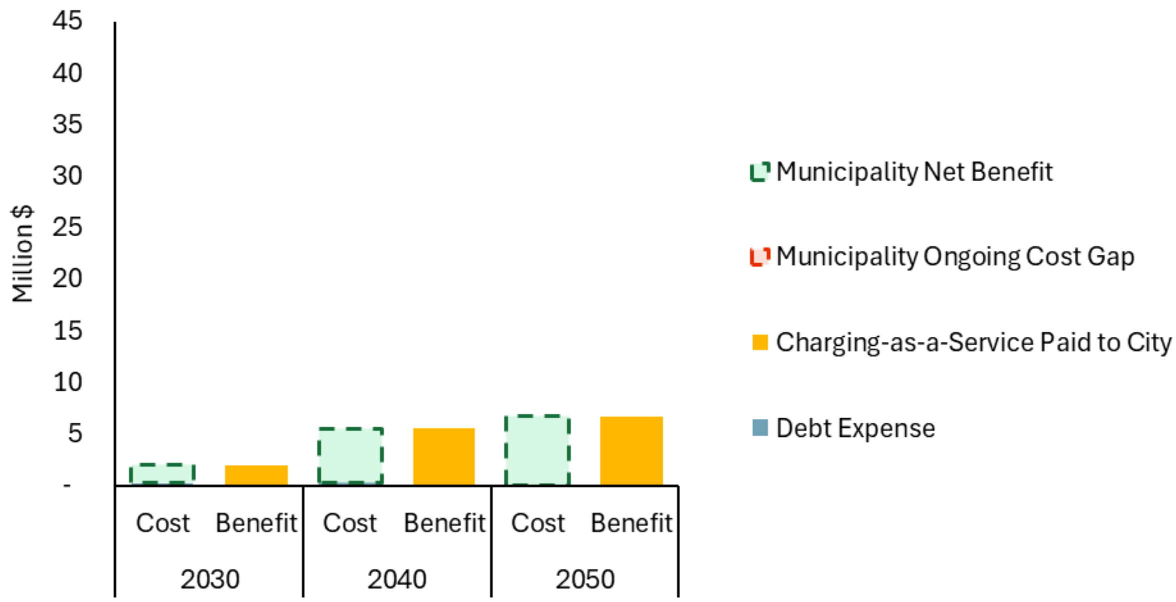
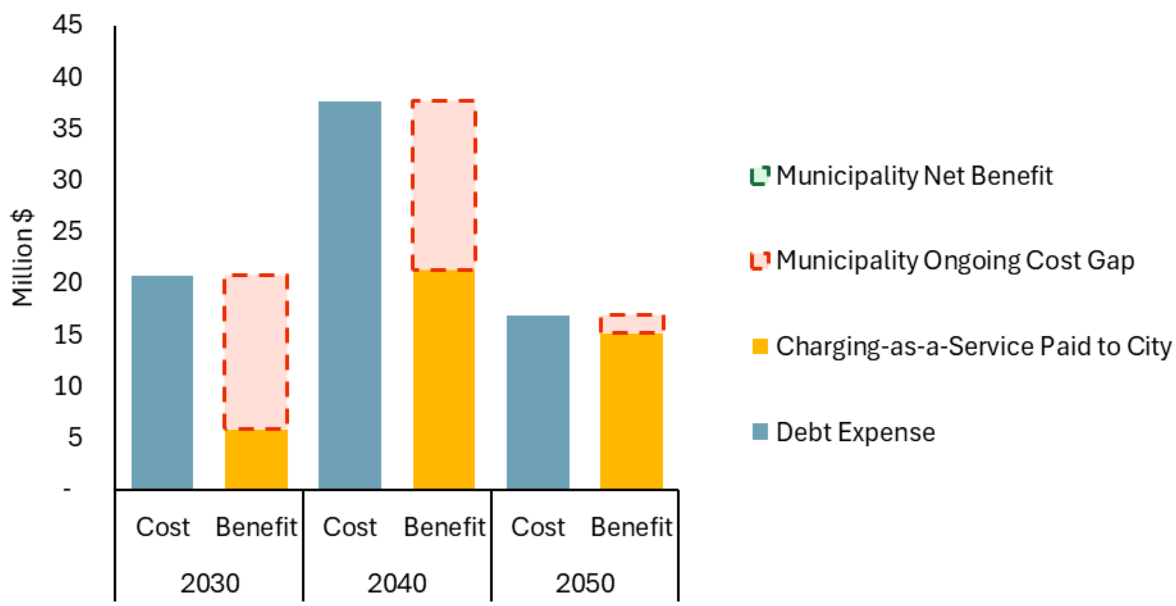
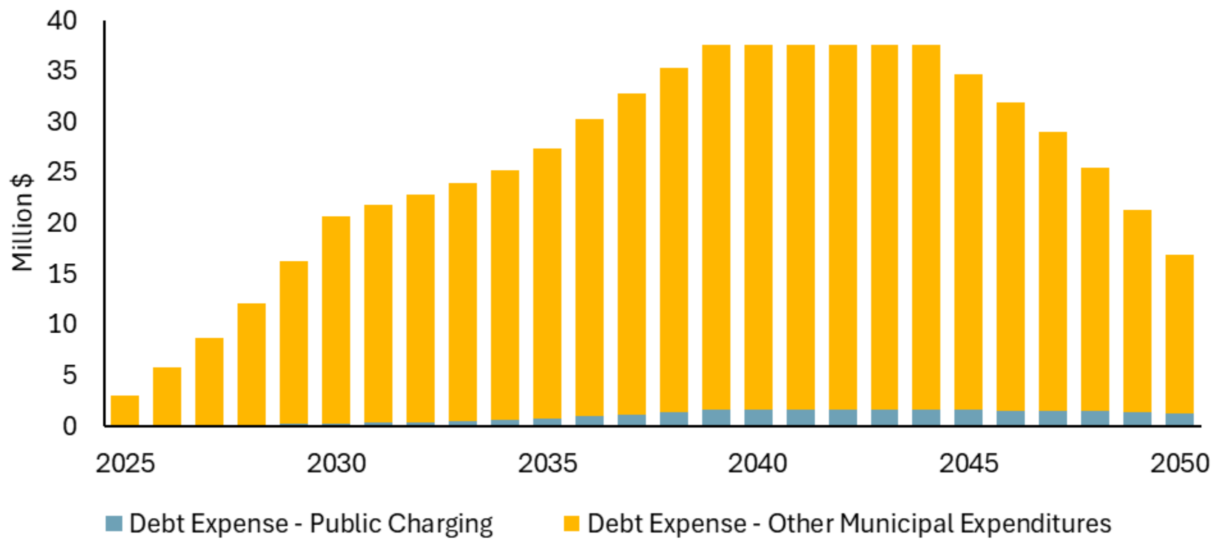


Figure 26. Ongoing City costs and benefits, municipality only, High Local Action scenario



Debt expense is caused by the issuance of municipal bonds in order to cover the purchase of City-owned vehicles and chargers (i.e., for City-owned fleets) and to provide incentives for electrification, as described on page 21 in the scenario definitions. As shown in Figure 27 below, between 2028-2039 in the High Local Action scenario the municipality is projected to issue $21 million in municipal bonds to cover the capital costs associated with public EV chargers. Figure 27 shows the breakdown of municipal debt expense caused by EV charger installation versus the ongoing debt expense associated with the electrification incentives. In the High Local Action scenario, the municipality is projected to issue $512 million in municipal bonds from 2025-2026. Based on the expenses incurred by the municipality, public EV charging causes about 5% of this debt issuance, whereas electrification incentives and other municipal expenses make up the remaining 95%. CaaS revenue generated by the City is modeled to pay back the debt expense incurred by the City (as a municipality and utility) from EV charger installation. Because CaaS revenues and debt expenses vary by year, in earlier years expenses exceed revenues and in later years public charging would be a net revenue generator for the City.

Figure 27. Municipal debt expense, High Local Action scenario



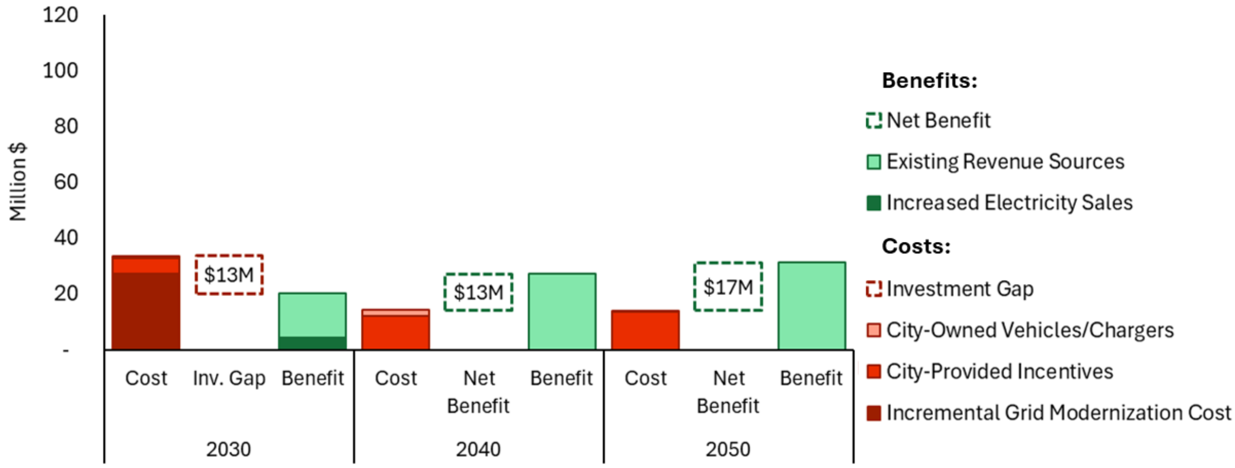
Upfront costs and benefits

Figure 28 and Figure 29 show the upfront costs and benefits from the City's perspective, with both Municipal and Utility costs and benefits included. Upfront costs are largely determined by the level of electric building equipment and EV adoption achieved in a given year, as well as the scenario's assumption about the City's provision of incentives to cover community member incremental upfront costs, as described on page 21 in the scenario definitions.

As stated in the Community Outcomes section, any upfront cost gap will result in the issuance of debt. From the City's perspective, this debt would either be in the form of municipal bonds or utility bonds.

Figure 28 shows the upfront costs and benefits from the City's perspective in the Low Local Action scenario. Under this scenario, the City incurs an investment gap of $13 million in 2030 due to the incremental grid modernization costs associated with electrification. However, in 2040 and 2050 the City receives a net benefit of $13 million and $17 million, respectively. The City's expenditures for City-owned vehicles and chargers will have largely decreased by 2050 given that more investment occurs in earlier years, which allows the City a higher net benefit relative to 2040.

Figure 28. Upfront City costs and benefits, Low Local Action[30]



The High Local Action scenario, shown in Figure 29, involves a large investment in both building and transportation electrification in early years and a high portion of upfront costs covered by the City (see Figure 4); these factors result in a large upfront investment gap for the City's perspective, totaling $72 million in 2030. Incremental grid modernization costs are also included (the cost of investments associated with increasing distribution system capacity for electrification as opposed to replacement of equipment serving existing electric loads). However, in later years as upfront costs decrease (because the grid modernization program is assumed to be completed earlier in the analysis period) and upfront benefits (e.g. Existing Revenue Sources) increase, the City receives a net benefit of $11 million in 2040 and $26 million in 2050.

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[30] Footnote to Figure 28 with additional detail on legend categories;

- "Net Benefit" or "Investment Gap" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Increased Electricity Sales" is the incremental new electric sales revenues net of the electric supply cost.
- "City-Owned Vehicles/Chargers" represents the cost of city vehicles, chargers, and public charging stations.
- "City-Provided Incentives" are the incentives provided to community members to cover the incremental up-front cost of electrifying equipment, as described on page 21 in the scenario definitions, and is assumed to be borne by lenders in this illustrative scenario.
- "Incremental Grid Modernization Cost" represents the incremental up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

Figure 29. Upfront City costs and benefits, High Local Action[31]

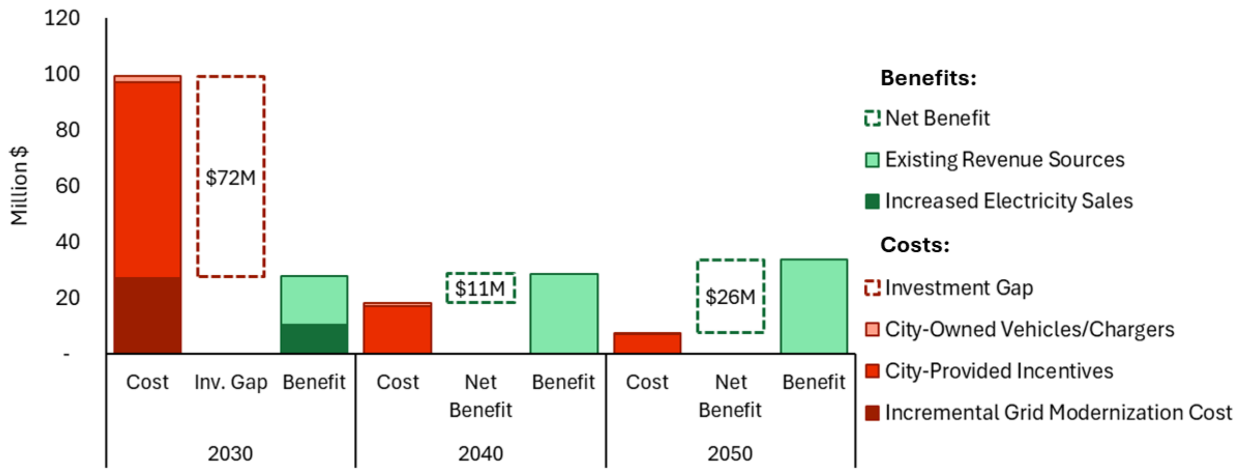


Figure 30 shows the upfront City investment gap or net benefit over time for both scenarios. In the High Local Action scenario, the City's upfront investment gap peaks in 2030, when incentives provided to community members are highest, at $72 million. The City's issuance of incentives decreases significantly in 2031 causing the investment gap to decrease sharply; however, costs of City-owned vehicles and chargers increases, causing the gap to widen again through from 2035-2036. The City begins to receive a net benefit in 2040, and does so for the remainder of the study period. Under the Low Local Action scenario, the City starts off with an upfront net benefit while investment in electrification is still relatively low. The City incurs an upfront investment gap from 2026-2030; the investment gap peaks at $17 million in 2027.

[31] Footnote to Figure 29 with additional detail on legend categories;

- "Net Benefit" or "Investment Gap" means all savings in the chart net of all costs in the chart
- "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues
- "Increased Electricity Sales" is the incremental new electric sales revenues net of the electric supply cost.
- "City-Owned Vehicles/Chargers" represents the cost of city vehicles, chargers, and public charging stations.
- "City-Provided Incentives" are the incentives provided to community members to cover the incremental up-front cost of electrifying equipment, as described on page 21 in the scenario definitions, and is assumed to be borne by lenders in this illustrative scenario.
- "Incremental Grid Modernization Cost" represents the incremental up-front costs of the electric utility grid modernization program and is assumed to be borne by lenders in this illustrative scenario (buyers of electric utility debt) with later repayment by electric ratepayers.
- Note that the beneficiaries and payors noted above can change based on the funding and financing strategies chosen. For example, under a system of up-front incentives, more of the up-front cost is paid by the City rather than lenders, while under a version with incentives paid over time (or funded by debt) the up-front cost is paid by lenders.

Figure 30. City funding gap/net benefit over time

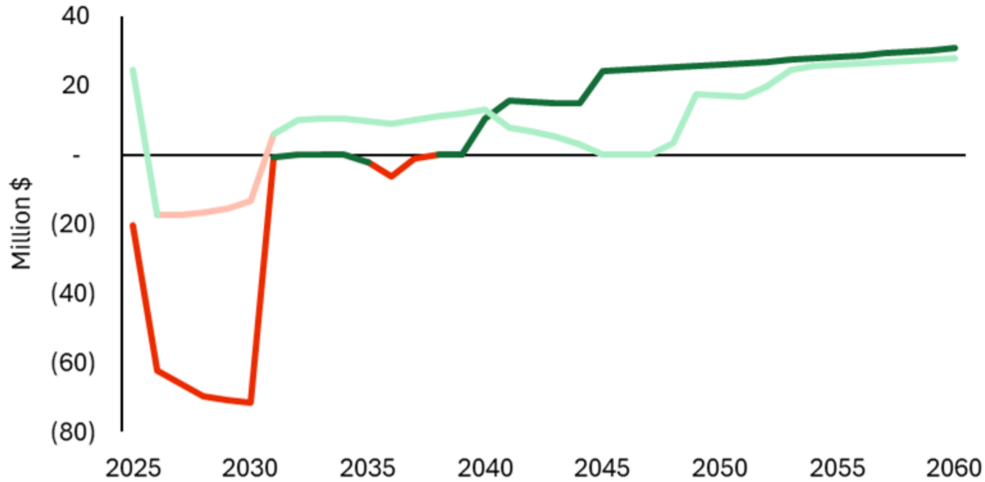


Figure 31 and Figure 32 show the upfront costs and benefits of the City in its role as a municipality. A major upfront cost for the municipality across scenarios is the purchase of City-owned vehicles and EV chargers. An additional upfront cost that has a significant impact in the early years of the High Local Action scenario is the municipality's portion of City-provided incentives paid to community members for electrifying their homes, businesses, and vehicles. Given these high costs and the relative lack of upfront benefits in early years, the City as a municipality has a cost gap of $63 million in 2030 in the High Local Action scenario. This assumes that the City would issue municipal bonds to raise the capital needed to provide these incentives.

In later years across scenarios the municipality will receive a net benefit, meaning benefits exceed costs.. The municipality's net benefit is caused by a reduction in upfront costs, as most community members are assumed to have already electrified in earlier years and less incentives are needed. The 2050 net benefit from the City's perspective as a municipality ranges from $14 million to $18 million.

Figure 31. Upfront City costs and benefits, Municipality only, Low Local Action scenario

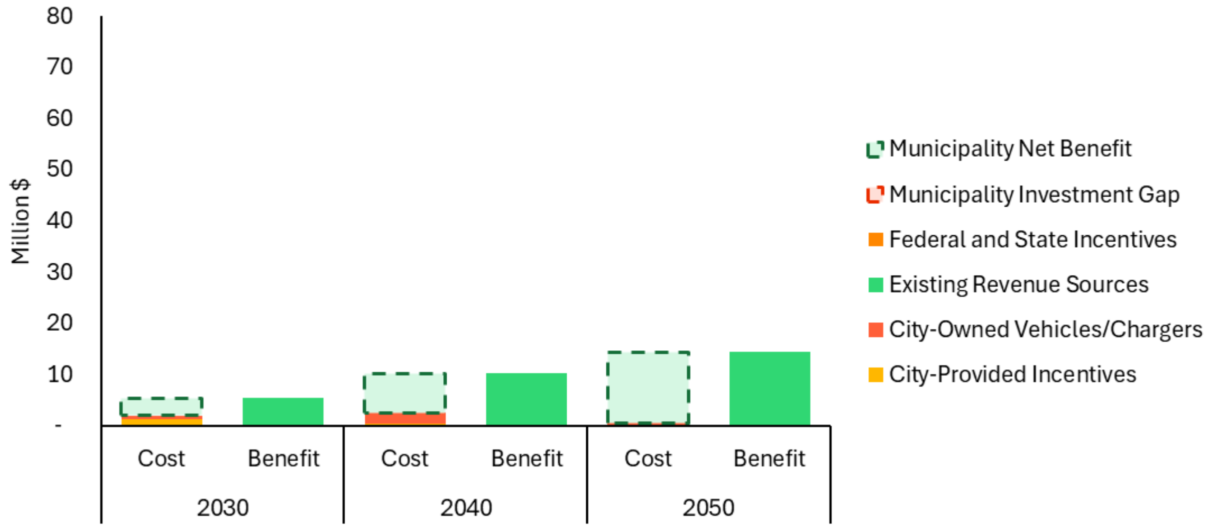


Figure 32. Upfront City costs and benefits, Municipality only, High Local Action scenario

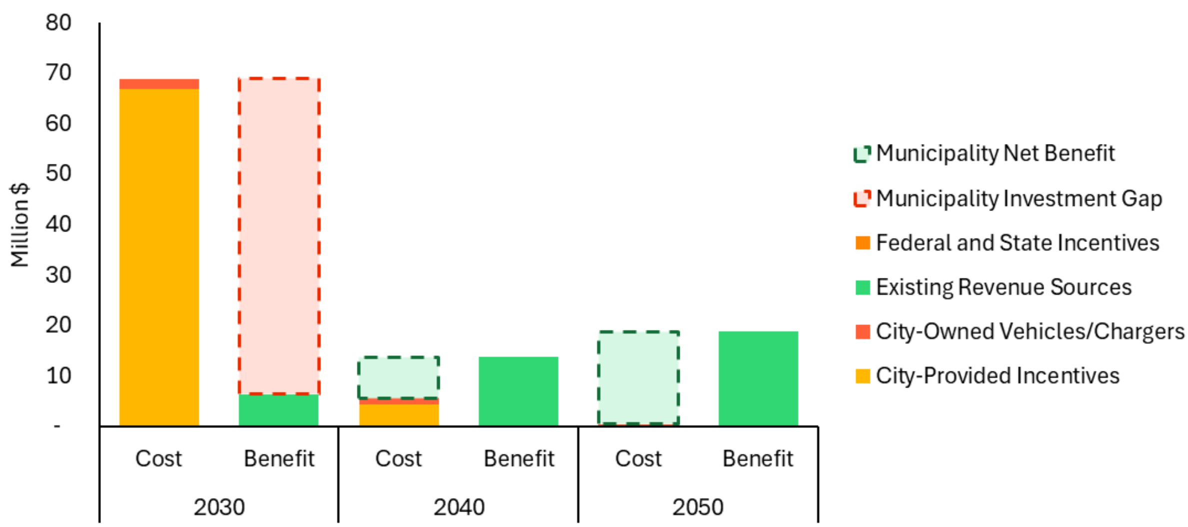


Figure 33 and Figure 34, similarly, show the City upfront costs and benefits specific to the City as a utility. A significant cost for the utility is the incremental electric system cost needed for grid modernization to support electrification. The other major cost incurred by the utility is the utility's portion of the City-provided incentives paid to community members. As shown below, the grid modernization cost in 2030 is significant, leading to an investment gap of $9-17 million for the utility. However, the utility receives a net benefit in both 2030 and 2040 in both scenarios.

It should be noted that as more community members electrify, the utility will receive increased capital from existing revenue sources as a result. For example, as more community members purchase EVs, the utility will receive more LCFS credits, which will lead to extra revenue that can be used to provide loans and incentives or purchase City-owned EVs and chargers.

Figure 33. Upfront City costs and benefits, Utility only, Low Local Action scenario[32]

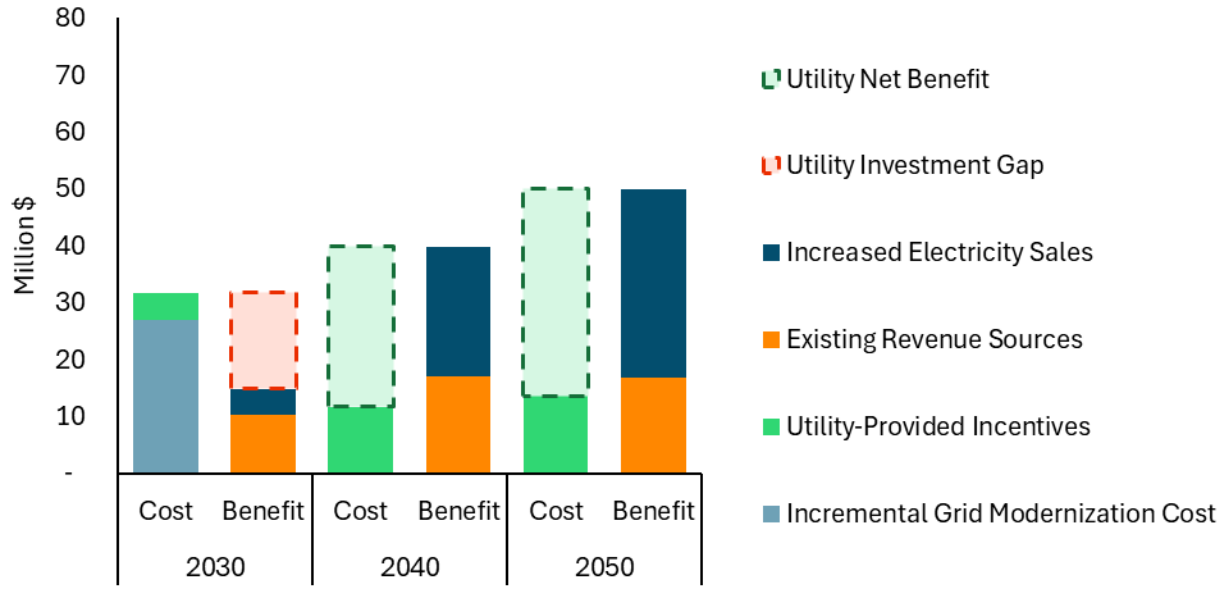


Figure 34. Upfront City costs and benefits, Utility only, High Local Action scenario[31]

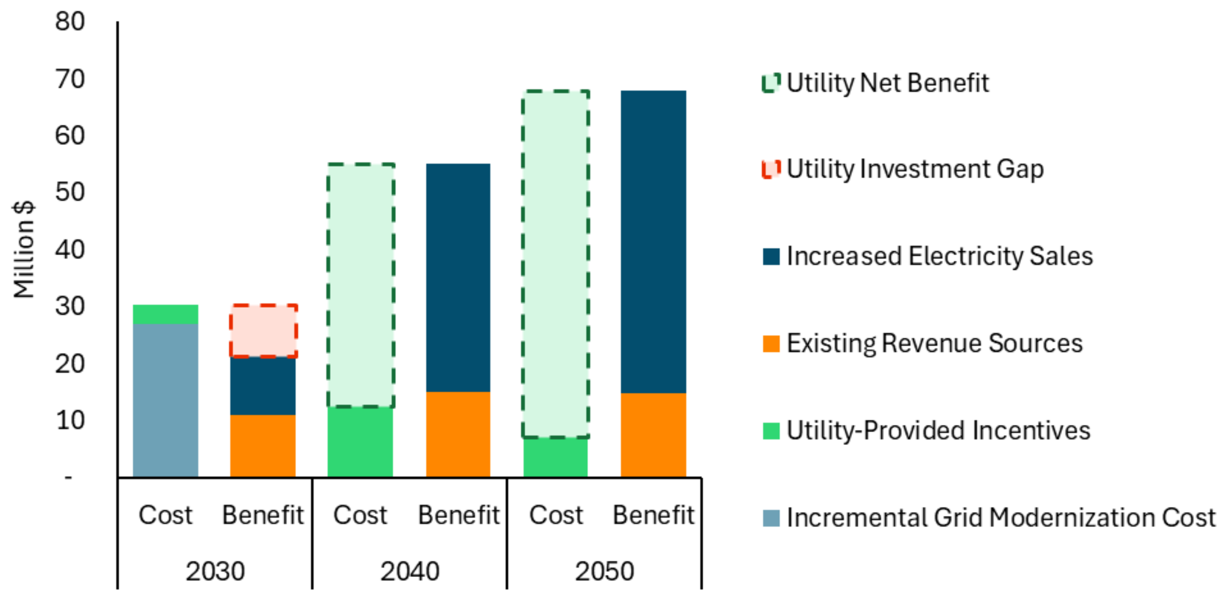


Figure 35 and Figure 36 below show the amount of necessary debt issuance from the City's perspective, split into municipal and utility bonds. The amount of debt issued in a given year is solely the amount necessary to cover upfront costs; the debt will be paid off over time, with principal and

[32] "Existing Revenue Sources" means Electric Public Benefits, Electric and Gas Cap and Trade, and Low Carbon Fuel Standard revenues

interest payments both contributing to the overall debt expense – an ongoing cost.

Figure 35. City borrowing, Low Local Action scenario

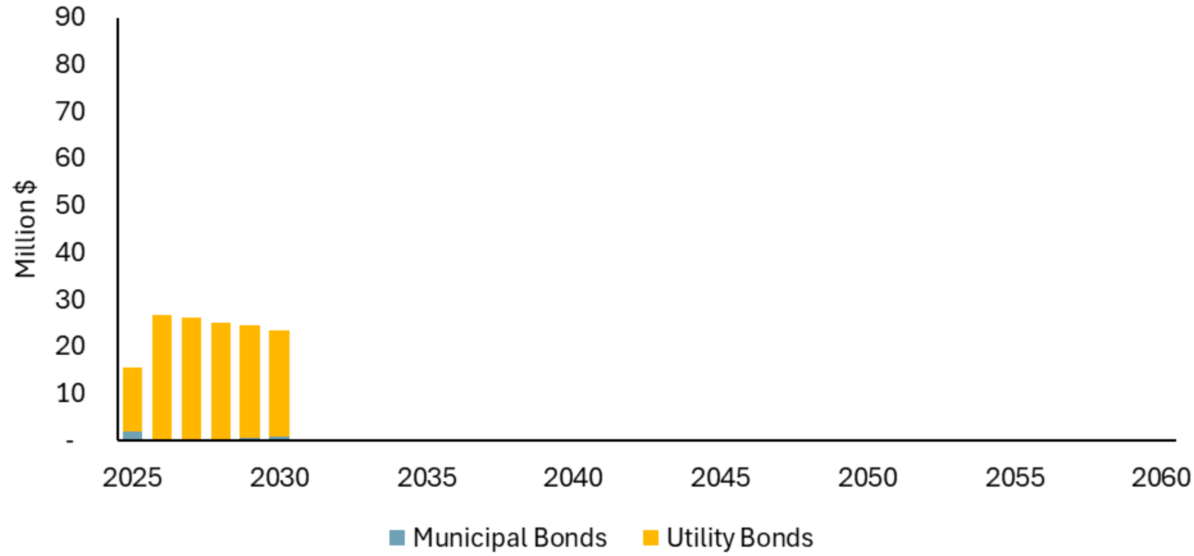
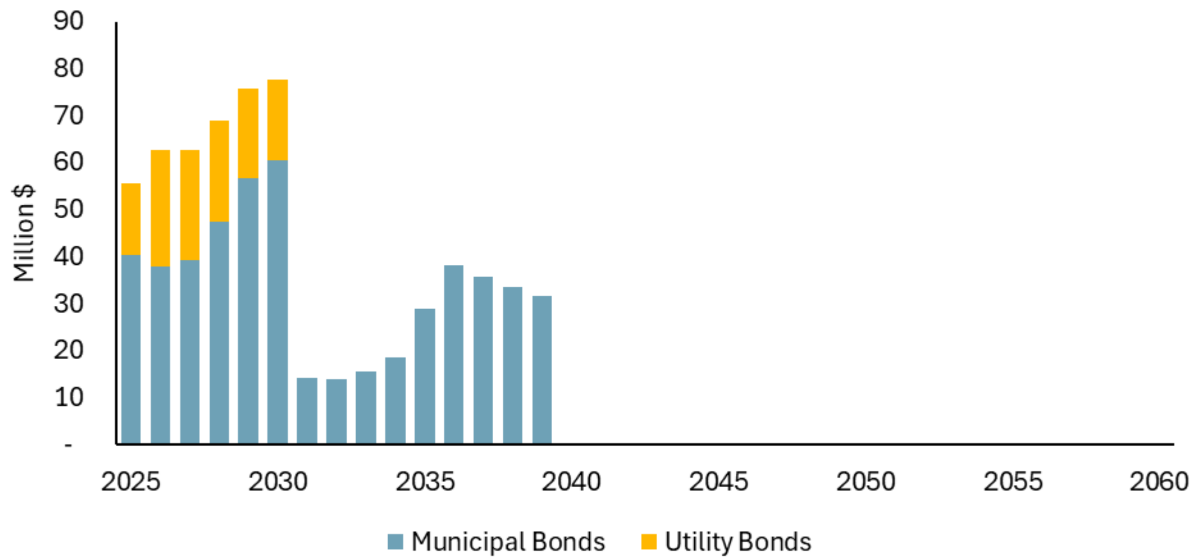


Figure 36. City borrowing, High Local Action scenario



Sectoral and Community Member Outcomes

In addition to the total community costs and funding gap for the City of Palo Alto, it is also critical to consider the impact of electrification on each sector (single family, multifamily, non-residential) and on annual household expenses for community members.

Transportation and building electrification impact the type and quantity of energy that community members use at home. For example, if a household or non-residential building transitions from a gas furnace to an all-electric ASHP, their natural gas consumption will decrease, but their electricity consumption will go up substantially. Similarly, if a household or non-residential building transitions from an ICE vehicle to an EV, their gasoline consumption will decrease, but if they charge their EV at home, their electricity consumption will increase significantly (however, use of an e-bike or alternative transportation will not increase electricity consumption significantly). Depending on the cost of each type of energy and the amount used, these changes in energy consumption could lead to either a net cost or a net benefit for the sector as a whole or an individual community member.

There are also significant upfront costs associated with transportation and building electrification. The upfront costs from the community members' perspective include any capital expenditure needed for building or transportation electrification, and any necessary electric panel or service upgrade cost. That being said, a customer also faces upfront costs to purchase non-electrified equipment, such as replacing their gas furnace or ICE vehicle at end of life. The difference in upfront cost between the electric equipment and the like-for-like non-electrified equipment is referred to as the "incremental cost." Often times, the electric equipment is more expensive than the non-electrified alternative, but this is not always the case, and as efficiencies are achieved over time these upfront costs for new electric technologies are expected to decrease. In the meantime, support from the federal and state government, third party loan providers, and from Palo Alto can help reduce upfront costs for residents by providing incentives (e.g., rebates that require no repayment), or loans.

Support from the federal, state, and local government is especially important for low- and moderate-income households in Palo Alto that may not otherwise be able to afford the upfront costs of electrification. While it may be more costly to the City to provide additional support to customers to reduce the burden of upfront electrification costs, this investment may be a critical component in advancing access to clean technologies in Palo Alto.

Across the different modeled local action scenarios, Palo Alto would provide varying levels of support to different sectors and individual households to offset upfront costs of electrification. For example, in the High Local Action scenario, Palo Alto provides greater support to defray those costs via incentives, encouraging early retirement of existing equipment. In the Low Local Action scenario, Palo Alto commits to less support for electrification, and relies more on the Zero NOx standard to drive adoption at the time of equipment burnout.

This section will cover the financial impacts on each sector in Palo Alto (single family, multifamily, and non-residential) as well as affordability impacts on individual electrifying vs. non-electrifying residential and commercial customers.

Sector-Level Impacts

Overall, this analysis found that while electrification will increase upfront costs, City-provided incentives and operational cost savings can offset those upfront costs to make electrification cost effective for residential sectors of the community, such as single family and multifamily buildings (Figure 37 and Figure 39), acknowledging, however, that the cost of these incentives will need to be recovered from the community through taxes or other revenue sources. For residential customers, avoided gasoline costs – as the result of switching ICE vehicles to EVs – are the primary driver of operational cost savings. For non-residential customers, avoided gasoline and natural gas are significant drivers of cost savings as well, but the non-residential sector also sees savings from avoided electricity consumption from air conditioning, as most commercial buildings have AC (Figure 41).

The residential sector will see large increases in upfront costs for building and vehicle electrification. For the High Local Action scenario, upfront costs are most likely to be seen in early years given significant capital investments are needed early on to reach aggressive 2030 emissions targets. Upfront building electrification costs for the single-family sector could total $91M/year and upfront transportation electrification costs could reach $63M/year by 2030 (Figure 38). For the multifamily sector, upfront building electrification costs could reach $59M/year and upfront transportation costs $65M/year by 2030 (Figure 40).

Upfront costs for residential customers are assumed to be met through a combination of savings from avoided fossil fuel equipment replacement (e.g., ICE vehicles, gas furnaces, etc.), City-provided incentives, federal/state incentives, and third-party external loans. The single family sector could see a range of $32M - $99M avoided fossil fuel equipment costs, $7M - $15M federal/state incentives, and $2M - $32M City-provided incentives, and $6M - $8M external loans by 2030 (Figure 38). The multifamily sector could see a range of $32M - $83M avoided fossil fuel equipment costs, $7M - $14M federal/state incentives, $3M - $22M City-provided incentives, and about $6M external loans by 2030 (Figure 40).

However, the residential sector will also see significant reductions in operating costs from electrification, with the single family sector avoided natural gas bills reaching up to $43M/year and avoided gasoline bills up to $88M/year by 2050 in the High Local Action scenario (Figure 37). Avoided natural gas bills in the multifamily sector could reach up to $17M/year and avoided gasoline bills up to $107M/year by 2050 in the High Local Action Scenario (Figure 39).[33] Overall, the single family sector could see a range of $20M - $28M of net ongoing cost savings in year 2030 (Figure 37), increasing to $55M - $72M by 2050. The multifamily sector could see a range of $22M - $30M cost savings in 2030, increasing to $73M - $89M by 2050. (Figure 39).

[33] Avoided gasoline costs for multifamily are higher than single family because current EV adoption is mostly driven by single family drivers. In the high EV adoption scenarios, a significant portion of EV adoption is driven by MF drivers since it is likely the SF sector will reach full saturation.

Figure 37: Single family sector-level ongoing cost results for Low vs. High Local Action (million $/year)

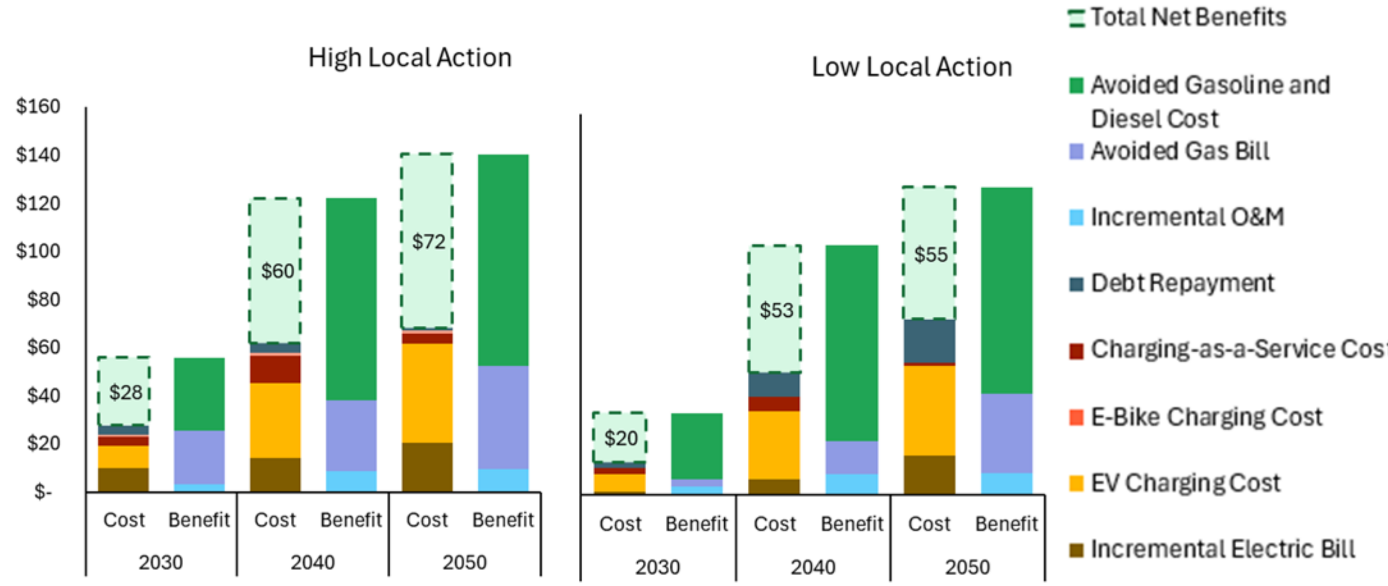


Figure 38: Single family sector-level upfront cost results for Low vs. High Local Action with incentives (million $/year)

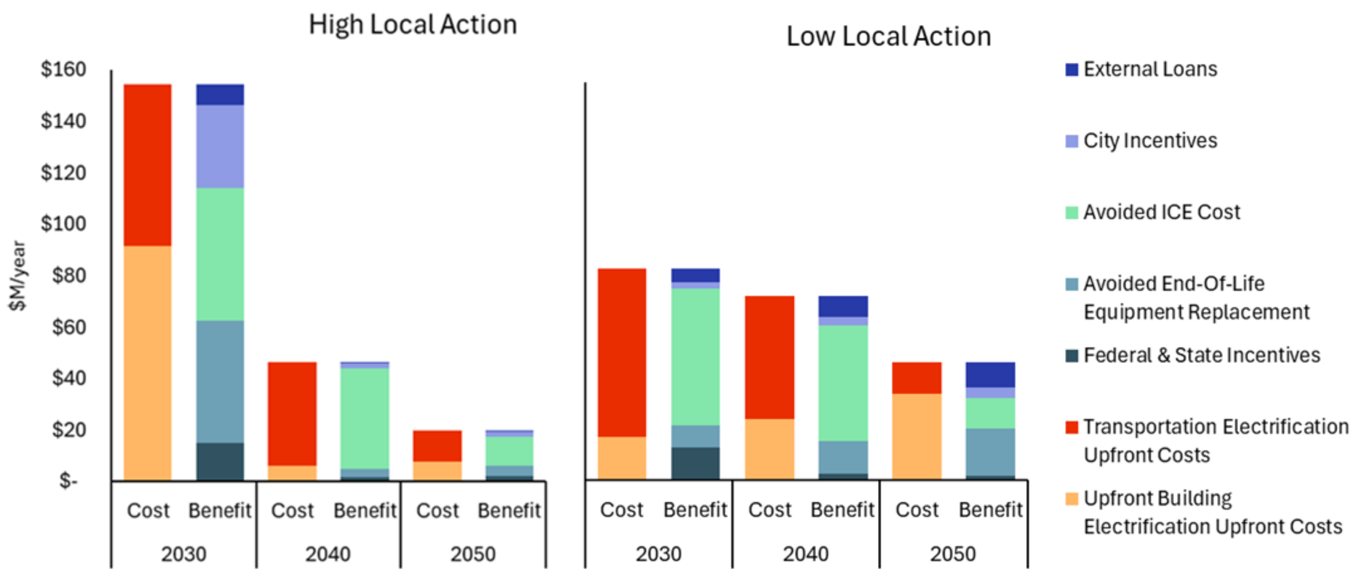


Figure 39: Multifamily sector-level ongoing cost results for High vs. Low Action with incentives (million $/year)

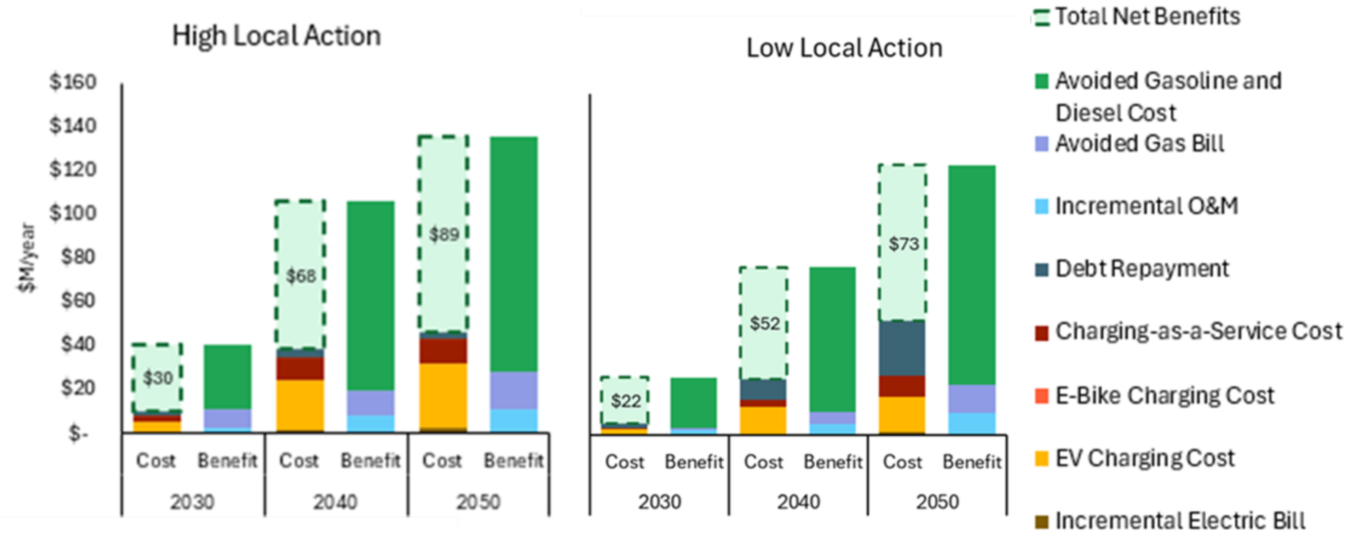
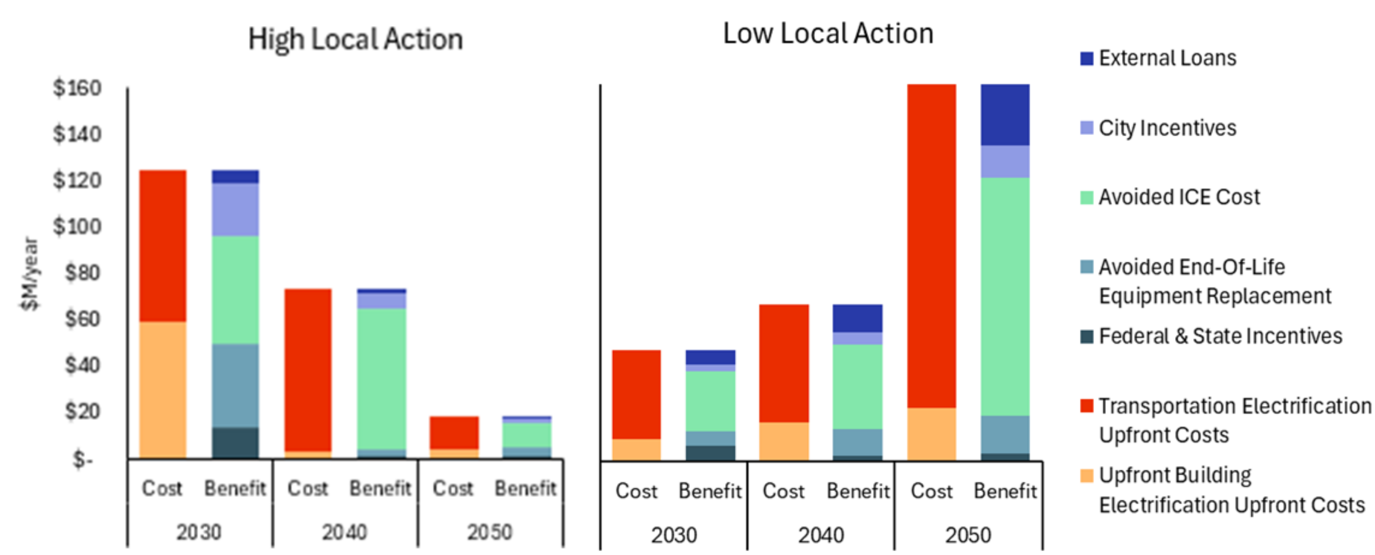


Figure 40: Multifamily sector-level upfront cost results for High vs. Low action with incentives (million $/year)



Similar to the residential sector, the non-residential sector – including office, education, and retail buildings – will experience significant new upfront costs for building electrification and the electrification of medium-duty commercial fleet vehicles. In the High Local Action scenario, upfront costs for building electrification could reach $124M/year for the entire non-residential sector (Figure 42) and $18M for commercial fleet electrification (Figure 42). These costs are assumed to be met through avoided fossil fuel equipment replacement, City-provided incentives, and external loans.

The non-residential sector is also expected to see significant ongoing net benefits in the High Local Action scenario, reaching nearly $27M ongoing cost savings by 2050 (Figure 41). These cost savings are primarily driven by avoided natural gas bills, avoided gasoline from commercial fleets, and avoided electricity from air conditioning. In the Low Local Action scenario, the lower levels of operational savings coupled with higher debt repayments leads to ongoing net costs, totaling about $8M in 2050 (Figure 41).

Figure 41: Non-residential sector-level ongoing cost results for High vs. Low action (million $/year)

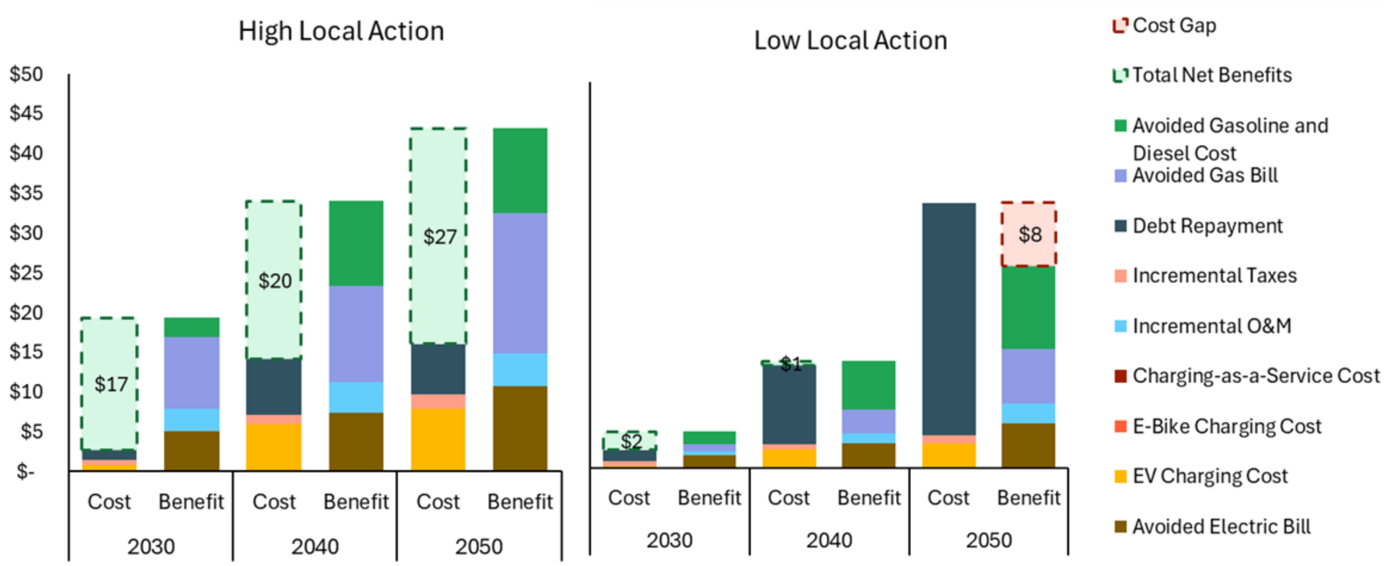
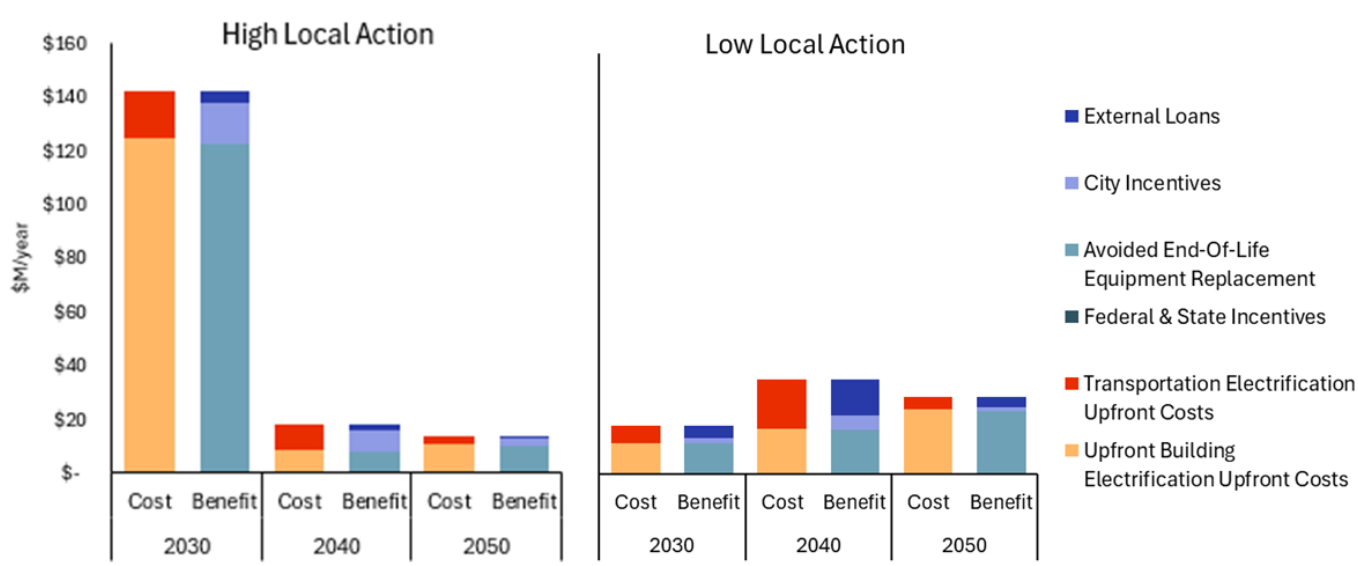


Figure 42: Non-residential sector-level upfront cost results for High vs. Low action with incentives (million $/year)



Under low levels of local action in Palo Alto, community members will have to take on a larger portion of the incremental cost of electrification. In the modeling, for simplicity, this is assumed to happen by financing upfront costs through external loans (i.e., third party lenders).

In the Higher Local Action scenario there are fewer external loans to community members, with the City providing a higher level of incentives. However, this creates a need for additional revenue sources such as taxes for the City to cover these incentives. The impact of these revenue sources on sectors and community members depends on the type of tax or revenue source considered. These impacts are not shown in this section, but are shown in the Section below titled Tax Implications.

Figure 43 and Figure 44 show the total external loans and City-provided incentives for the Low Local Action scenario and High Local Action scenario, respectively. In the High Local Action scenario, the short-term incremental electrification costs are higher, but Palo Alto provides the residential sector with significant levels of support through incentives. In the Low Local Action scenario, the near-term incremental electrification costs are less extreme, but the residential sector must rely more heavily on external loans since City-provided support is lower.

Figure 43: External loans and City-provided incentives for Low Local Action by sector (millions $/year)

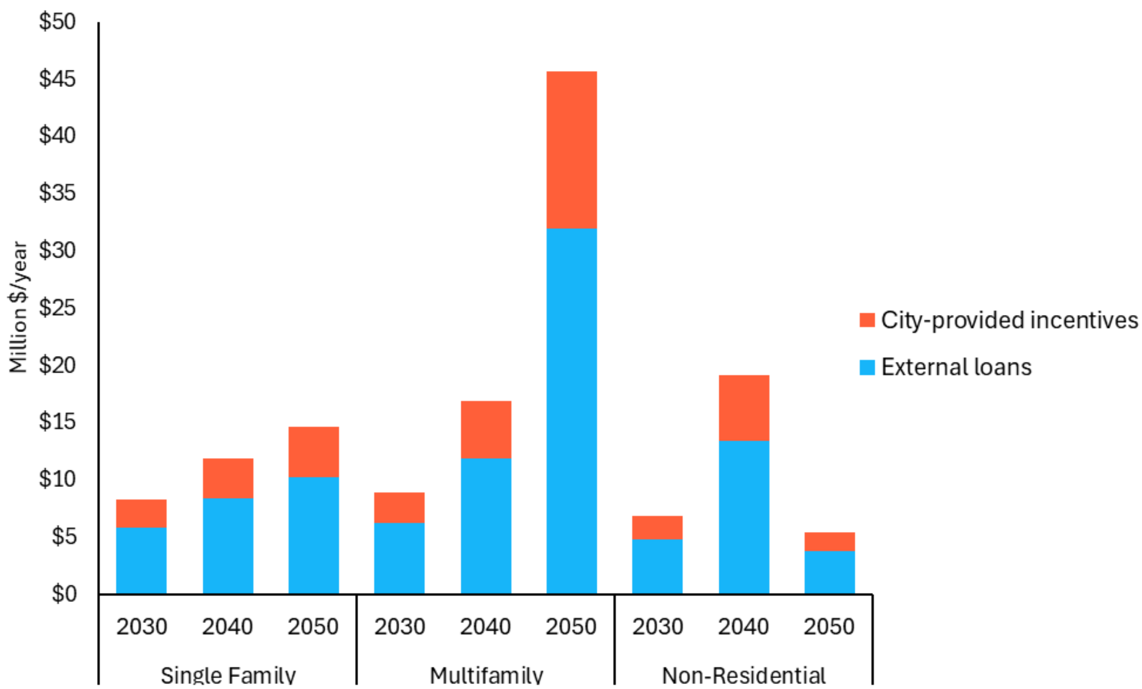
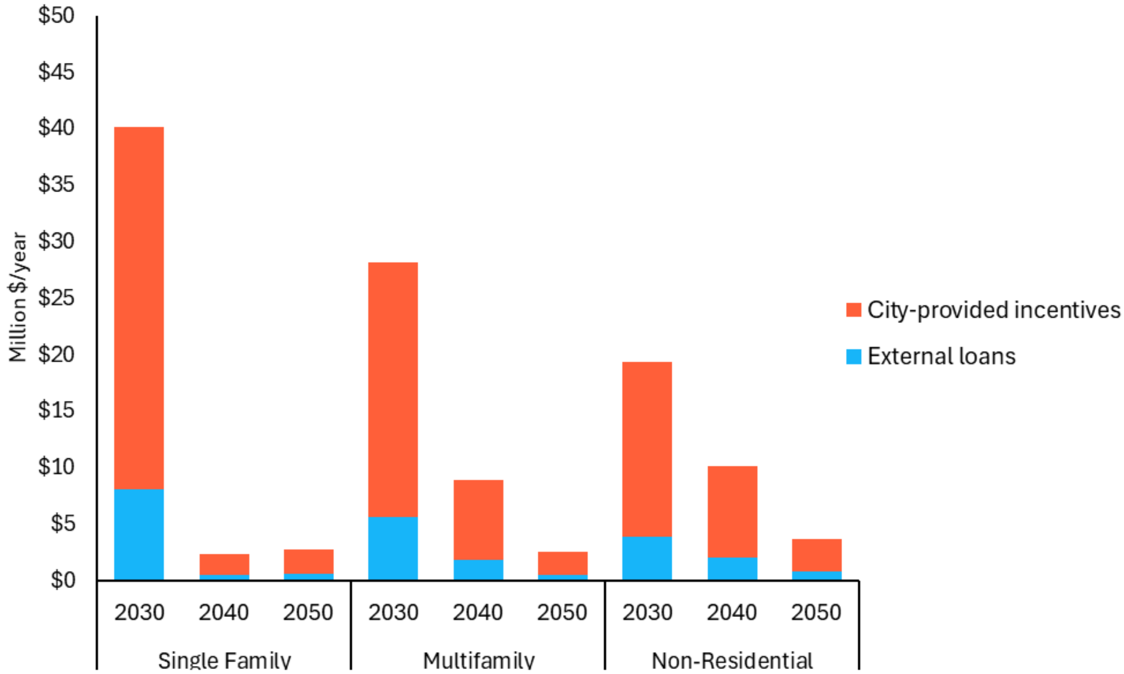


Figure 44: External loans and City-provided incentives for High Local Action by sector (millions $/year)



Across all scenarios, as electrification increases, customer debt also increases. This is because customers are likely to have to finance the upfront expenses for electrification equipment and pay back the cost over time. However, for the residential sector, the ongoing debt repayment may be partially or entirely offset by the significant ongoing operational cost savings of electrifying, as seen in Figure 37 and Figure 39 above.

Household Expenses for Individual Customers

While the section above describes the cost results for the residential and non-residential sectors as a whole, it is also important to explore the impacts of electrification on individual customers, by comparing their annual household energy expenses with and without different types of electrification, as well as with and without City-provided incentives. For this analysis, E3 utilized the Palo Alto Affordability Calculator.

The annual household energy expenses considered in this analysis include:

- Electricity costs
- Natural gas costs
- Gasoline costs
- Incremental ICE maintenance cost (compared to EV)
- Debt repayment
- Incremental appliance cost (e.g., for an ASHP vs. a gas furnace)
- Incremental vehicle cost (ICE vs. EV considering available incentives)
- Incremental e-bike cost

- E-bike maintenance cost

The annual household benefits considered in this analysis include:

- Federal and state incentives (e.g., the IRA tax credits for heat pumps)
- Prospective incentives provided by Palo Alto (calculated in the S/CAP Funding Model)
- Prospective loans provided by Palo Alto (calculated in the S/CAP Funding Model)
- Prospective loans provided by third-party lenders (calculated in the S/CAP Funding Model)

Overall, this analysis found that **transportation electrification is cost effective** for both single family and multifamily customers, even before City-provided incentives are included. With the current electric/gas rate structure and federal/state incentives available – not including any additional City incentives – building electrification would incur additional costs for single family residents and would cost about the same as non-electrification for multifamily residents. In both cases, results vary depending on whether the home already has air conditioning.

Additional City-provided incentives could help make building electrification more cost effective for customers. The results in this section assume that City-provided support for electrification will come in the form of incentives alone. In reality, it is a policy decision for the City on how much of the support will be provided via incentives vs. via loans to customers. It's important to note that the results in this section do not include the impact of generating new funding sources for the City to provide incentives. For example, this section does not include the impact of incremental taxes used to generate additional revenue on individual community members' household expenses; those impacts are instead shown in the Tax Implications section.

All results in this section consider upfront costs as the **incremental cost compared to the like-for-like replacement of existing equipment**. That is, the incremental cost of an ASHP is calculated as the cost of an ASHP less the cost of a gas furnace + AC (if the household has AC). It's important to note that when considering federal and state incentives for building and transportation electric technologies, such as ASHPs and EVs, some non-electrified technologies are slightly more expensive than electric technologies (represented in the figures below as "incremental" costs). For example, since there are generous federal and state incentives available for EVs, it is actually more expensive on a lifecycle basis to purchase an ICE vehicle than an EV, even before considering any additional Palo Alto-provided incentives.

Annul household expenses for a mixed fuel single family home with an ICE vehicle in 2025 total about $6,000 (Table 1, Figure 45) and about $4,500 for a multifamily home (Table 1, Figure 46). The largest expenses for non-electrified customers in 2025 are electricity (for appliances, air conditioning, etc.), natural gas, and gasoline.

For a mixed fuel household, the introduction of transportation electrification alone leads to a significant decrease in annual household expenses – annual household costs decrease by nearly $2,400/year for a total annual household cost of about $3,500 (Table 1, Figure 45). These cost savings are driven by the avoided gasoline cost and avoided ICE maintenance cost. For multifamily customers, purchasing an EV leads to similarly large cost savings of about $2,300/year for a total annual household cost of about $2,300 (Table 1, Figure 46). The modeled households also purchased an e-bike. While there are some new costs incurred by the homeowner, such as the upfront cost of the e-bike and increased electricity usage to charge the EV (it is assumed that the customers shown all charge their EV at home), these costs are entirely offset by the significant gasoline savings. As stated above, the incremental cost of the EV is eliminated due to the federal and state rebates that are available, such as the Inflation Reduction Act EV tax credit, the CA Clean Vehicle Credit (CVAP), and the California Electric Car Rebate (CVRP).[34]

Before considering City-provided incentives, the addition of building electrification increases the cost for households that already have an EV. The cost increases are more significant for homes that do not already have air conditioning, since those households are likely to see higher electricity bills and higher incremental upfront costs. The electrification of home equipment and appliances increases annual operating costs for single family households with AC by about $800/year, bringing total annual household costs to about $4,200 and reducing cost savings to $1,700/year (Table 1, Figure 45). The electrification of home equipment and appliances increases annual costs for single family homes without AC by about $2,000/year, bringing total annual household costs to about $4,600 and reducing cost savings to just $400/year (Table 1, Figure 45). Building electrification in multifamily buildings leads to slightly lower cost increases for households that already have an EV. This is primarily due to the fact that the upfront cost for multifamily residential ASHPs is smaller than the upfront cost for single family residential ASHPs. For multifamily units with AC, building electrification increases costs by about $200/year, reducing overall cost savings to $2,100/year (Table 1, Figure 46). For multifamily units that do not have AC, building electrification increases costs by about $500/year, reducing overall cost savings to about $1,800/year (Table 1, Figure 46).

Table 1. Annual household expenses for different household scenarios*

	SF - Cost	SF - Savings	MF - Cost	MF - Savings	SF - Cost	SF - Savings	MF - Cost	MF - Savings
Mixed Fuel + ICE Vehicle	$6,000	n/a	$4,600	n/a	$5,000	n/a	$4,400	n/a
Mixed Fuel + EV	$3,500	$2,400	$2,300	$2,300	$2,600	$2,400	$2,100	$2,300
All-Electric + EV	$4,200	$1700	$2,500	$2,100	$4,600	$400	$2,600	$1,800

**Totals in Table 1 are rounded to the nearest 100th and may not exactly match the charts below for this reason*

[34] It should be noted that all modeling assumptions around Federal incentives were made in 2024, prior to the repeal of the Inflation Reduction Act. Therefore, the level of Federal incentives included in results may not be currently available, but represent the point in time at which the model was created.

Figure 45: Annual household energy costs for single-family household under different electrification scenarios in 2025 (no City-provided incentives)

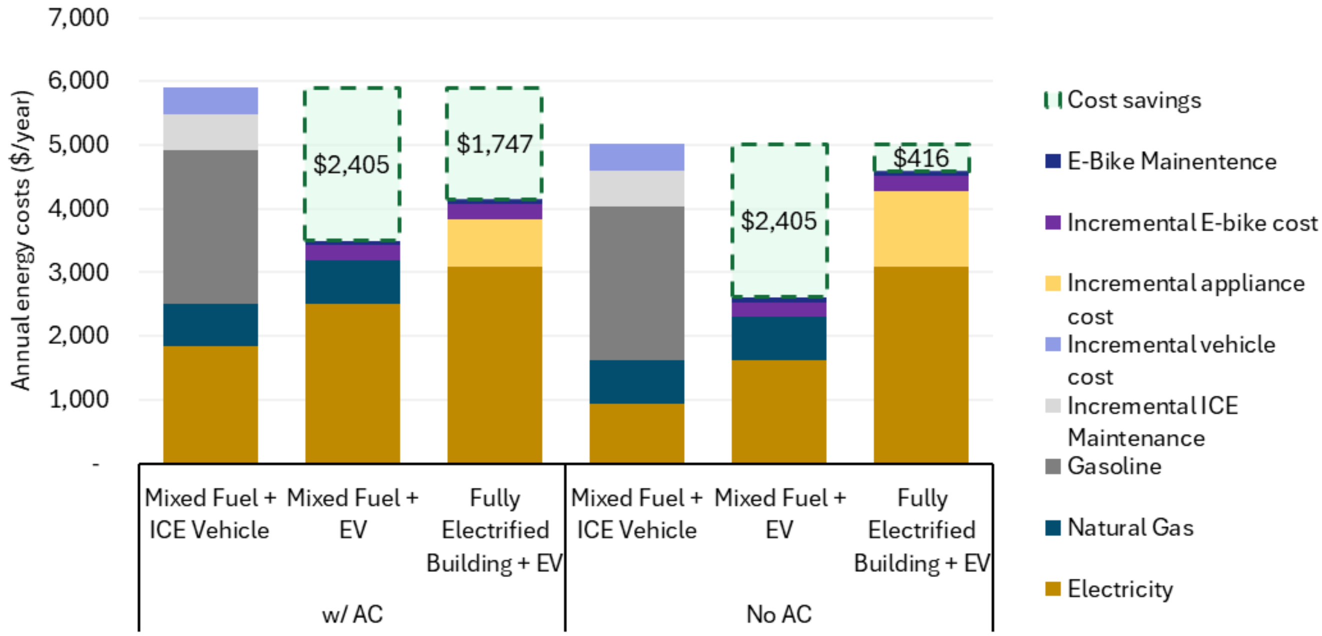
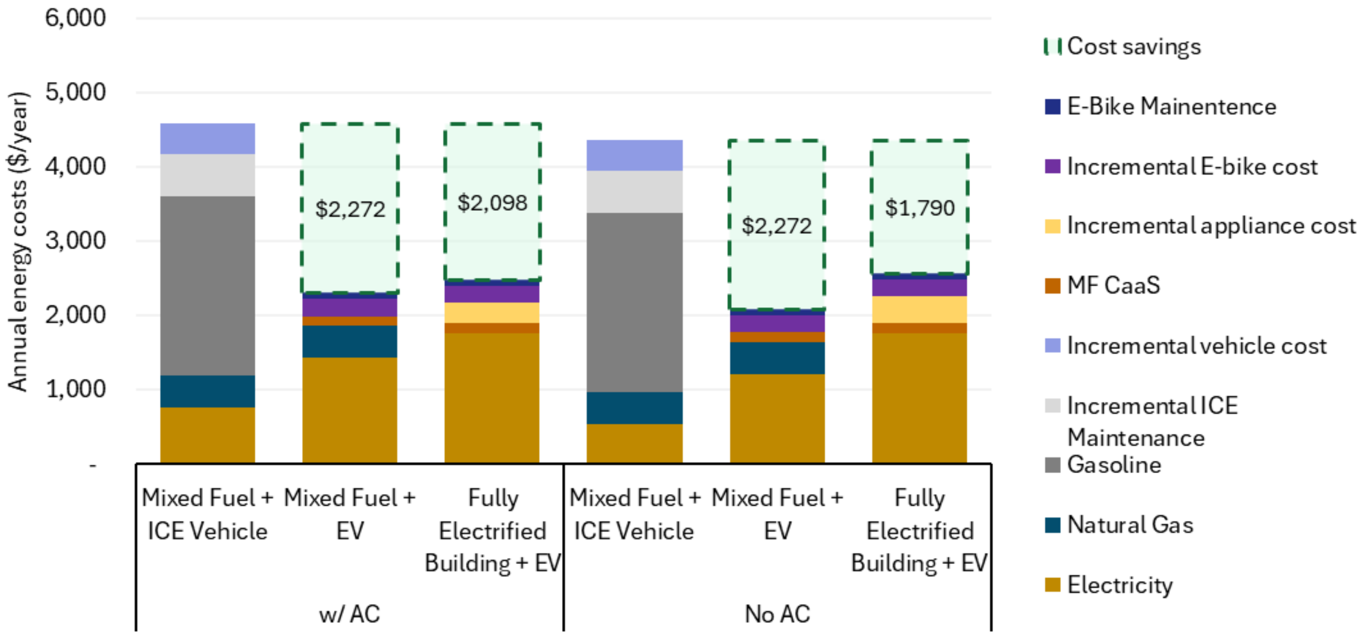


Figure 46: Annual household energy costs for multifamily household under different electrification scenarios in 2025 (no City-provided incentives)



The above figures and section describe the costs for single family and multifamily households under different levels of electrification, assuming no City-provided incentives. The following section shows results for individual household expenses with the additional help of City-provided incentives. Again, these results do not include the additional costs borne by customers to generate the revenue needed for these City-provided incentives. Those results are shown in the Tax Implications section.

Overall, with the addition of City-provided incentives, household cost savings post-electrification increase for both single family and multifamily homes. City-provided incentives drastically reduce upfront costs for all-electric appliances, removing the disincentive to electrify the building. For example, for a single family household undergoing building electrification, the City incentives shown in Figure 47 reduce upfront appliance costs from $1,190/year (levelized) to $550/year (levelized). Cost savings grow from $780/year to $1,600/year. For a representative multifamily household undergoing building electrification, the incentives shown in Figure 48 reduce upfront appliance costs from $350/year (levelized) to $0/year. Cost savings grow from $2,000/year to nearly $2,700/year, leading to savings almost as large as just adopting an EV alone. The results shown below represent the incentives provided under the High Local Action scenario. For other levels of local action, the cost savings from City-provided incentives would be smaller.

It is also important to highlight that in the example shown below, it is assumed that the single family customer does all of their EV charging at home and that multifamily customers will charge at their building for a $/kWh rate consistent with a Charging-as-a-Service program. In a situation in which the customer does some portion of their EV charging using public or workplace chargers, their EV charging costs may be higher.

Figure 47: Annual household energy costs for a single-family customer before and after City-provided incentives in year with peak investment gap (High Local Action, 2030, without AC)

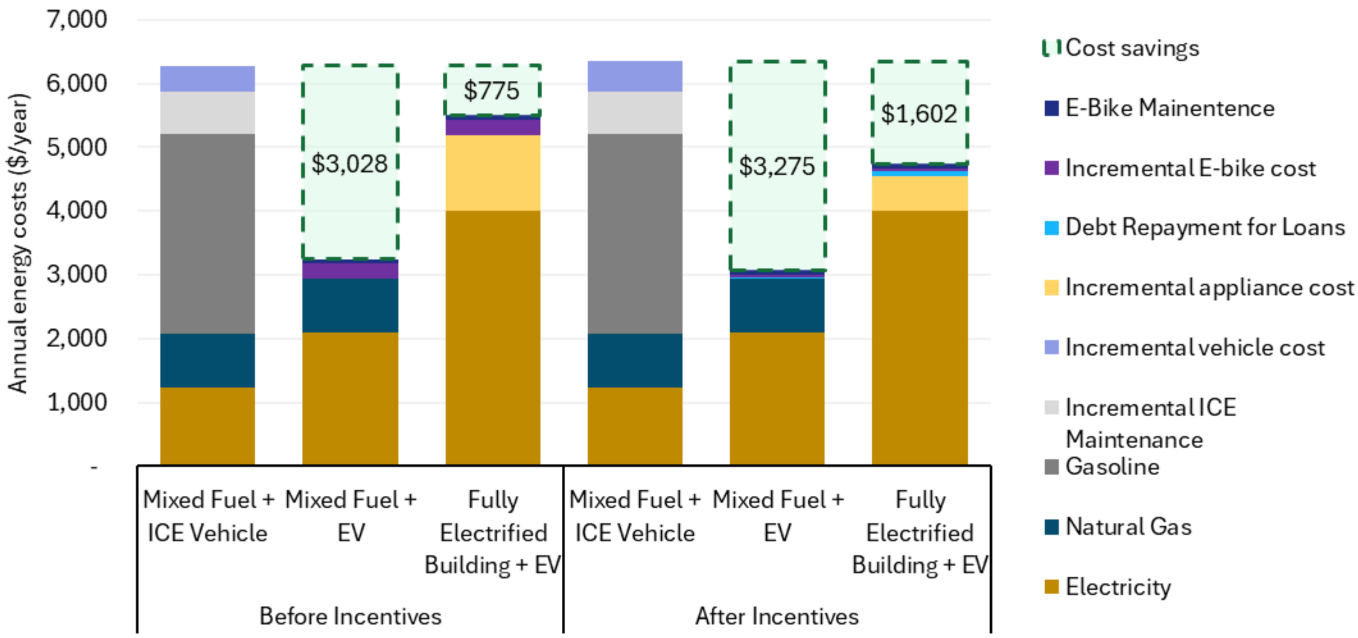
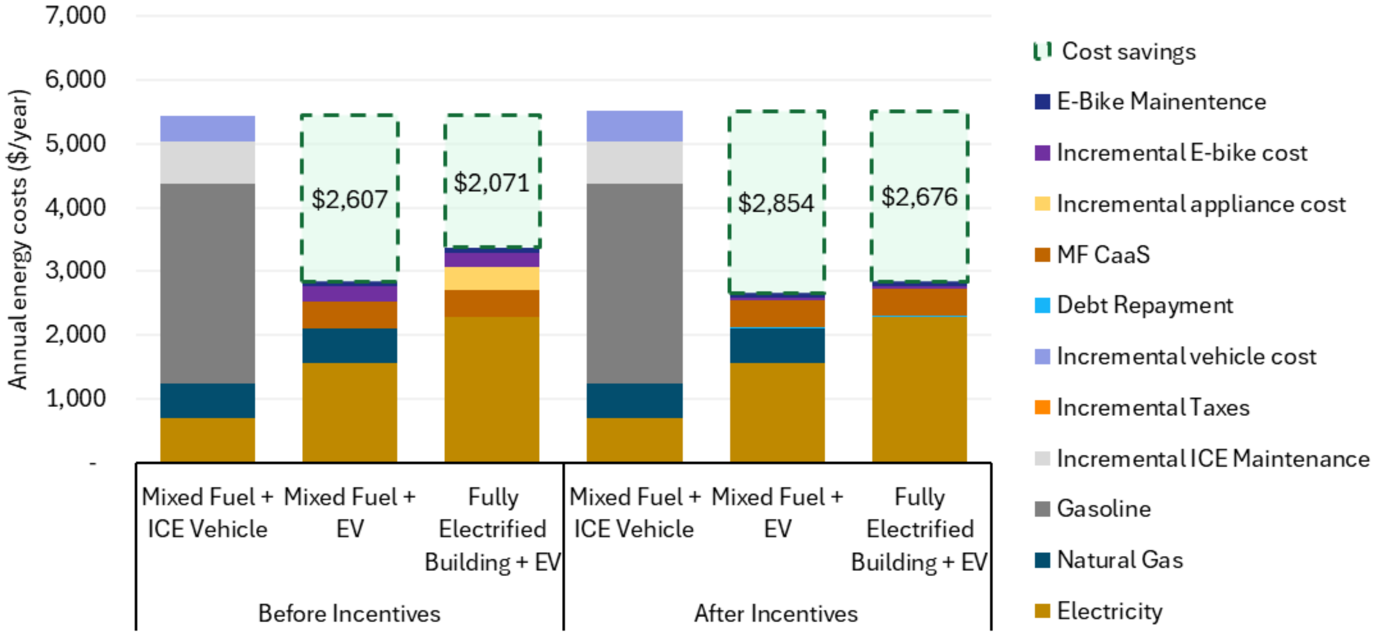


Figure 48: Annual household energy costs for a multifamily customer before and after City-provided incentives in year with peak investment gap (High Local Action, 2030, without AC)



An additional consideration when analyzing household expenses for individual customers is the impact of decarbonization on low-income households. These households typically have a lower willingness or ability to pay high upfront costs associated with electrification, such as upgrades to all-electric household appliances or purchasing electric vehicles. As a result, they often face longer replacement cycles, continuing to rely on older, less efficient technologies that may increase energy use and costs. To offset this lower willingness to pay, the City may need to offer higher and more accessible incentives to significantly reduce the financial burden on low-income households.

The situation is particularly complex for low-income multifamily tenants, where electrification efforts could lead to rent increases and the energy savings from electrification may not flow directly to tenants. Further, low-income multifamily residents are less likely to have access to home EV charging, creating additional barriers to EV adoption and ownership.[35] To address these challenges, the City could consider a coordinated strategy for multifamily electrification, including tenant protections from rent hikes and direct assistance for multifamily building owners. Additionally, higher incentives targeted at MF buildings can help offset the high upfront cost and prevent rent increases.

Additionally, achieving bill neutrality, i.e., total monthly energy costs remaining unaffected after electrification, is of critical importance for low-income customers. Increases in electricity bills, especially for a low-income customer that previously did not have AC, could lead to energy insecurity

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[35] See the EV Charger Needs Assessment report for a detailed discussion on multifamily EV charging considerations and potential program design.

and further barriers to electrification. Expanded bill assistance programs may be necessary for low-income households to achieve bill neutrality after electrification and ensure protection against bill increases.

Nonresidential Expenses

In addition to household expenses for individual residential customers, it will also be important for Palo Alto to consider the impacts of electrification on non-residential commercial community members. To conduct this analysis, E3 built an Affordability Tool for non-residential community members.

The annual non-residential costs considered in this analysis include:

- Electricity costs
- Natural gas costs
- Debt repayment
- Incremental appliance cost (e.g., for an ASHP vs. a gas furnace)
- Incremental EV charger cost (e.g., workplace L2 chargers provided at an office building)

The annual non-residential benefits considered in this analysis include:

- Federal and state incentives (e.g., the IRA tax credits for heat pumps)
- Prospective incentives provided by Palo Alto (calculated in the S/CAP Funding Model)
- Prospective loans provided by Palo Alto (calculated in the S/CAP Funding Model)
- Prospective loans provided by third-party lenders (calculated in the S/CAP Funding Model)

The different non-residential building types modeled in the Affordability Tool include:

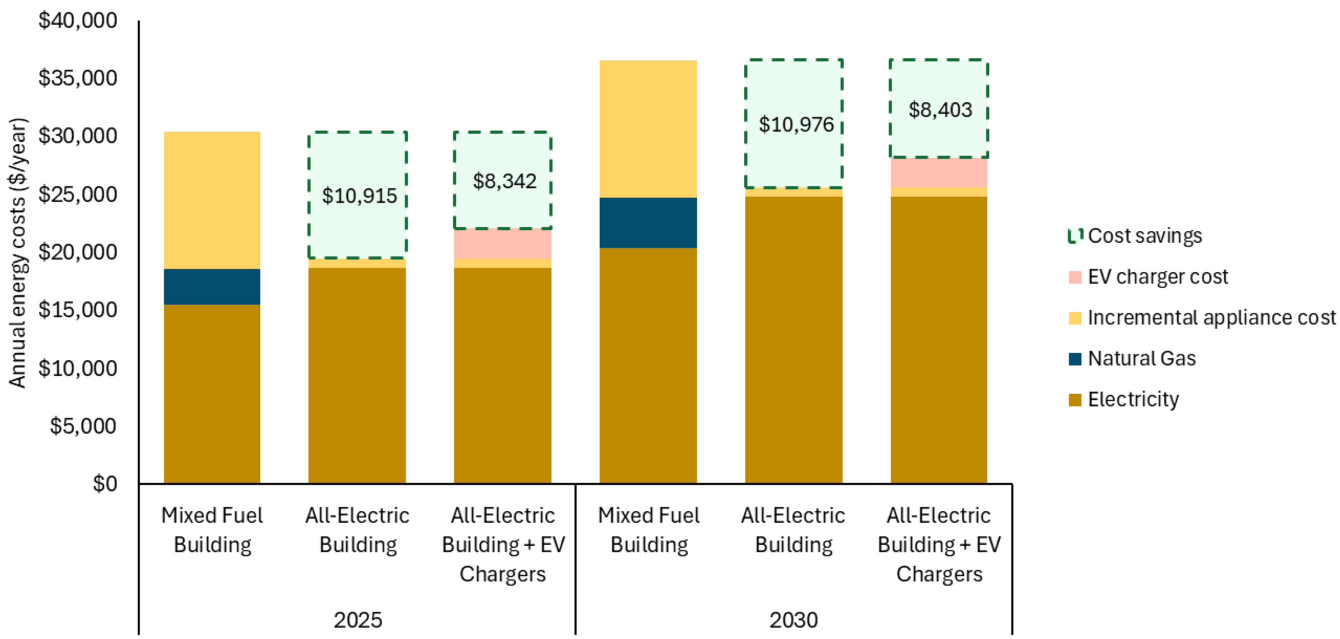
- Office
- Retail
- Education
- Assembly
- Medical

The Affordability Tool also allows the user to model three different sizes of non-residential buildings:

- Small
- Medium
- Large

Overall, this study found that the cost effectiveness of building electrification in commercial buildings is largely dependent on the type and size of building. For many commercial building types, the upfront cost of electrification is lower than the cost of non-electrified building equipment, due to the high cost of gas appliances and air conditioning. For example, Figure 49 shows the annual energy cost results for a medium office building in Palo Alto for a mixed fuel buildings vs. an all-electric building in both 2025 and 2030. For a medium-sized office building, building electrification alone is the most cost-effective option in both 2025 and 2030, leading to nearly $11,000/year in total cost savings, due to the avoided natural gas costs and the lower capital cost (leading to nearly zero incremental upfront costs).[36] If this same medium office building decided to provide workplace L2 chargers onsite for employees, that would add an additional $2,500/year of expenses, but overall annual costs are still lower than pursuing no electrification.[37,38] Note that Figure 49 does not include the costs associated with commercial MHDV fleet electrification.

Figure 49: Annual energy costs for a mixed fuel vs. all-electric medium office building under different electrification scenarios



For some commercial buildings, the cost to electrify is much higher, making a mixed fuel building the more cost-effective option. This is especially relevant for large medical and industrial buildings that have very high energy demand and where the upfront cost for all-electric HVAC systems could reach nearly $72M.

Potential Role of Gas Prices and the Cost of Carbon

A major component of the ongoing costs incurred by Palo Alto residents is energy expenditures; this

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[36] Note that while the entire non-residential sector is likely to experience electricity bill savings from avoided air conditioning, this same result may not be true for specific individual buildings, such as the medium office building shown here.

[37] Assuming 4 L2 workplace chargers are built onsite.

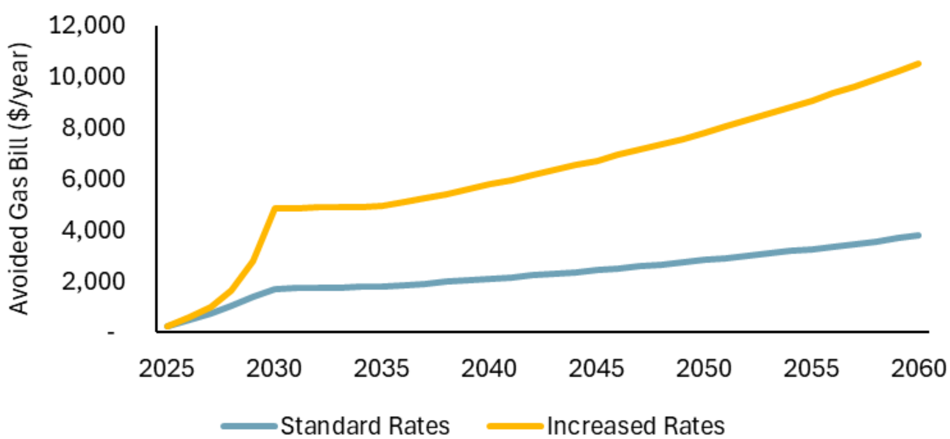
[38] Due to the high cost of counterfactual equipment (e.g., gas furnaces, natural gas water heaters, etc.), there are not significant incentives provided by the City for building electrification. That is why incentives are not included in Figure 45.

includes any incremental electricity costs caused by higher electricity demand, and any benefits received from reduced natural gas costs. Increases in natural gas costs to reflect additional costs of decarbonization under continued use of gas appliances (such as by purchasing biogas, which theoretically has net zero carbon emissions, instead of fossil methane, which extracts carbon from the ground) would raise natural gas prices and change the cost-effectiveness of building electrification.

As seen above, building electrification is likely to add additional costs compared to a mixed fuel residential building with an EV. Renewable natural gas is currently about $4.50 per therm in California,[39] or $2.84 per therm more costly than fossil natural gas (valued at $1.66 per therm for the Pacific region). In the future, fossil gas may be blended with biogas to help reach emissions reductions targets, increasing the cost of gas prices. In addition, gas prices are expected to rise as more gas customers electrify, raising gas prices closer to the incremental cost of carbon stated above.

Figure 50 below shows the avoided gas bill of an electrifying single-family homeowner under the natural gas rates projected in the City's adopted FY 2025 Gas Utility Financial Plan ("Standard Rates") versus an alternative, illustrative higher natural gas rate ("Increased Rates"). In the chart below, the higher gas rate was calculated by determining what an increased rate would need to be to pay for gas system operation as gas usage decreases. In later years, as gas throughput decreases, the alternate natural gas rate spikes, leading to a higher avoided gas bill. This would lead to a significant increase in bill savings for electrifying customers compared to customers remaining on the gas system.

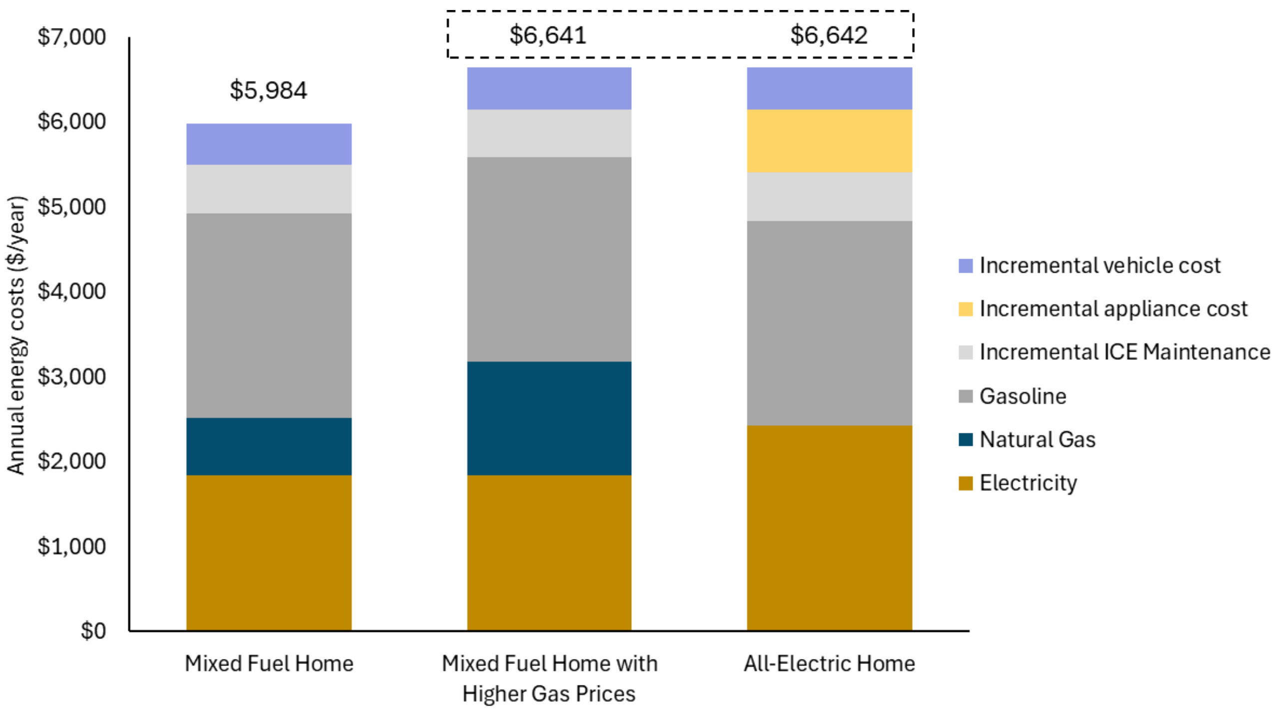
Figure 50: Avoided gas bill of average single-family homeowner under illustrative higher gas prices, High Local Action scenario



Due to Prop 26, gas rates in Palo Alto must reflect the actual cost of delivering service, and any portion of increased rates beyond service costs is deemed a tax which requires 2/3 of voters to approve. It is possible that future biogas blending into the system will increase costs. Figure 51 shows how potential increased natural gas prices from biogas blending would affect building electrification cost effectiveness compared to a mixed fuel building. Figure 51 shows an illustrative example of a household's costs assuming higher natural gas prices that reflect potential biogas blending, increasing the cost of gas. For the example below, a higher gas price of $2.75/therm for Tier 1, a $2.10 increase above standard rates, leads to cost parity for building electrification in 2025 compared to mixed fuel for a home with an existing AC unit. For a customer without AC, those gas prices would need to be even higher to reach cost parity.

In a scenario involving rising gas prices, the focus of the High Local Action scenario might switch from incentives to financing. While this scenario was not modeled, the Funding Model is capable of modeling this scenario and it could be a focus of future investigations.

Figure 51: Impact of increased natural gas prices on single family household expenses across different electrification scenarios in 2025 (with AC)



Tax Implications

If Palo Alto wants to accelerate building electrification adoption faster than the BAAQMD mandate requires to achieve its 80x30 emissions reduction target, as shown in the High Electrification scenario, the City will need to support community members in making the switch to all-electric appliances by providing incentives to help close the upfront cost gap. This will be of particular importance for low-income individuals and households that do not have disposable income to invest in building electrification technologies. Additionally, to support widespread transportation electrification, Palo Alto will need to greatly increase access to EV charging infrastructure. The City may decide to own and operate a portion of public and multifamily chargers, rather than a Third-

Party company having ownership, in order to invest in higher-need areas, such as multifamily buildings. More details on this can be found in the EV Charger Needs Assessment Report. In order to provide incentives to individuals and invest in EV charger infrastructure, Palo Alto will require additional sources of revenue. The Funding Source Survey has details on many of the revenue-generating options available to the City, but implementing a new tax is a common strategy taken by other jurisdictions.

There are a number of different types of taxes that the City could explore to generate revenue in support of electrification. The Funding Source Survey dives into the detailed mechanisms to implement each tax, but two common types of taxes that were explored in this analysis are:

- **Parcel tax:** a form of voter-approved property tax that is assessed at a rate based on the characteristics of the parcel, often as a flat fee per parcel.
- **Utility users tax:** a voter-approved tax that is based on the amount of energy used by a customer[40]

To explore the impact of an illustrative parcel and utility users tax on individual households and non-residential buildings, it is assumed that the amount of tax dollars raised each year would be equivalent to the total municipal debt expense needed to provide incentives. The model operates under the simplifying assumption that the allocation to individual customer types for a utility users tax is based on energy demand by sector. For a parcel tax, the model uses the capital investment needed to electrify each sector as a simplified proxy for parcel count. Note that the examples provided in this section are very preliminary and only to begin initial discussion, and this study did not conduct detailed quantitative analysis on the impact of different types of tax structures. A more detailed study and analysis would be required to assess the specific tax structures and implications for different customer types and fuel users—such as whether a customer is electrifying or not—as this study was intentionally high-level, representative, and preliminary in nature.

California is unique in that its constitution restricts the use of tax revenues for specific purposes and mandates voter approval for taxes and charges that exceed constitutional cost-of-service requirements. California law also provides public agencies with a variety of ways to raise revenue by issuing bonds, along with specific requirements on legally valid uses of bond proceeds. The legality of programs and funding mechanisms implemented in Palo Alto will be very fact-dependent, and in-depth legal analysis will be necessary before proceeding with individual measures.

Figure 52 and Figure 53 show household energy expenses with the impacts of a potential utility users tax. For example, a representative single family customer is estimated to pay approximately $200/year for a utility users tax (or a similarly structured tax based on energy usage).

Figure 52: Annual household energy costs for single family customer before and after City-provided incentives in year with peak investment gap for High Local Action (2030), illustrative utility users tax impacts included

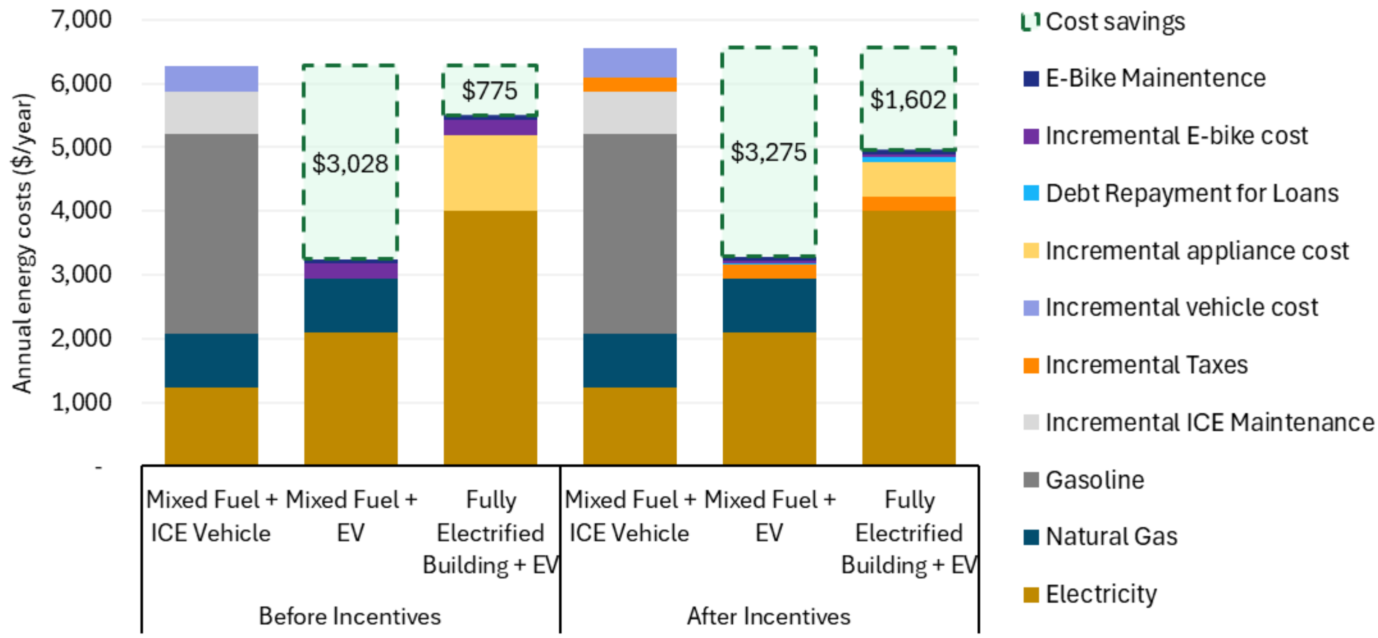


Figure 53: Annual household energy costs for multifamily customer before and after City-provided incentives in year with peak investment gap for High Local Action (2030), illustrative utility users tax impacts included

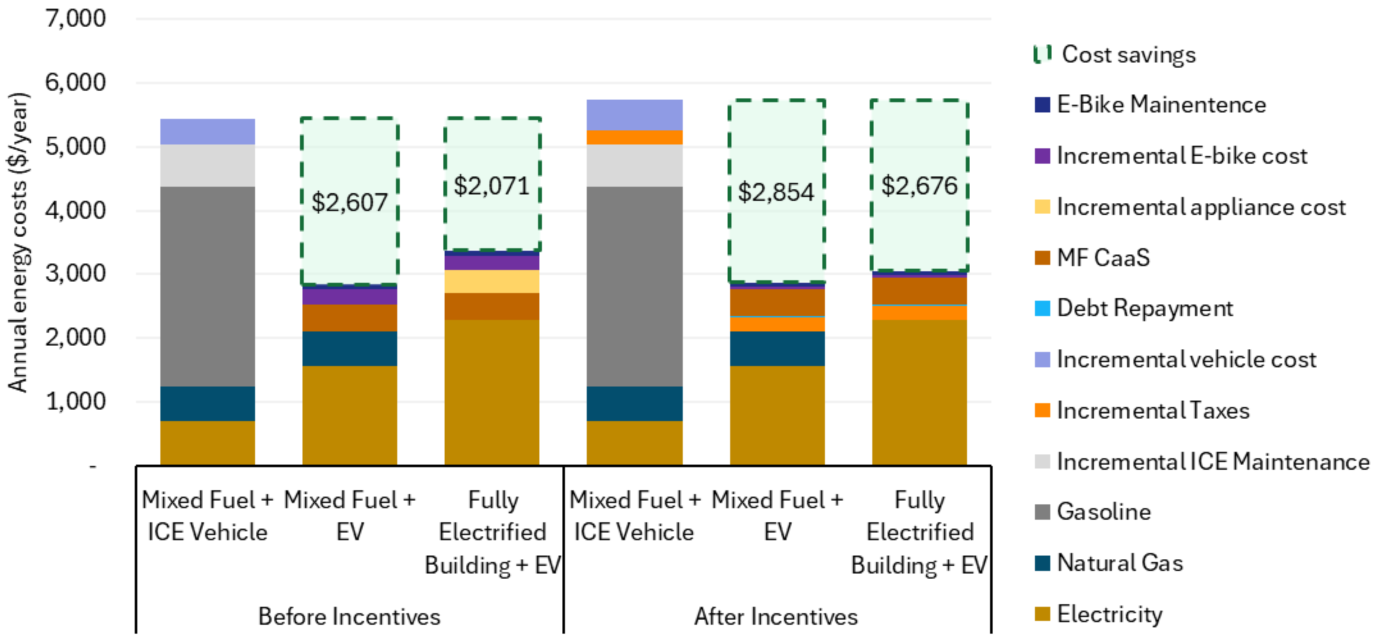


Figure 54 and Figure 55 show the impacts of homeowner energy expenses with the impacts of a parcel tax.[41] For example, a representative SF customer is estimated to pay approximately $400/year for a parcel tax, or a similarly structured tax based on capital investment needs (as described on page 68). More detail on parcel taxes is included in a separate report (the Funding Source Survey).

[41] As a simplification for modeling purposes, it was assumed that multifamily residents would be responsible for paying a parcel tax. In reality, the details of how the tax burden would fall on landlords and renters would be determined based on the tax structure and requirements.

Figure 54: Annual household energy costs for single family customer before and after City-provided incentives in year with peak investment gap for High Local Action (2030), <u>illustrative</u> parcel tax impacts included

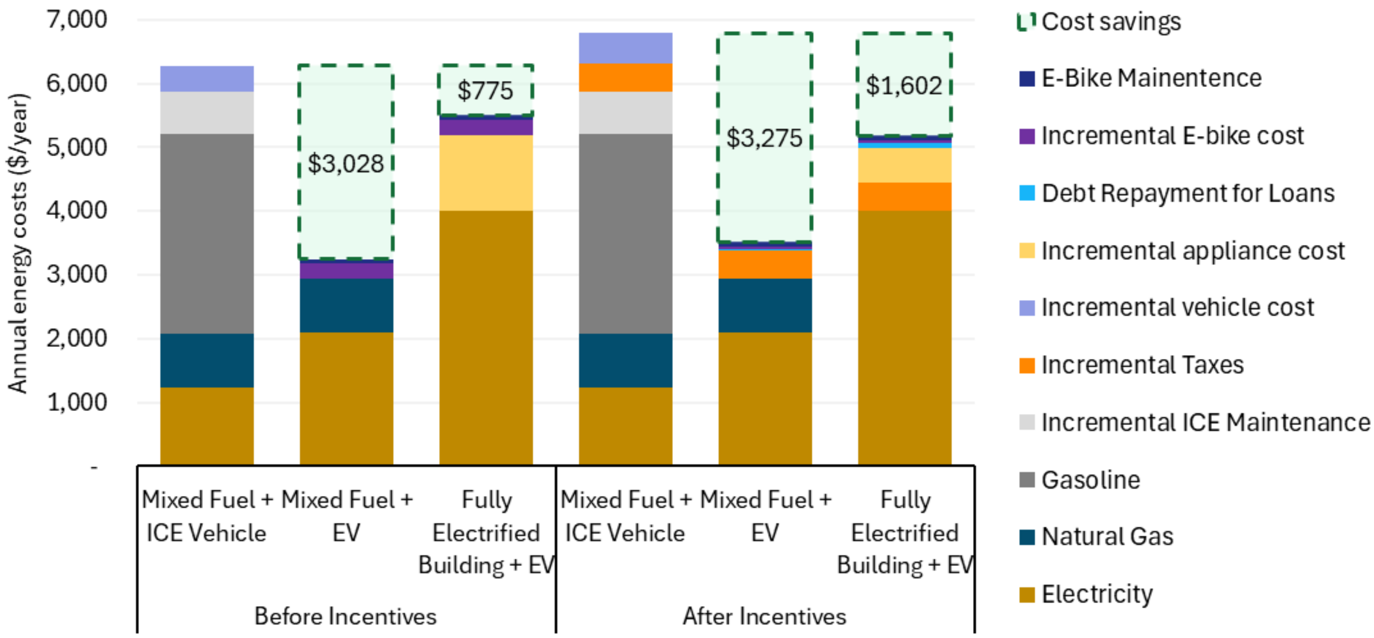
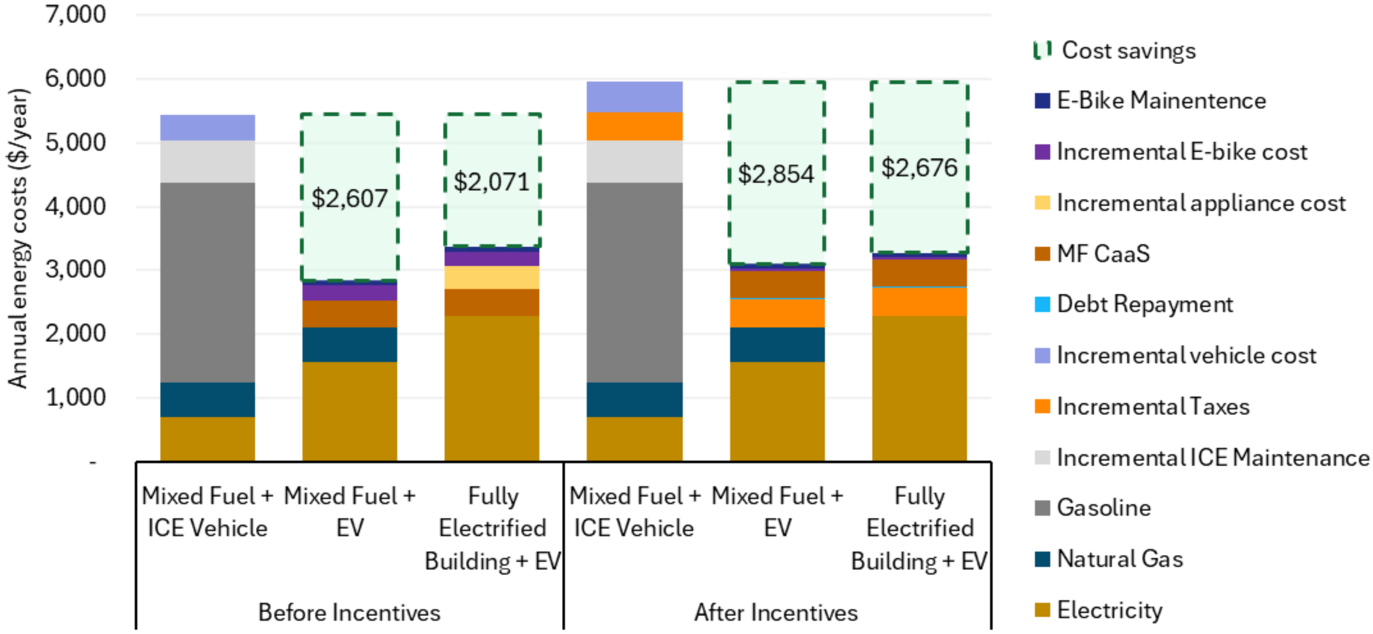


Figure 55: Annual household energy costs for multifamily customer before and after City-provided incentives in year with peak investment gap for High Local Action (2030), illustrative parcel tax impacts included



Note that the cost savings experienced by an individual customer paying into a utility users tax or parcel tax, under current model assumptions, are the same, but overall annual customer expenditures differ.

Non-residential customers may also be asked to approve new taxes to generate revenue to provide electrification-supporting incentives. Figure 56 and Figure 57 show the impacts of a potential utility user tax and parcel tax on a representative commercial office building. Because the non-residential tax base is lower, and energy demand and capital investment are high, the tax impacts on non-residential customers are proportionally higher than on residential customers.

Figure 56: Annual energy costs for a mixed fuel vs. all-electric medium office building under different electrification scenarios with illustrative utility user tax impacts included

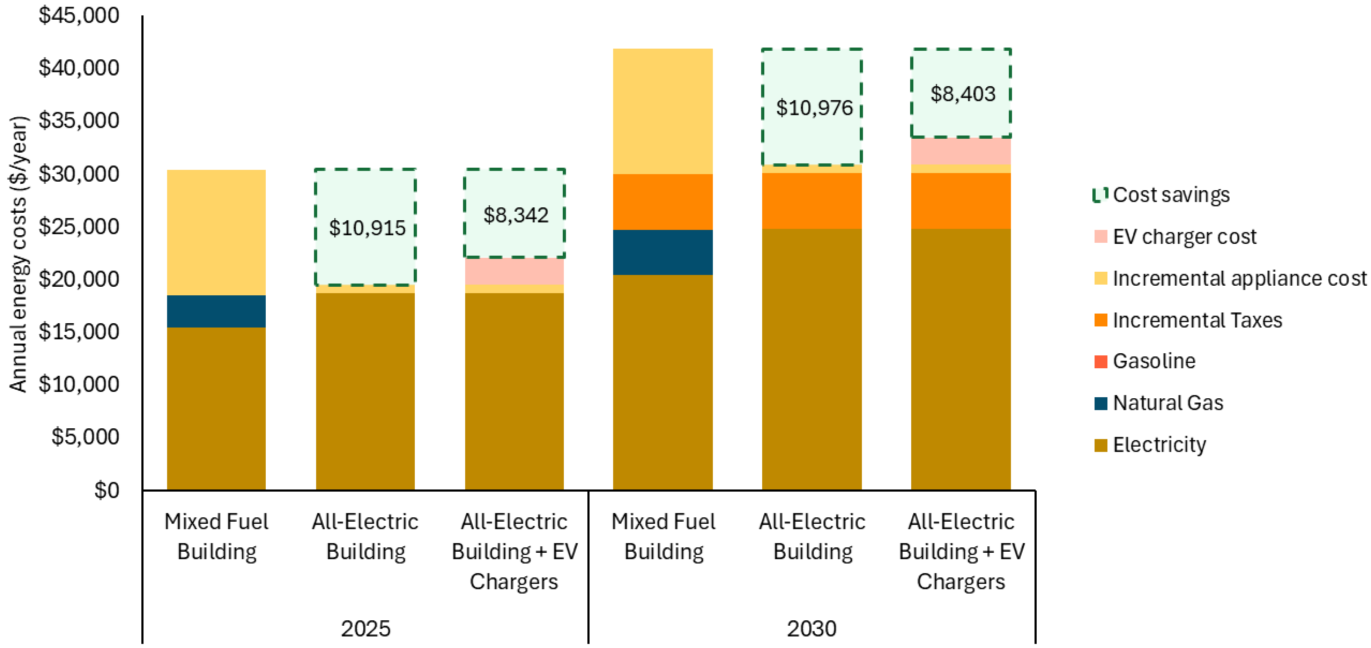


Figure 57: Annual energy costs for a mixed fuel vs. all-electric medium office building under different electrification scenarios with illustrative parcel tax impacts included

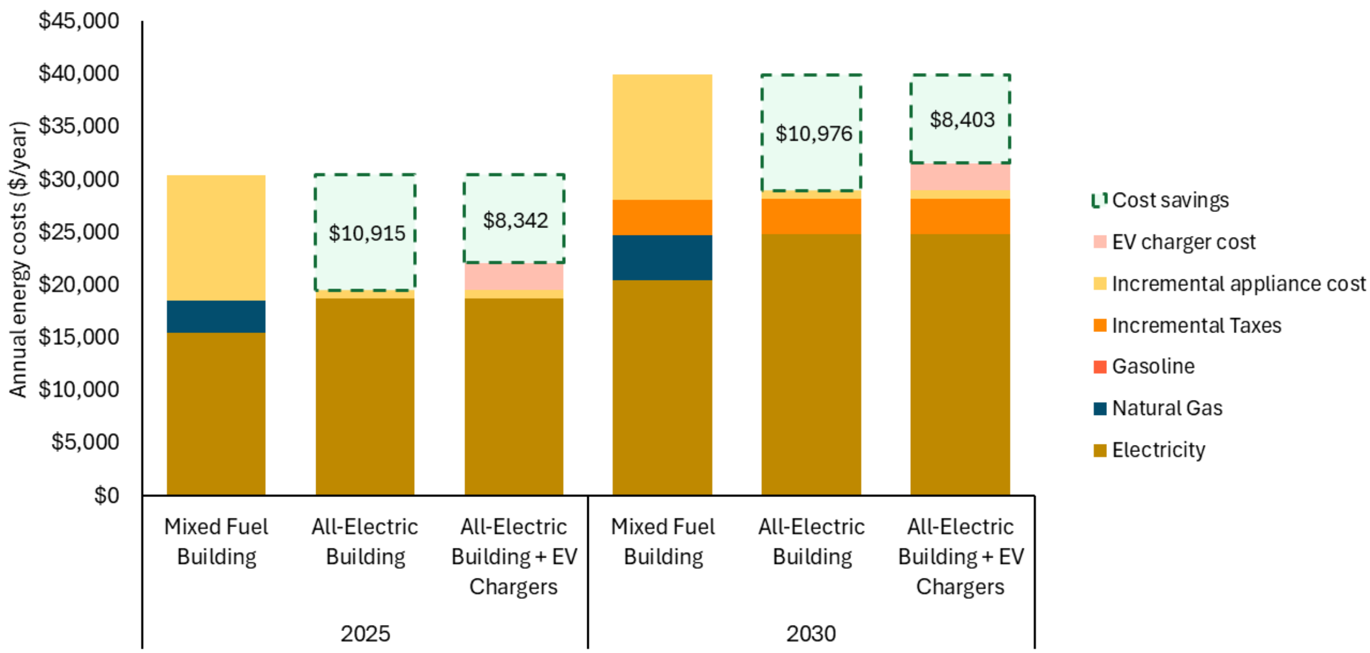


Figure 58 summarizes the average incremental tax amount for residential and non-residential customers for an illustrative utility users tax and a parcel tax. For residential customers, the utility users tax was calculated to be about $200/year in 2030, while the parcel tax was calculated to be about $450/year in 2030. For non-residential customers, the utility users tax was calculated to be about $5,300/year in 2030, while the parcel tax was calculated to be about $3,350/year in 2030. As stated above, these tax amounts were determined using the total municipal debt expense as a result of bond issuance for the City to support electrification efforts.

Figure 58: Summary of Average Incremental Tax Amounts in 2030 for Residential and Non-Residential Customers in High Local Action

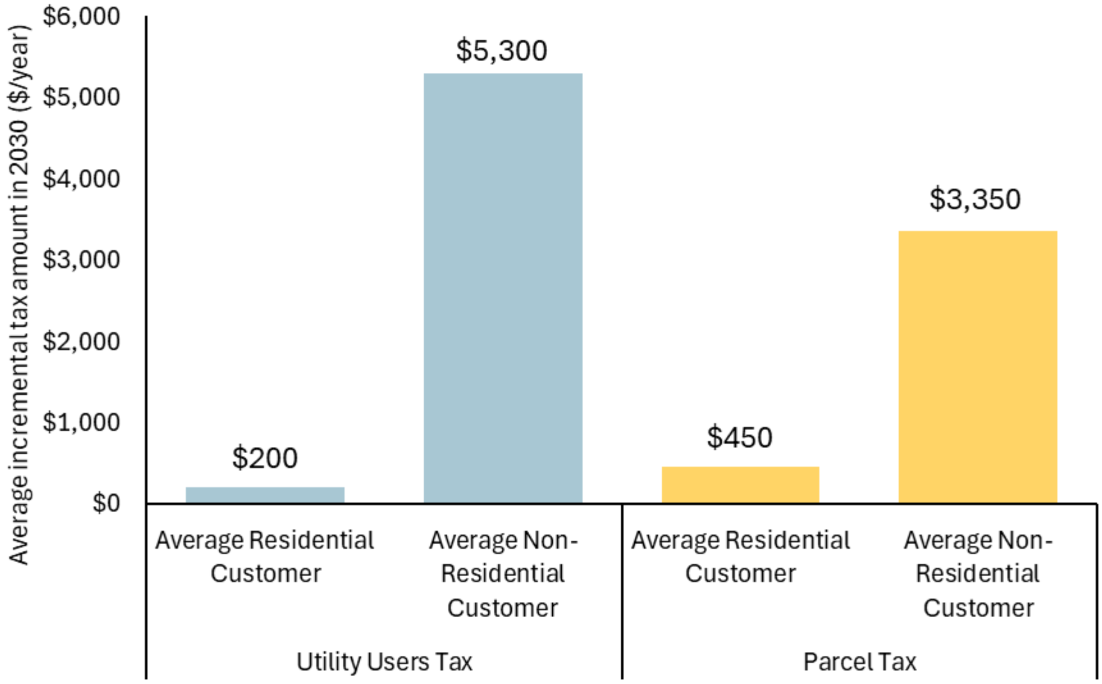


Figure 59 and Figure 60 below represent the portion of tax revenue that is paid by residential vs. non-residential customers for a utility users tax and a parcel tax. For the utility users tax, non-residential customers would be responsible for paying for a greater proportion of the tax revenue due to high energy demands, driven by high-consuming buildings such as large medical facilities. For the parcel tax, residential customers would be responsible for paying for a greater proportion of the tax revenue because the ratio of residential to commercial parcels is higher than the ratio of residential energy use to commercial energy use.

Figure 59: Percent of Tax Revenue Paid by Residential vs. Non-Residential Customers for Illustrative Utility Users Tax

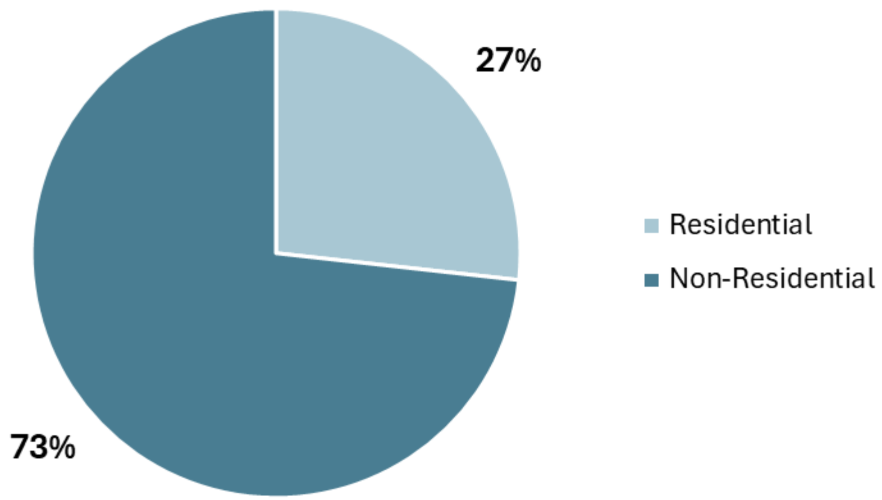
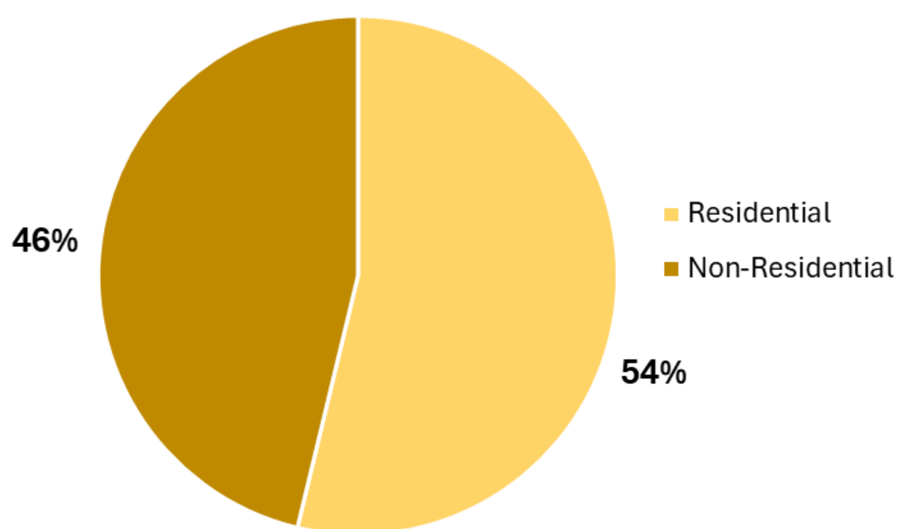


Figure 60: Percent of Tax Revenue Paid by Residential vs. Non-Residential Customers for Illustrative Parcel Tax



Conclusion

Palo Alto, in line with California as a whole, has ambitious climate targets in the coming years; specifically, to achieve an 80% greenhouse gas emissions reduction, relative to 1990, by 2030. Achieving this target will require significant investment in electric vehicles, electric appliances, EV charging infrastructure, and an updated electrical grid to support this growth, all of which will require financial investment.

Electrification will require community members and the City to incur both ongoing and upfront costs, but will also provide cost reductions and benefits. The extent to which costs exceed benefits, or vice versa, depends on a myriad of factors including the speed of electrification, the availability of Federal and State incentives, the City's contribution to lowering household expenses, and many more. These factors also impact the level of debt taken out by the community; this includes bonds issued by the municipality or utility, as well as loans taken out by community members from third-party lenders.

Reaching the 80x30 emissions reduction target will require high local investment to support the ambitious levels of transportation and building electrification needed in early years. These upfront costs will be significant, but the City can support community members in the transition by providing incentives to ease the cost of electrification. In order to provide incentives to the community, the City will need to generate new revenue streams, such as through the implementation of new taxes. While challenging, with early action, the City and Community will experience earlier benefits from electrification as well.

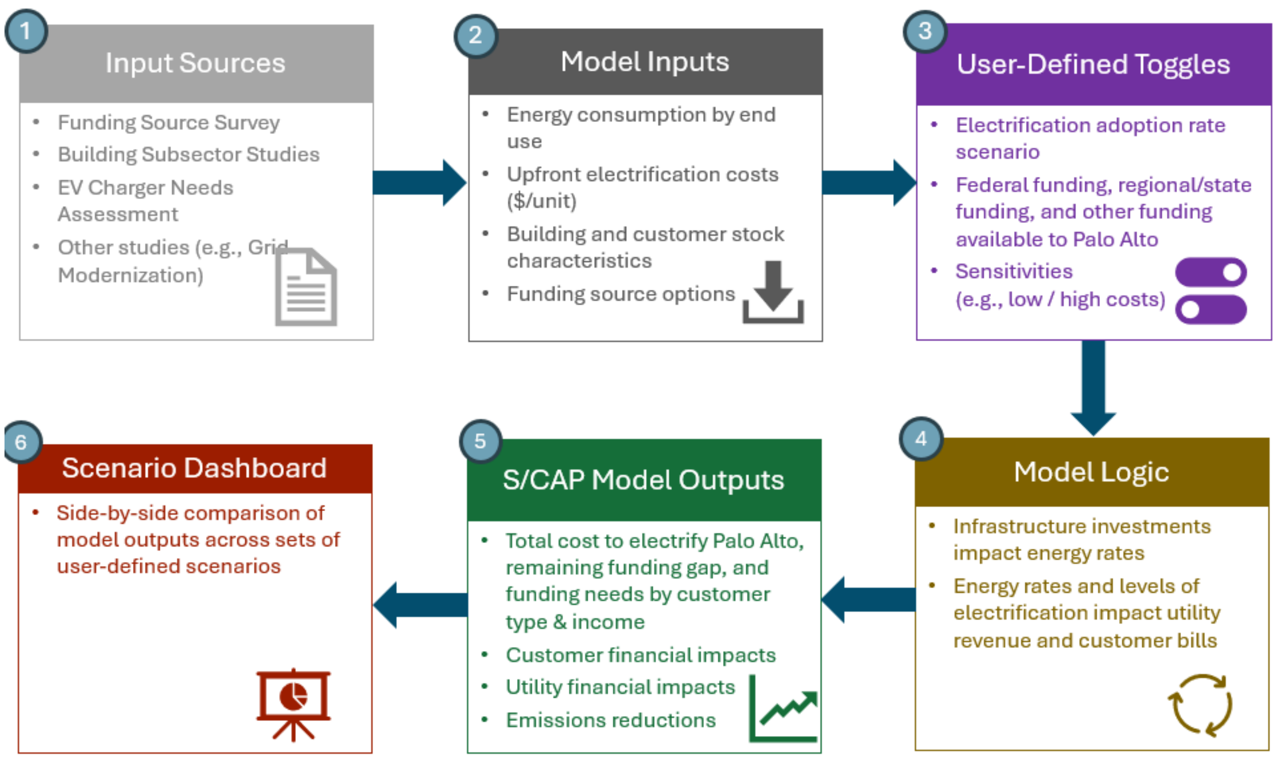
Reaching an 80% emissions reduction at a slower pace than the 2030 target would require lower upfront local investment and avoid the need to retire building equipment early. However, a slower pace of electrification, while potentially easier and less expensive, would lead to delayed benefits, including delayed greenhouse gas emissions reductions, delayed local air quality improvements and delayed fossil fuel savings.

Appendix A. Detailed Funding Model Methodology

Overview

The Funding Model combines data from the building and transportation sub-studies, along with the funding and financing source survey, to calculate the total cost of communitywide electrification in Palo Alto, under different scenario parameters and inputs. At a high level, the model compares the costs, emissions, and energy demand within an active mitigation scenario and a 'baseline,' or business-as-usual (BAU) scenario.

Figure A. 1 Overview of S/CAP funding model methodology



Major Model Inputs & Assumptions

Model Inputs

The funding model includes multiple model inputs that materially impact results. Specific inputs include:

Upfront costs

Upfront building equipment costs can be found in the Building Subsector Studies (e.g., MF Sector Study, SF Sector Study, and Non-Residential Sector Study).

Upfront vehicle costs are included in Table 2 below.

Table 2: Upfront vehicle costs (real 2024$)

EV	LDV	40,079
PHEV	LDV	39,442
EV	MHDV	79,609
ICE	LDV	33,765
ICE	MHDV	65,557

Upfront charger costs can be found in the EV Charger Needs Assessment report.

Percent of cost gap covered by the City

In the model, the electrification cost gap is calculated across each housing and transportation subsector; the cost gap is essentially the upfront cost less any available incentives and the community members' contribution to capital (discussed in-depth below). A portion of that cost gap will be covered by the City, via loans and/or incentives, and a portion will be the responsibility of the community member (for simplicity, the model assumes community members seek third-party private loans). That breakout is determined by the user.

Prospective funding source amounts, communitywide caps, and start years

The model includes multiple types of funding sources available to the municipality and the utility. These sources are: public-private partnerships (PPPs), taxes, state and federal incentives available to the City, existing funding sources (Low Carbon Fuel Standard credits, Cap-and-Trade credits, etc.), revenue from increased electricity sales, and gas system savings caused by decreased gas use.

Starting values are E3 estimates that have been calculated based on research for the Funding Source Survey. Amounts have been estimated based on existing programs around the US, and adjusted based on Palo Alto's population, Palo Alto's gross domestic product, and other economic indicators. However, the model allows the user to change these starting values and specify how much is available on a communitywide basis from each of these sources, and the year that each source becomes available. Taxes are an even more dynamic funding source; multiple tax types are included in the model, and the user can set different start years for each tax type. The user can also determine what percentage of tax revenue is paid by residential taxpayers vs nonresident taxpayers. This will impact the incremental tax expense per community member, depending on if the community member is a residential or commercial taxpayer.

Existing Federal, State, and regional incentives

When city staff adjust or manipulate the Funding model, they can specify what existing incentives to apply within the model. The available Federal incentives are those provided via the Inflation Reduction Act (IRA):

- Personal Clean Vehicle Credit
- Commercial Clean Vehicle Credit, available for both light duty and medium-heavy duty vehicles
- Home Electrification and Appliance Rebates (HEAR), available for heat pumps, heat pump water heaters, electric stoves, and electric clothes dryers
- Home Owner Management Energy Savings Program (HOMES)
- Enhancement of Energy Efficient Home Improvement Credit

State and regional incentives include those made available through Technology and Equipment for Clean Heating (TECH) Clean California and the Bay Area Air Quality Management District (BAAQMD). These incentives provide upfront cost reduction with purchase of EVs, heat pumps, heat pump water heaters, and other efficient and electric equipment. The user can opt into providing these incentives and reducing the electrification cost gap.

Funding source use

The model designates some funding sources as being used for direct funding, meaning that the capital will be funneled directly into incentive or loan programs, whereas some funding sources will be used for debt repayment. This is because it is likely that new taxes and other prospective funding sources will take multiple years to implement; in the meantime, if incentive or loan programs are established, Palo Alto will need to issue debt (either municipal or utility debt, discussed below) in order to finance these programs, and will need capital to cover the interest and principal payments of this debt.

Capital allocation

The user can determine what percentage of utility and municipal funding would be allocated to buildings (split across single family and multifamily residential buildings, and commercial buildings), electric vehicles, and chargers. Within the set capital allocation, the user can also determine what portion of municipal and utility funding is allocated to community members via direct incentives and what portion is allocated via loans. The allocation can also be set independently for single family buildings, multifamily buildings, commercial buildings, EVs, and EV chargers.

Debt allocation

The user can determine the percentage of debt that would be issued by the municipality versus the utility. The only caveat is that any debt necessary to purchase City-owned vehicles and chargers must be issued by the municipality. This is discussed in-depth below.

Interest rates

The model allows the user to set both external interest rates that will be used to determine interest payments due to external loan providers, and City discount rates used to calculate the net present value of future cashflows. The model's default interest rate is 4%, which was provided by the City.

Inflation

The user can set a specific inflation rate that will be applied from 2026 onwards. The model's default annual inflation rate is 3%.

Length of Analysis Period

The analysis goes from 2024 to 2060. 2024 is largely used as a base year, with incremental adoption of electric vehicles and appliances being calculated from 2025 onward.

Electric System Costs

The model assumes that increased vehicle and transportation electrification will require the City to invest in electric system upgrades. This type of development would fall under Palo Alto's Capital Improvement Program (CIP).[42] The City provided data for the necessary CIP spending around the improved electrical program, both with and without accelerated levels of electrification. Other user-defined inputs include the financing timeline, and the interest rate. The inputs are used to calculate the annual cost of financing this investment in the electrical system, which is labeled as a communitywide infrastructure cost.

Avoided Gas System Costs

Another aspect of the energy infrastructure of Palo Alto is the potential for savings due to decreased investment in the gas system. As ratepayers move away from gas-fired furnaces and stoves in order to electrify their homes and businesses, it is possible that the City would be able to decommission portions of the gas system, thus eliminating the need for upkeep costs associated with those portions.

If the model user chooses to opt in to including avoided gas system costs in the model, the user can then select a low, medium, or high level of savings associated with decommissioning portions of the gas system. The system cost savings are initially provided on a dollars per mile of pipeline decommissioned; the user can also enter an estimated number of miles of pipeline decommissioned. The resulting savings value, along with a user-defined timeline and interest rate, is used to calculate annual savings over the course of the analysis period. This is considered a communitywide benefit, as it represents avoided spending. Avoided Gas System Costs are not included in the results shown throughout the body of the report.

Electrical Grid Emissions Factors

Electricity emissions are inherently more dynamic than fossil fuel emissions, which are discussed below, as the emission factor depends on the resource mix that the electrical grid relies on. As renewable energy development accelerates, the emissions per Watt-hour of electricity used will

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[42] City of Palo Alto

decrease. Different electrical grid emission factors were utilized, all coming from National Renewable Energy Laboratory (NREL) Cambium. The user can select one of the available grid emission projection scenarios. The different projections available in the model are:

- Mid-case
- Low renewable energy cost
- High renewable energy cost
- Low natural gas prices
- High natural gas prices
- High demand growth
- 95% decarbonization by 2050
- 100% decarbonization by 2035
- Zero emissions – assumes the electrical grid is emissions-free from 2024

The extent to which the electrical grid is assumed to be decarbonized impacts the potential mitigation that will occur with increased adoption of electric vehicles and electric appliances. These factors are critical inputs to the model's determination of marginal abatement associated with electrification, the resulting marginal abatement cost on a $/ton of CO2e basis, and whether or not Palo Alto is projected to meet long-term emissions targets. As a default, the 'zero emissions' electrical grid emissions projection is selected in the model, assuming that Palo Alto's electric supply is carbon neutral.

Default Model Assumptions

Certain assumptions are natively built into the model and cannot be changed by the user. A primary assumption is that whatever Federal incentives are selected by the user to be included in the model will be applied to every community member. In terms of State and regional incentives, they will also be applied to every community member, either in the maximum per community member amount or until the communitywide spending cap is met; each community member is modeled to receive the average per-community member incentive amount, based on each program's spending cap and the relevant technology's adoption level in a given year.

The other default assumption has to do with the community members' contribution to the capital cost of electrification. The model assumes that non-low and median income (non-LMI) community members are willing to pay the amount of the avoided replacement device's cost towards their electric device. For example, a non-LMI homeowner looking to replace their gas furnace with a heat pump is assumed to be willing to pay the capital cost of a replacement furnace, as they would incur that cost even if they weren't electrifying. To calculate the value of the avoided replacement cost, the model assumes that the existing device is halfway through its useful life, and that a like-for-like device replacement would take place at burnout. Thus, the calculated avoided end-of-life equipment cost is equal to the discounted value of an avoided like-for-like equipment replacement in X years, where X is equal to half of the equipment's useful life. The discount rate used in the model is 4%, as provided by Palo Alto.

Energy Demand

Beyond the funding and financing of the upfront costs associated with electrification, a portion of model results are driven by shifts in energy demand. The shifts in the active scenario are primarily increased electricity demand and decreased demand of natural gas, gasoline, and diesel from gas appliances and internal combustion engine (ICE) vehicles.

The stock trajectories within each scenario are used in combination with annual energy demand estimates and load shapes are used to calculate annual electricity, gasoline, and diesel demand. The energy demand results, in combination with other inputs, are used to calculate multiple other model results, such as:

- Greenhouse gas emissions
- Energy expenditures for community members
- Low Carbon Fuel Standard (LCFS) credit revenue
- Increased electricity revenue for utility

While emissions and energy expenditures are end results, it should be noted that LCFS credit revenue and increased electricity revenue values are funneled back into the funding sources available to the utility.

GHG Emissions Factors

Greenhouse gas (GHG) emission factors were calculated based on a 100-year global warming potential (GWP) emissions accounting standard, from the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5). This accounting standard applies a GWP of 1 to CO_2 emissions, 28 to CH_4 emissions, and 265 to N_2O emissions.

Fossil fuel emissions were taken from the Environmental Protection Agency's (EPA) GHG Emission Factors Hub for each major gas.[43] These resulting emissions, calculated on an emissions of CO_2 equivalent (CO_2e) per unit of energy basis, are used in the model to determine the emissions associated with continued use of gas appliances and internal combustion engine (ICE) vehicles, both in the active and baseline scenarios.

Building Load Shapes

To calculate the distribution of electrical load across different building types and end-uses, E3 leveraged data from the National Renewable Energy Laboratory (NREL) ResStock[44] and ComStock databases.[45]

Residential load shapes were taken from the 2022 release of ResStock, and represent the Average

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[43] EPA
[44] NREL
[45] NREL

Meteorological Year (AMY) 2018. Load shapes were aggregated based on building type (single-family or multifamily housing unit) and space heating fuel (gas or electric). Commercial load shapes were taken from the 2023.2 release year of ComStock, also representing AMY 2018, and were aggregated based on building size and space heating fuel. The imposed cutoff for small versus large commercial buildings was 50,000 square feet. These load shapes illustrate how electrical demand varies across the year for average buildings of each typology, changing based on season and time of day.

Once aggregated load shapes were available, the percentage of electrical demand used for heating, cooling, fans, water, cooking, clothes drying, and other uses was calculated. For commercial buildings, load was first calculated on a kWh/square foot basis to normalize the data. For each building category, E3 also calculated maximum load, peak load, and percentage of load occurring during on-peak periods.

In the Funding Model, annual electricity demand provided by Palo Alto and the calculated load distribution was used to determine energy expenditures given Palo Alto's example time-of-use (TOU) electric rates.

Customer Segmentation and Building Subsector Inputs

The funding model includes representation of residential (single-family and multi-family) and commercial buildings and technologies in Palo Alto. The 42 modeled building customer types are shown in Table A. 1 while the 18 modeled building technology types are shown in Table A. 2. Building customer types are segmented by sector (single-family, multi-family, and commercial), building type (e.g., vintage for single-family, size and vintage for multi-family, size and use-case for commercial), AC status, and income level (for single family). Building technology types are characterized by end-use (e.g., space heating), fuel (electricity and natural gas), and case (electrification or counterfactual, i.e., pre-electrification). Combining building customer and technology types enables capturing a detailed depiction of the building stock overtime. Key building subsector data inputs include:

- **Starting 2024 building stock:** The number of total buildings for each type in the existing Palo Alto building stock.
- **Starting 2024 building-technology share:** For each building, the starting share of technologies that are currently installed. Multiplying this share by the starting building stock provides the total breakdown of starting building-technology stock.
- **Upfront Cost:** All in $ / unit of installing a new technology (e.g., $ / heat pump), distinguished by customer type.
- **O&M Expense:** $ / year of operating and maintenance expenses for each technology, distinguished by customer type.
- **Annual Energy Consumption:** Annual energy consumption (kWh for electricity, BTU for gas devices).

Table A. 1 Modeled residential and commercial building customer types

Sector	Building Type	AC Status	Income Level
Single-Family	Pre-1980	AC	Low Income

Single-Family	Pre-1980	AC	Mod Income
Single-Family	Pre-1980	AC	High Income
Single-Family	Pre-1980	No AC	Low Income
Single-Family	Pre-1980	No AC	Mod Income
Single-Family	Pre-1980	No AC	High Income
Single-Family	Post-1980	AC	Low Income
Single-Family	Post-1980	AC	Mod Income
Single-Family	Post-1980	AC	High Income
Single-Family	Post-1980	No AC	Low Income
Single-Family	Post-1980	No AC	Mod Income
Single-Family	Post-1980	No AC	High Income
Multi-Family	3-4 Unit-Pre-1960	AC	-
Multi-Family	5-20 Unit-Pre-1960	AC	-
Multi-Family	Over 20 Unit-Pre-1960	AC	-
Multi-Family	3-4 Unit-Pre-1960	No AC	-
Multi-Family	5-20 Unit-Pre-1960	No AC	-
Multi-Family	Over 20 Unit-Pre-1960	No AC	-
Multi-Family	3-4 Unit-1960-1987	AC	-
Multi-Family	5-20 Unit-1960-1987	AC	-
Multi-Family	Over 20 Unit-1960-1987	AC	-
Multi-Family	3-4 Unit-1960-1987	No AC	-
Multi-Family	5-20 Unit-1960-1987	No AC	-
Multi-Family	Over 20 Unit-1960-1987	No AC	-
Multi-Family	3-4 Unit-Post-1987	AC	-
Multi-Family	5-20 Unit-Post-1987	AC	-
Multi-Family	Over 20 Unit-Post-1987	AC	-
Multi-Family	3-4 Unit-Post-1987	No AC	-
Multi-Family	5-20 Unit-Post-1987	No AC	-

Multi-Family	Over 20 Unit-Post-1987	No AC	-
Commercial	Office-0-3499	AC	-
Commercial	Retail-0-2799	AC	-
Commercial	K-12-0-24999	AC	-
Commercial	Assembly-0-3199	AC	-
Commercial	Office-3500-10999	AC	-
Commercial	Retail-2800-5999	AC	-
Commercial	K-12-25000-49999	AC	-
Commercial	Assembly-3200-7499	AC	-
Commercial	Office->=11000	AC	-
Commercial	Retail->=6000	AC	-
Commercial	K-12->=50000	AC	-
Commercial	Assembly->=7500	AC	-
Commercial	Medical/Industrial	AC	-

Table A. 2 Modeled residential and commercial building technology types

End-Use	Fuel	End-Use Type	Case
ASHP	Electricity	HVAC	Electrification
HPWH	Electricity	Water Heating	Electrification
Electric Cooking	Electricity	Kitchen (Cooking)	Electrification
Electric Clothes Drying	Electricity	Clothes Drying	Electrification
Electric Pool Heater	Electricity	Swimming Pool	Electrification
Electric Spa Heater	Electricity	Spa	Electrification
Panel Upgrade	Electricity	Panel & Service Upgrade	Electrification
Service Upgrade	Electricity	Panel & Service Upgrade	Electrification
Gas Space heating	Natural Gas	HVAC	Counterfactual
Space Cooling	Electricity	AC + Fans	Counterfactual
Electric Space Heating	Electricity	HVAC	Counterfactual

Gas WH	Natural Gas	Water Heating	Counterfactual
Electric WH	Electricity	Water Heating	Counterfactual
Gas Cooking	Natural Gas	Kitchen (Cooking)	Counterfactual
Gas Clothes Drying	Natural Gas	Clothes Drying	Counterfactual
Gas Pool Heater	Natural Gas	Swimming Pool	Counterfactual
Gas Spa Heater	Natural Gas	Spa	Counterfactual
Other Electric[46]	Electricity	Other	Both

Alternative Rates

The S/CAP Funding Model includes the ability to model increased natural gas rates to simulate the price impact if the CPAU reflected the additional decarbonization costs without electrification in the gas rates (such as by buying biogas). The alternate natural gas rate is based on the gas demand in the active scenario versus the baseline scenario. The ratio of the baseline gas demand relative to the active gas demand, in therms, is multiplied by the original distribution rates. If this option is selected by the model user, the updated distribution rates are added to the supply costs to calculate a final natural gas price on a $/therm basis. This is described in the two formulas below:

$$\text{Distribution Rate}_{New} = \text{Distribution Rate}_{Existing} * (\text{Gas Demand}_{Baseline\ Scenario} / \text{Gas Demand}_{Active\ Scenario})$$

$$\text{Gas Rate} = \text{Distribution Rate} + \text{Supply Rate}$$

If the user does not opt into using the increased gas rates, the 'standard' gas rate structure will be used, meaning no change will be applied to the existing distribution rate.

Transportation Model Methodology

The transportation portion of the modeling was conducted as part of the EV Charger Needs Assessment, a separate study to analyze EV charging infrastructure needs and costs under different levels of EV adoption in Palo Alto. The EV Charger Needs Assessment quantifies the number of EVs needed to reach Palo Alto's climate goals, the number of EV chargers that would be needed to support them, and the costs to build and serve those charges under several different business models. The quantitative analysis for the EV Charger Needs Assessment was conducted utilizing both in-house E3 models and inputs from external modeling tools. The modeling framework combines raw inputs, broad scenario design assumptions, and calculated inputs from external models to calculate the scale and cost of EV charging infrastructure needed to support different

[46] "Other Electric" captures electricity demand from plug loads (computers, phones, speakers, printers, etc.), secondary heating, or any other end-use not captured in the existing stock categories

levels of transportation electrification in Palo Alto. The transportation modeling framework consists of the following broad components:

- **Scenario design:** three EV penetration scenarios for both light-duty vehicles (LDV) and medium-duty vehicles (MDV) representing adoption rates ranging from current business-as-usual levels to the level of EV adoption necessary to hit emissions targets
- **Inputs and assumptions:** key inputs and assumptions include costs that would factor into increased EV adoption, such as electricity costs or charger costs, as well as inputs that would impact the total amount of electricity needed under each scenario, such as number of chargers needed, the number of miles each EV is expected to drive each year, and vehicle-specific charging patterns
- **Modeling:** E3 conducted the modeling for the EV Charger Needs Assessment as part of the Funding Model
- **Outputs:** outputs of the modeling include the total number of chargers needed, the cost to install those chargers, the impact on the electrical system from increased EV charging demand, and the associated cost to charge EVs

More in-depth information on the transportation modeling can be found in the EV Charger Needs Assessment Report.

Building Stock

Housing Type	Stock (Residential Housing Units OR # Commercial Buildings)
SF-Pre-1980-No AC-Low Income	508
SF-Pre-1980-No AC-Mod Income	1219
SF-Pre-1980-No AC-High Income	1917
SF-Pre-1980-AC-Low Income	693
SF-Pre-1980-AC-Mod Income	1438
SF-Pre-1980-AC-High Income	2666
SF-Post-1980-No AC-Low Income	182
SF-Post-1980-No AC-Mod Income	292
SF-Post-1980-No AC-High Income	547
SF-Post-1980-AC-Low Income	219
SF-Post-1980-AC-Mod Income	511
SF-Post-1980-AC-High Income	2225
MF-3-4 Unit-Pre-1960-No AC	247
MF-5-20 Unit-Pre-1960-No AC	651
MF-Over 20 Unit-Pre-1960-No AC	377
MF-3-4 Unit-Pre-1960-AC	595
MF-5-20 Unit-Pre-1960-AC	1549
MF-Over 20 Unit-Pre-1960-AC	848
MF-3-4 Unit-1960-1987-No AC	83
MF-5-20 Unit-1960-1987-No AC	304
MF-Over 20 Unit-1960-1987-No AC	1132
MF-3-4 Unit-1960-1987-AC	215
MF-5-20 Unit-1960-1987-AC	825
MF-Over 20 Unit-1960-1987-AC	3016

MF-3-4 Unit-Post-1987-No AC	5
MF-5-20 Unit-Post-1987-No AC	72
MF-Over 20 Unit-Post-1987-No AC	283
MF-3-4 Unit-Post-1987-AC	14
MF-5-20 Unit-Post-1987-AC	231
MF-Over 20 Unit-Post-1987-AC	942
Comm-Office-0-3499-AC	181
Comm-Retail-0-2799-AC	133
Comm-K-12-0-24999-AC	31
Comm-Assembly-0-3199-AC	12
Comm-Office-3500-10999-AC	229
Comm-Retail-2800-5999-AC	144
Comm-K-12-25000-49999-AC	15
Comm-Assembly-3200-7499-AC	11
Comm-Office->=11000-AC	234
Comm-Retail->=6000-AC	145
Comm-K-12->=50000-AC	18
Comm-Medical/Industrial	10
Comm-Assembly->=7500-AC	13

Building Electrification Rates

Low Adoption Scenario:

Building Sector	End-use	2025	2030	2040	2050	2060
SF	HVAC	*7%*	*16%*	*44%*	*72%*	*100%*
SF	Water Heating	*2%*	*19%*	*58%*	*96%*	*100%*
SF	Kitchen (Cooking)	*29%*	*39%*	*58%*	*77%*	*96%*
SF	Clothes Drying	*51%*	*61%*	*80%*	*99%*	*100%*
SF	Swimming Pool	*36%*	*46%*	*65%*	*84%*	*100%*
MF	HVAC	*8%*	*18%*	*45%*	*73%*	*100%*
MF	Water Heating	*2%*	*12%*	*50%*	*89%*	*100%*
MF	Kitchen (Cooking)	*72%*	*76%*	*84%*	*92%*	*100%*
MF	Clothes Drying	*73%*	*77%*	*85%*	*93%*	*100%*
MF	Swimming Pool	*1%*	*5%*	*13%*	*21%*	*30%*
Comm (Med/Industrial)	HVAC	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Water Heating	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Kitchen (Cooking)	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Clothes Drying	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Swimming Pool	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Small)	HVAC	*9%*	*16%*	*33%*	*50%*	*66%*
Comm (Small)	Water Heating	*5%*	*15%*	*38%*	*61%*	*84%*
Comm (Small)	Kitchen (Cooking)	*11%*	*20%*	*39%*	*58%*	*78%*
Comm (Small)	Clothes Drying	*2%*	*12%*	*31%*	*50%*	*69%*
Comm (Small)	Swimming Pool	*2%*	*12%*	*31%*	*50%*	*69%*
Comm (Large)	HVAC	*6%*	*13%*	*27%*	*41%*	*55%*
Comm (Large)	Water Heating	*5%*	*14%*	*33%*	*53%*	*72%*
Comm (Large)	Kitchen (Cooking)	*30%*	*20%*	*39%*	*58%*	*78%*
Comm (Large)	Clothes Drying	*2%*	*12%*	*31%*	*50%*	*69%*
Comm (Large)	Swimming Pool	*2%*	*12%*	*31%*	*50%*	*69%*

Medium Adoption Scenario:

Building Sector	End-use	2025	2030	2040	2041	2050	2060
SF	HVAC	*14%*	*57%*	*73%*	*76%*	*100%*	*100%*
SF	Water Heating	*9%*	*56%*	*72%*	*76%*	*100%*	*100%*
SF	Kitchen (Cooking)	*34%*	*69%*	*79%*	*80%*	*89%*	*98%*
SF	Clothes Drying	*54%*	*80%*	*90%*	*91%*	*100%*	*100%*
SF	Swimming Pool	*40%*	*73%*	*82%*	*83%*	*92%*	*100%*
MF	HVAC	*15%*	*57%*	*74%*	*77%*	*100%*	*100%*
MF	Water Heating	*10%*	*56%*	*94%*	*98%*	*100%*	*100%*
MF	Kitchen (Cooking)	*72%*	*76%*	*84%*	*85%*	*92%*	*100%*
MF	Clothes Drying	*73%*	*77%*	*85%*	*86%*	*93%*	*100%*
MF	Swimming Pool	*1%*	*5%*	*13%*	*14%*	*21%*	*30%*
Comm (Med/Industrial)	HVAC	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Water Heating	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Kitchen (Cooking)	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Clothes Drying	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Swimming Pool	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Small)	HVAC	*16%*	*58%*	*65%*	*66%*	*78%*	*94%*
Comm (Small)	Water Heating	*13%*	*58%*	*81%*	*83%*	*100%*	*100%*
Comm (Small)	Kitchen (Cooking)	*11%*	*20%*	*40%*	*42%*	*59%*	*79%*
Comm (Small)	Clothes Drying	*3%*	*16%*	*35%*	*37%*	*55%*	*75%*
Comm (Small)	Swimming Pool	*3%*	*16%*	*35%*	*37%*	*55%*	*75%*
Comm (Large)	HVAC	*13%*	*56%*	*63%*	*64%*	*70%*	*77%*
Comm (Large)	Water Heating	*12%*	*57%*	*67%*	*68%*	*76%*	*86%*
Comm (Large)	Kitchen (Cooking)	*30%*	*20%*	*40%*	*42%*	*59%*	*79%*
Comm (Large)	Clothes Drying	*3%*	*16%*	*35%*	*37%*	*55%*	*75%*
Comm (Large)	Swimming Pool	*3%*	*16%*	*35%*	*37%*	*55%*	*75%*

High Adoption Scenario:

Building Sector	End-use	2025	2030	2040	2050	2060
SF	HVAC	*21%*	*100%*	*100%*	*100%*	*100%*
SF	Water Heating	*17%*	*100%*	*100%*	*100%*	*100%*
SF	Kitchen (Cooking)	*39%*	*100%*	*100%*	*100%*	*100%*
SF	Clothes Drying	*58%*	*100%*	*100%*	*100%*	*100%*
SF	Swimming Pool	*45%*	*100%*	*100%*	*100%*	*100%*
MF	HVAC	*22%*	*100%*	*100%*	*100%*	*100%*
MF	Water Heating	*17%*	*100%*	*100%*	*100%*	*100%*
MF	Kitchen (Cooking)	*72%*	*76%*	*84%*	*92%*	*100%*
MF	Clothes Drying	*73%*	*77%*	*85%*	*93%*	*100%*
MF	Swimming Pool	*1%*	*5%*	*13%*	*21%*	*30%*
Comm (Med/Industrial)	HVAC	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Water Heating	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Kitchen (Cooking)	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Clothes Drying	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Med/Industrial)	Swimming Pool	*0%*	*0%*	*0%*	*0%*	*0%*
Comm (Small)	HVAC	*23%*	*100%*	*100%*	*100%*	*100%*
Comm (Small)	Water Heating	*20%*	*100%*	*100%*	*100%*	*100%*
Comm (Small)	Kitchen (Cooking)	*11%*	*20%*	*40%*	*60%*	*80%*
Comm (Small)	Clothes Drying	*3%*	*20%*	*40%*	*60%*	*80%*
Comm (Small)	Swimming Pool	*3%*	*20%*	*40%*	*60%*	*80%*
Comm (Large)	HVAC	*21%*	*100%*	*100%*	*100%*	*100%*
Comm (Large)	Water Heating	*19%*	*100%*	*100%*	*100%*	*100%*
Comm (Large)	Kitchen (Cooking)	*30%*	*20%*	*40%*	*60%*	*80%*

Comm (Large)	Clothes Drying	3%	20%	40%	60%	80%
Comm (Large)	Swimming Pool	3%	20%	40%	60%	80%

EV and Charger Stock

Low Scenario:

EV Stock:

EV Type	Resident Type	Customer Type	2025	2030	2040	2050	2060
LDV	SF	Resident	*8,095*	*14,437*	*28,950*	*31,177*	*33,404*
LDV	MF	Resident	*1,907*	*4,673*	*12,743*	*26,692*	*31,939*
LDV	Commuter	Commuter	*24,406*	*46,631*	*101,736*	*148,816*	*159,446*
MHDV	MHDV	MHDV	*7*	*131*	*761*	*2,019*	*2,163*

Number of Chargers:

Charger Owner Type	Customer Type	Charger Location	2025	2030	2040	2050	2060
SF	SF	Home L1	*2,221*	*3,930*	*7,756*	*8,353*	*8,949*
SF	SF	Home L2	*4,638*	*8,202*	*16,168*	*17,412*	*18,656*
Work	SF	Work L2	*298*	*542*	*1,128*	*1,215*	*1,301*
Public	SF	Public L2	*364*	*662*	*1,379*	*1,485*	*1,591*
Public	SF	Public DCFC	*29*	*53*	*112*	*121*	*129*
MF	MF	Home L1	*523*	*1,272*	*3,414*	*7,151*	*8,557*
MF	MF	Home L2	*1,092*	*2,655*	*7,117*	*14,907*	*17,838*
Work	MF	Work L2	*70*	*175*	*496*	*1,040*	*1,244*
Public	MF	Public L2	*86*	*214*	*607*	*1,271*	*1,521*
Public	MF	Public DCFC	*7*	*17*	*49*	*103*	*124*
Work	Commuter	Work L2	*224*	*436*	*987*	*1,444*	*1,547*
Public	Commuter	Public L2	*275*	*536*	*1,215*	*1,777*	*1,904*
Public	Commuter	Public DCFC	*22*	*43*	*99*	*144*	*154*
Work	City	Work DCFC	*7*	*109*	*534*	*1,417*	*1,519*

Medium Scenario:

EV Stock:

EV Type	Resident Type	Customer Type	2025	2030	2040	2050	2060
LDV	SF	Resident	*8,155*	*14,826*	*28,950*	*31,177*	*33,404*
LDV	MF	Resident	*2,251*	*6,229*	*16,987*	*29,810*	*31,939*
LDV	Commuter	Commuter	*25,391*	*51,378*	*112,093*	*148,816*	*159,446*
MHDV	MHDV	MHDV	*13*	*238*	*1,386*	*2,019*	*2,163*

Number of Chargers:

Charger Owner Type	Customer Type	Charger Location	2025	2030	2040	2050	2060
SF	SF	Home L1	*2,237*	*3,790*	*6,313*	*6,799*	*7,284*
SF	SF	Home L2	*4,672*	*7,909*	*13,161*	*14,173*	*15,185*
Work	SF	Work L2	*300*	*628*	*1,548*	*1,667*	*1,786*
Public	SF	Public L2	*367*	*768*	*1,892*	*2,037*	*2,183*

Public	SF	Public DCFC	29	60	146	157	168
MF	MF	Home L1	618	1,592	3,704	6,501	6,965
MF	MF	Home L2	1,289	3,323	7,722	13,552	14,520
Work	MF	Work L2	83	264	908	1,594	1,707
Public	MF	Public L2	101	323	1,110	1,948	2,087
Public	MF	Public DCFC	8	25	86	150	161
Work	Commuter	Work L2	466	1,084	2,985	3,963	4,247
Public	Commuter	Public L2	573	1,334	3,673	4,876	5,225
Public	Commuter	Public DCFC	46	105	282	375	402
Work	City	Work DCFC	12	198	973	1,417	1,519

High Scenario:

EV Stock:

EV Type	Resident Type	Customer Type	2025	2030	2040	2050	2060
LDV	SF	Resident	8,240	15,215	28,950	31,177	33,404
LDV	MF	Resident	2,568	7,785	21,232	29,810	31,939
LDV	Commuter	Commuter	26,375	56,125	122,450	148,816	159,446
MHDV	MHDV	MHDV	19	346	1,874	2,019	2,163

Number of Chargers:

Charger Owner Type	Customer Type	Charger Location	2025	2030	2040	2050	2060
SF	SF	Home L1	2,261	3,731	5,412	5,828	6,244
SF	SF	Home L2	4,721	7,788	11,284	12,151	13,019
Work	SF	Work L2	303	691	1,810	1,949	2,088
Public	SF	Public L2	371	844	2,212	2,382	2,553
Public	SF	Public DCFC	30	66	167	180	193
MF	MF	Home L1	705	1,909	3,969	5,572	5,970
MF	MF	Home L2	1,472	3,985	8,273	11,616	12,446
Work	MF	Work L2	95	353	1,327	1,864	1,997
Public	MF	Public L2	116	432	1,622	2,278	2,441
Public	MF	Public DCFC	9	34	122	172	184
Work	Commuter	Work L2	726	1,904	5,721	6,953	7,449
Public	Commuter	Public L2	893	2,342	7,039	8,554	9,165
Public	Commuter	Public DCFC	71	181	529	643	689
Work	City	Work DCFC	17	287	1,316	1,417	1,519

Model Logic

Stock Rollover

Within the model, device costs and energy demand are driven by device and vehicle stock trajectories, which are based upon adoption scenario. Each adoption scenario is set up to reach a certain penetration of electrified equipment stock by key model years (e.g., 2030, 2040, etc.). Annual EV sales and building electric device installations are calculated based on these stock targets, as well as on a natural device retirement schedule calculated using standard device or vehicle lifetimes. These sales and installations are split by sector, community member type, and device type.

In some cases, the electric equipment stock targets require adoption that is faster than what would occur naturally if community members were replacing their equipment or vehicles on burnout. For example, in the High Electrification scenario for buildings, it is assumed that building owners must purchase all-electric appliances before their existing appliances have reached the end of their useful lives, thus leading to early retirement of appliances. Mandates, such as the Zero NOx Standard, will force the adoption of efficient electric devices at the end of current devices' useful lives, but local action and increased financial incentives can also drive this accelerated level of adoption. In the Low Electrification scenario, it is assumed that building owners will use their existing equipment until burnout (i.e. the end of its useful life), at which point a specified portion of those building owners will replace the existing appliances with the all-electric alternative.

The EV stock assumptions for the transportation electrification scenarios are all based upon the stock rollover from the California Air Resources Board (CARB) Scoping Plan Mitigation scenario. CARB's stock rollover modeling accurately reflects the timing of purchases and the associated turnover for the replacement of vehicles. That is, the stock rollover trajectory created by CARB captures the time lag between annual sales of new vehicles and how the overall population of vehicles will change over time. E3 leveraged the existing mitigation trajectory modeled for the CARB scoping plan for the modeled adoption scenarios, but benchmarked the adoption forecast to Palo Alto's current adoption levels and future penetration targets. The EV Charger Needs Assessment Report includes further details on the methodology used to develop the EV adoption scenarios.

Total upfront costs are calculated using the annual sales, based on the aforementioned stock trajectories, multiplied by the equipment cost. Energy demand is calculated using the total equipment stock levels multiplied by the energy consumption of each technology type, and energy costs multiply the energy demand by fuel and electricity rates.

Financing Order of Operations

After device stocks, sales, energy demand, and costs are calculated, the next step in the model is to calculate the existing funding available to pay for electrification and the remaining funding gap. The model includes a list of existing funding sources that can be used to cover certain costs of electrification and the user can specify which sources to include vs. which to exclude from the calculations. Additional user inputs and model assumptions are used to determine the portion of the cost burden that will fall on community members as opposed to the City.

The model utilizes a set of steps to determine the overall financing landscape of communitywide electrification. These steps are:

Calculating the total upfront cost of electrification

Upfront costs are calculated by multiplying device capital costs and the incremental adoption in each year. This is done across building subsectors and end uses, and both privately owned and City-owned vehicles and chargers.

Calculate the Total Investment Gap

The Total Investment Gap is the total upfront cost less available IRA incentives, State and regional incentives, and the community members' contribution to capital, as discussed above. The resulting number represents the remaining cost of electrification after existing funding sources and community member capital is applied.

Determine capital needs

Based on the total electrification investment gap and user inputs, the model calculates the amount of capital necessary to deliver incentives and loans to community members across sectors. It is assumed that the municipality is responsible for 100% of the cost of City-owned vehicles and chargers, and so these costs are included in the total capital requirements of the City. The percentage of Investment Gap to be closed by the City depends on the scenario:

- Low Local Action:30%
- Medium Local Action: 50%
- High Local Action: 80%

Funding allocation

Once the amount of capital needed to cover City-owned transportation equipment, incentives, and loans is calculated, the available funding designated for direct funding is applied. A baseline assumption in the model is that municipal funding is first applied to City-owned vehicles and chargers, and the remaining capital, if any is available, can be used for incentives and loans. Available municipal and utility funding is applied as it is available, until either funding is depleted, or capital requirements are met.

It is possible for available funds to exceed capital needs. In this case, the model is set up to bank leftover funds; if funding exceeds capital need in one year, the remaining capital can be used for vehicle or charger purposes, incentives, or loans in the next year. Because capital allocation is not optimized and is instead based on a user-defined allocation, it is possible for there to be excess funding in one sector and a shortage of funding in another.

Remaining capital need

In the event that capital need exceeds available funding for direct funding within a given sector, the remainder of the expenses will be covered by issuing debt. The ratio of municipal to utility debt is determined by a user input (discussed above), with the caveat that any leftover expenses from the purchase of City-owned vehicles and chargers must be covered by municipal debt.

Debt expense calculations

Once the amount of municipal and utility debt issued in each year is calculated, the model calculates the debt expense (principal + interest). The model uses the Excel function =PMT() to calculate the annual payment that would be required based on the present value of the debt issued in each year, the user-defined interest rate, and the user-defined debt maturity. This value is calculated for each year's debt issuance, and the cumulative debt expense in each year is calculated based on the debt maturity.

Funding sources that are marked as being applied to debt repayment are used to cover this debt expense; like the funding sources used to purchase vehicles and chargers or provide loans and incentives, funds are banked when left unused. In the event that the debt expense exceeds the amount of funding available in that year, the model will allocate that value to a "remaining debt expense balance." Theoretically, the municipality or utility would need to use alternate funds to cover this remaining balance.

Cost and Benefits Included

Table A. 3 Benefit and cost components analyzed for each perspective

Example Cost	c
Examble Benefit	b

Category	Component	Communitywide Perspective	Participant Perspective	CPAU Perspective
Funding and Incentives	Upfront Building Electrification Costs	c	c	
	Upfront Transportation Electrification Costs	c	c	
	City-Owned Vehicles/Chargers/E-Bikes	c		c
	Avoided End-Of-Life Equipment Replacement Costs	b	b	
	Avoided ICE Replacement Costs	b	b	
	Federal and State Incentives	b	b	b
	CPAU Incentives and Loans		b	c
	Existing Revenue Sources	b		b
	Private Capital	b		b
	External Loans	b	b	
	Bonds	b		b
System Costs	Incremental Electric System Costs	c		c
	Avoided Gas System Cost	b		b
Operating Costs	Incremental Electric Bill		c	b
	EV/E-Bike Charging Cost		c	b
	Incremental Taxes		c	b
	Incremental Third Party Charging-as-a-Service Cost	c	c	
	Incremental O&M	c/b	c/b	
	Avoided Gasoline Cost	b	b	
	Avoided Natural Gas Bill		b	c
Debt Repayment	Debt Repayment to External Sources	c	c	c
	Debt Repayment to CPAU		c	b

Table A. 4 Description of benefit and cost components

Component	Description	Data Source(s)
Upfront Building Electrification Costs	Equipment costs for electrifying space heating, water heating, stove, and clothes dryer equipment	Building Subsector Studies led by Willdan and Rincon
Upfront Transportation Electrification Costs	Equipment costs for EVs, EV chargers, and E-bikes	Various sources, including utility program data, ICCT, RMI, and CALeVIP
City-Owned Vehicles/Chargers/E-Bikes	Equipment costs, specifically for the EVs, EV chargers, and E-bikes owned by the City of Palo Alto	Various sources, including utility program data, ICCT, RMI, and

		CALeVIP
Avoided End-Of-Life Equipment Replacement Costs	Avoided equipment costs for end-of-life replacement of space heating, space cooling, water heating, stove, and clothes dryer equipment	Building Subsector Studies led by Willdan and Rincon
Avoided ICE Replacement Costs	Avoided costs for end-of-life replacement of ICE vehicles	ICCT report[47]
Federal and State Incentives	Tax credits and incentives made available from Federal programs (IRA, IIJA) and State/Regional organizations (TECH Clean CA, BAAQMD)	Tech Clean California,[48] BAAQMD,[49] US Federal Government
City Incentives and Loans	Incentives and loans provided to community members from the City to purchase heat pumps, heat pump water heaters, EVs, etc.	Calculated based on user-defined percentage of cost gap closed by City
Existing Revenue Sources	Revenue sources that the City or Utility already receives; this captures Low Carbon Fuel Standard (LCFS) and Cap-and-Trade credit revenue	Palo Alto FY 2024 Operating Budget[50]
Private Capital	Capital provided to the community from private institutions via Public Private Partnerships (PPP)	User defined
External Loans	Loans taken out by community members from third-party lenders to close the electrification cost gap remaining after City incentives and loans are distributed	Calculated based on remaining cost gap after City incentives/loans are applied
Bonds	Municipal and Utility debt issued to raise the capital needed to cover the remaining cost of providing incentives, loans, and purchasing City-owned vehicles/chargers/e-bikes, after all funding sources have been applied as specified in the model	Calculated based on debt issuance required to cover the gap filled by Palo Alto

[47] Assessment of light-duty electric vehicle costs and consumer benefits in the United States in the 2022–2035 time frame
[48] TECH Clean California
[49] BAAQMD
[50] City of Palo Alto

Incremental Electric System Costs	Cost to upgrade electric system to support increased electrification	Provided by Palo Alto
Avoided Gas System Cost	Avoided capital costs of gas main and service replacement due to targeted electrification and gas decommissioning	City of Palo Alto Report on the Impacts of Electrification on Gas Distribution System Costs[51]
Incremental Electric Bill	Customer electric bill change due to additional electric usage	Calculated using the total energy usage (provided by the Building Subsector Studies) and the electricity rates (provided by Palo Alto)
EV/E-Bike Charging Cost	Customer costs from charging EVs and E-Bikes	Calculated using the load shapes produced by E3's EVGrid (detailed methodology explained in the EV Charger Needs Assessment) and electricity rates (provided by Palo Alto)
Incremental Taxes	The additional taxes paid by Palo Alto residents and businesses to fund electrification programs	Simplified calculation based on total taxes raised divided by total number of business or resident taxpayers
Incremental Third-Party Charging-as-a-Service Cost	The cost that EV charging customers will pay to charge their vehicles at chargers that are owned/operated by a third party	Calculated based on costs of EV charging infrastructure divided by utilization in kWh
Incremental O&M	The difference in O&M costs incurred by community members due to electrification; this can be a cost or a benefit, depending on if post-electrification O&M is higher or lower than the baseline O&M	Building Subsector Studies led by Willdan and Rincon
Avoided Gasoline Cost	Customer gasoline expense decrease due to reducing gasoline usage to zero	Calculated using vehicle efficiencies from ICCT and gasoline costs from EIA AEO 2023
Avoided Natural Gas	Customer gas bill decrease due to	Calculated using energy

[51] City of Palo Alto

Bill	reducing gas usage to zero	usage from Building Subsector Studies and natural gas rates from Palo Alto
Debt Repayment to External Sources	Community member and community repayment of debt to third-party lenders, including principal and interest	Calculated using the total external loans issued by customers and total debt issued by Palo Alto (calculated), the relevant interest rates (user input), and relevant payback periods (user input)
Debt Repayment to City	Community member repayment of debt provided via City loans, including principal and interest	Calculated using the total loans issued by customers (calculated), the interest rate (user input), and payback period (user input)

Results

MAC Curve – Low Local Action

MF Cooking	98	(648)
SF Cooking	616	(401)
LDV Electrification	132,934	(321)
E-Bikes	1,285	(69)
MF HVAC	3,759	(3)
Commercial HVAC	3,779	11
SF Swimming Pool	233	69
Commercial Water Heating	613	82
SF Water Heating	7,065	101
MHDV Electrification	9,930	169
MF Water Heating	4,694	183
SF HVAC	13,198	302
SF Clothes Drying	559	1,745

MAC Curve – High Local Action

MF Cooking	29	(648)
SF Cooking	1,568	(397)
LDV Electrification	64,688	(251)
E-Bikes	1,981	(49)
Commercial HVAC	16,716	(48)
MF HVAC	9,768	2
SF Swimming Pool	644	73
Commercial Water Heating	2,012	133
MHDV Electrification	5,526	169
SF HVAC	34,927	194
SF Water Heating	13,247	327
MF Water Heating	10,338	364
SF Clothes Drying	996	1,621