Exhibit 1

CITY OF GLENDALE, CALIFORNIA

Municipal Electric Vehicle

Fleet Electrification Study

Presented by Center for Transportation and the Environment
September 2022

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List of Acronyms

A&E	Architecture and Engineering
BEB	Battery Electric Bus
CTE	Center for Transportation and the Environment
CI	Carbon Intensity
DOE	Department of Energy
DGE	Diesel Gallons Equivalent
dHEB	Diesel Hybrid
EPA	Environmental Protection Agency
EV	Electric Vehicle
ESS	Energy Storage System
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicles
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
kWh	Kilowatt Hour
kWh/mi	Kilowatt-hour/mile
LCFS	Low Carbon Fuel Standard
MPO	Metropolitan Planning Organization
MW	Megawatt
MWh	Megawatt-hours
NFPA	National Fire Protection Association
OCTA	Orange County Transportation Authority
OEM	Original Equipment Manufacturer
ROW	Right-of-Way
TOU	Time-of-Use
ZEB	Zero-Emission Bus

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Executive Summary

The City of Glendale, California (the City) engaged the Center for Transportation and the Environment (CTE) to perform an electric vehicle (EV) fleet electrification study to evaluate the requirements, operational considerations, and costs to transition all vehicles in the municipal fleet to 100% EV by either 2035 or 2040. The results of the study will inform the City of the estimated costs, benefits, constraints, and risks of the transition to an EV fleet and will guide future planning and decision-making.

Baseline

As of October 2021, The City owns and operates a fleet of 1,018 vehicles. Eliminating trailers, non-vehicular equipment, and parade antiques from the analysis, the City's fleet consists of 863 vehicles, which is the basis for the analysis. As shown in **Figure 1**, City vehicles are categorized as Light-, Medium-, and Heavy-Duty (based on GVWR classification), Pursuit, and Non-Road vehicles.

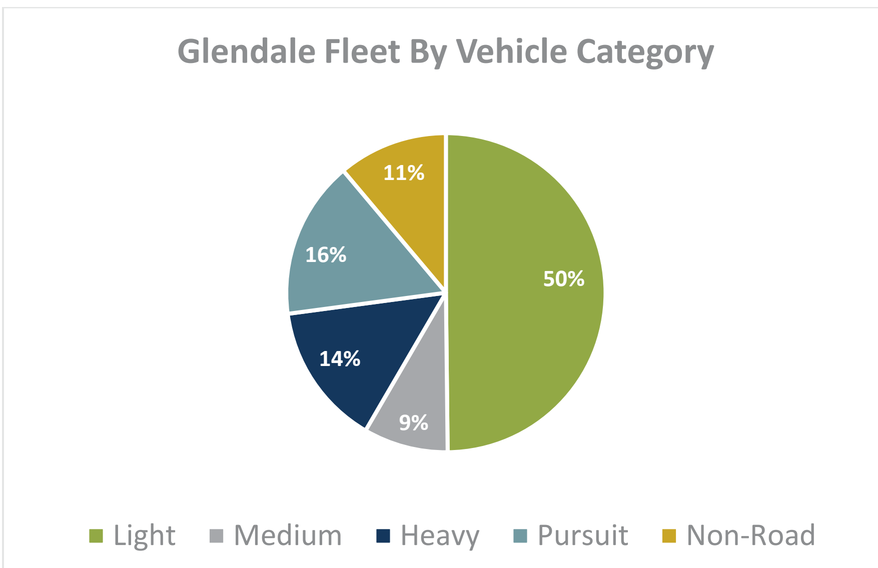

Figure 1. Glendale Fleet Distribution by Vehicle Category

Each Vehicle Category consists of several types of vehicles, as shown in **Table 1**:

Table 1. Fleet composition by Vehicle Category and Type

Light		Medium		Heavy		Pursuit		Non-road	
1 ton Pickup	46	1 ton Pickup	1	Crane Truck	7	Sedan	11	Backhoe/Loaders	19
1/2 ton Pickup	37	Dump Truck	12	Dump Truck	15	SUV	127	Bunker Rake	6
3/4 ton Pickup	47	Flatbed	10	Emergency	6			Compact Excavator	2
Cargo Van	25	Heavy Truck	12	Fire Engine	16			Electric Cart	13
Compact Pickup	60	Manlift Truck	8	Flatbed	1			Forklift	12
Dump Truck	2	Rescue	14	Heavy Truck	14			Mowers	11
Flatbed	5	Specialty	5	Ladder Truck	4			Non-road	1
Heavy Truck	1	Walk-in Van	12	Manlift Truck	10			Track Loader	1
Manlift Truck	1			Refuse	44			Utility Sweeper	7
Mini Van	26			Roll-off Truck	2			Utility Trucksters	21
Motorcycle	28			Street Sweeper	5			Wheel Loader	3
Passenger Mini Van	7			Walk-in Van	1				
Refuse-bin truck	14								
Sedan	76								
Std Passenger Van	2								
SUV	46								
	423		**74**		**125**		**138**		**96**

The City operates 716 of these vehicles out of 6 primary facilities; Public Works Yard, City Hall Complex, Glendale Water & Power Utility Operations Center, Integrated Waste Yard, Fire Station 21, and the Glendale Police Department. The remaining 146 vehicles are spread out among smaller facilities across the City. This distribution is shown in **Figure 2**. While the study considers all vehicles in the City fleet, the infrastructure and electricity demand assessments focused on the six primary parking facilities.

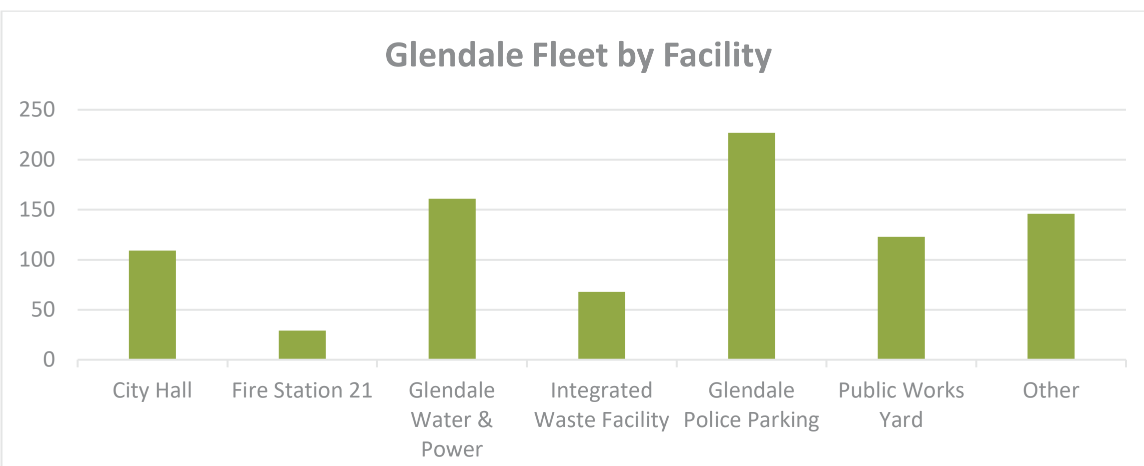

Figure 2. Glendale Fleet Distribution by Facility

Market Analysis

To start the EV Transition Analysis, CTE conducted an EV market analysis to determine the EVs currently available that could be a suitable replacement for the City's fleet. The assessment also looked at new developments in the EV market that may benefit future vehicle replacements. The scope of the analysis is limited to battery electric vehicles. While the City operates many kinds of vehicles, commercially available EVs are currently limited to sedans, SUVs, medium-duty trucks and vans, and motorcycles**. Table 2** shows the EV availability across vehicle types. EVs in other fleet categories have limited application or are in development. However, we expect continuous development and that new vehicles will enter the market in the future.

Table 2. Electric Vehicle Market Availability by Vehicle Type

Vehicle Type	Electric Version Availability
Sedans	Available
Light-Duty Pickup Trucks	In development
SUVs	Available
Light-Duty Vans	PHEV minivan available; no fully electric minivan currently available
Medium-Duty Trucks	Available
Medium-Duty Vans	Electric cargo and passenger vans are available
Heavy-Duty Trucks	In development
Pursuit Vehicles	Pursuit-rated vehicles are not currently available
Motorcycles	Available
Non-road/off-road	In development

A summary of available comparable EVs by type and corresponding charging infrastructure are provided in Appendix A and Appendix B respectively.

Feasibility Assessment

An essential element in developing an EV Transition Plan is feasibility, which, in this context, is the measure of the likely range of an EV under strenuous conditions as compared to the required daily duty cycle. In other words, does the EV have enough battery energy to operate a full day, with air conditioning or heating, before returning to its designated parking area for an overnight charge.

Key assumptions in this assessment include:

- Fleets typically charge overnight during off-peak hours when the cost of energy is lowest, thus each EV needs enough energy to complete a full daily duty cycle.
- EV efficiency and range is impacted by topography, traffic speed and conditions, and climate. Thus, it is important to determine the efficiency and range that accounts for these factors when determining feasibility.

Table 3 below summarizes the expected feasible range by vehicle type based on the expected operating conditions (topography, speed, and climate) in Glendale. The "Achievable" range is the daily mileage that is feasible under most conditions. The "Uncertain" range is the daily mileage that may be feasible under some conditions (light traffic, minimal A/C or heater use). The "Unachievable" range is considered not feasible under any normal conditions. We recommend using the Achievable range for planning purposes.

Table 3. Expected Range Feasibility by Vehicle Type

Vehicle Type		Achievable	Uncertain	Unachievable
Light Duty	SUV (Subaru Solterra*)	0 – 150 miles	150-175 miles	>175 miles
	Sedan (Nissan Leaf S*)	0 – 100 miles	100 – 125 miles	>125 miles
	Pickups (Lordstown Endurance*)	0 - 175 miles	175 – 225 miles	> 225 miles
Medium-Duty	Vans (MT50e All-Electric Chassis*)	**0 – 96 miles**	**96 -120 miles**	**>120 miles**
	Dump Trucks (BYD 6F Chassis*)	0 - 75 miles	75 – 125 miles	>125 miles
Heavy Duty	Trucks (BYD 8TT*)	**0 – 125 miles**	**125 – 150 miles**	**>150 miles**
	Dump (Peterbilt 520EV*)	0 – 50 miles	50 -75 miles	>75 miles
Pursuit	Sedans (Tesla Model 3*)	**0 – 195 miles**	**195 – 224 miles**	**>224 miles**
	Motorcycles (Model FX*)	0 – 50 miles	50 -75 miles	>75 miles

** Vehicle shown is the basis for the "Achievable" range calculation.*

Based on the City's duty cycle for every vehicle in the fleet, EV adoption is highly feasible, except for Pursuit Motorcycles, as indicated in **Table 4**. Medium-Duty Dump Trucks and Heavy-Duty Refuse Trucks are moderately feasible. We expect feasibility to improve over time with advances in EV technologies and improvements in battery energy density.

Table 4. Expected Transition Achievability by Vehicle Type

Vehicle Type		Achievable	Uncertain	Unachievable
Light Duty	SUV	91%	7%	2%
	Sedans	90%	4%	6%
	Pickups	90%	4%	6%
	Vans	90%	4%	6%
Medium-Duty	Vans	95%	1%	4%
	Dump Trucks	60%	35%	5%
Heavy Duty	Trucks	87%	10%	3%
	Refuse Trucks	50%	39%	11%
Pursuit	Sedans	95%	3%	2%
	Motorcycles	30%	23%	47%

Fleet Transition Assessment

The timing of replacing ICE vehicles with EVs is based on four primary factors:

- Asset Replacement Schedule: is the vehicle ready for replacement based on age, mileage, or hours?
- Duty Cycle Feasibility: can the replacement EV feasibly meet the daily duty cycle?
- Vehicle Availability and Suitability: is the EV commercially available and is it a suitable replacement
- Glendale Transition goals: What procurement strategy allows the City to reasonably achieve a 100% zero emission fleet over time?

The fleet transition assessment assumes that vehicles in the City's fleet will be replaced at the end of their planned useful life. **Table 5** shows the number of vehicles currently approved for replacement each fiscal year.

Table 5. Glendale Replacement Schedule Overview

Fiscal Year	# Of Vehicles Approved for Replacement	Original Budget
18-19	150	$13,694,500
19-20	100	$8,159,500
20-21	50	$4,793,000
21-22	65	$10,715,621
22-23	75	$8,731,300

However, the City currently has 328 vehicles in their fleet that are overdue for replacement. It may be burdensome to replace these vehicles all at once. Thus, the transition plan assumes that all vehicles will be replaced at the end of their useful life, AND the City will replace 25% of the backlog of vehicles overdue for replacement over the next four years.

We have determined that EV technology can feasibly meet the same vehicle duty cycle in the City's current fleet. However, that does not mean that there are EVs currently available to perform the same operation and meet the same requirements as the City's current fleet. Thus, in addition to feasibility, we also consider suitability. Suitability considers commercial availability through multiple OEMs, track record for deployment, and can replace ICE vehicles on a 1:1 basis.

Table 6 is used to assess EV suitability each year of the transition. Once an EV achieves a score of 4 or 5, they are considered eligible to replace an ICE vehicle.

Table 6. Electric Vehicle Suitability Scoring Assumptions

	Score	Definition
Eligible for transition	5	**Very High Suitability – (Widespread Adopters)** Meets all commercial availability criteria, can likely be a 1:1 replacement with proper charging infrastructure, vehicle options from more than 5 OEMs available
	4	**High Suitability (Limited Adopters)** - Meets all commercial availability criteria, can likely be a 1:1 replacement with proper charging infrastructure, vehicle options from more than 1 OEM available
Not eligible for transition	3	**Medium Suitability (Early Adopter)** - Meets all commercial availability criteria except for "Cost Effective." Available for purchase, few commercial deployments, but past the prototyping stage. May not be 1:1 replacement
	2	**Low Suitability (First Customer)** - Can be ordered, but may not be able to be immediately entered into production. In pilot/prototyping stage of development
	1	**Not yet available for purchase**

Using this method, each Vehicle Category by GVWR class is assigned a suitability score for each year of the transition period. **Table 7** is a sample of the Suitability Score used for the Glendale analysis.

Table 7. Suitability Score by Year and Vehicle Type

Vehicle & GVWR Class	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Light Duty - 1	5	5	5	5	5	5	5	5	5	5	5	5	5
Light Duty - 2	3	3	3	4	4	5	5	5	5	5	5	5	5
Light Duty - 3	2	3	3	3	4	4	5	5	5	5	5	5	5
Medium Duty - 4	2	3	3	3	4	4	5	5	5	5	5	5	5
Medium Duty - 5	1	1	1	2	3	4	5	5	5	5	5	5	5
Medium Duty - 6	1	1	1	2	3	4	5	5	5	5	5	5	5
Heavy Duty - 7	1	1	1	2	3	4	5	5	5	5	5	5	5
Heavy Duty - 8	1	1	1	2	3	4	5	5	5	5	5	5	5
Pursuit - 1	3	3	4	4	4	4	4	5	5	5	5	5	5
Pursuit - 2	1	1	3	3	4	4	4	5	5	5	5	5	5
Non-Road - Backhoes, loaders, etc.	1	1	1	2	2	3	4	5	5	5	5	5	5
Heavy - Specialty, Fire Engines, etc.	1	1	1	1	1	1	1	2	2	3	3	4	5

Glendale's stated goal is to transition to a 100% zero emission fleet strategically and responsibly. This report will look at two scenarios, using both 2035 and 2040 as transition goals. Based on current market availability and the extended asset life of some types of vehicles in the City's fleet, this goal may not be achievable. With each scenario, we set a target procurement percentage for each year of the transition period, as shown in **Table 8.**

For example, in both scenarios, the target is 10% of all new vehicle purchases to be EVs in 2023. The escalating target allows time for the market to develop the types of vehicles required by the City. It also allows the City to avoid early retirement of vehicles in the 2040 scenario and to start building out the required infrastructure to support those vehicles. The California Air Resources Board is in the process of finalizing a ruling that will apply to State and Local fleets such as Glendale. The Advanced Clean Fleets (ACF) Regulation will set zero emission vehicle purchase requirements as a percent of purchases by year. The City will need to monitor the progress of the ruling and potentially adjust purchase requirements to meet the new regulation.

Table 8. EV Procurement Targets by 2035 and 2040 Scenarios

Year	2035 EV Procurement Target	2040 EV Procurement Target
2023	10%	10%
2024	10%	10%
2025	25%	25%
2026	50%	25%
2027	50%	50%
2028	75%	50%
2029	75%	75%
2030	100%	75%
2031	100%	100%
2032	100%	100%
2033	100%	100%
2034	100%	100%
2035	100%	100%
2036		100%
2037		100%
2038		100%
2039		100%
2040		100%

As a result of the City's asset replacement schedule, duty cycle feasibility, vehicle type suitability, and the City's transition goals, **Table 8** outlines the annual number of EVs purchased that represent first-time replacement of ICE with EVs for a given vehicle for each scenario. Tracking the cost of first-time replacements of conventional vehicles with EVs is important to understand the cost to transition. **Figure 3** shows the first-time EV procurement quantities each year for the two scenarios, and **Figure 4** shows the annual cost associated with the first-time EV procurements each year by scenario.

Table 9. First Time EV Procurements for each Scenario

Year	2035 EV Procurements	2040 EV Procurements
2023	8	8
2024	20	20
2025	35	35
2026	56	36
2027	24	24
2028	44	34
2029	54	54
2030	126	98
2031	125	133
2032	50	62
2033	49	56
2034	81	86
2035	62	71
2036	38	51
2037	24	25
2038	10	12
2039	6	6
2040	9	10

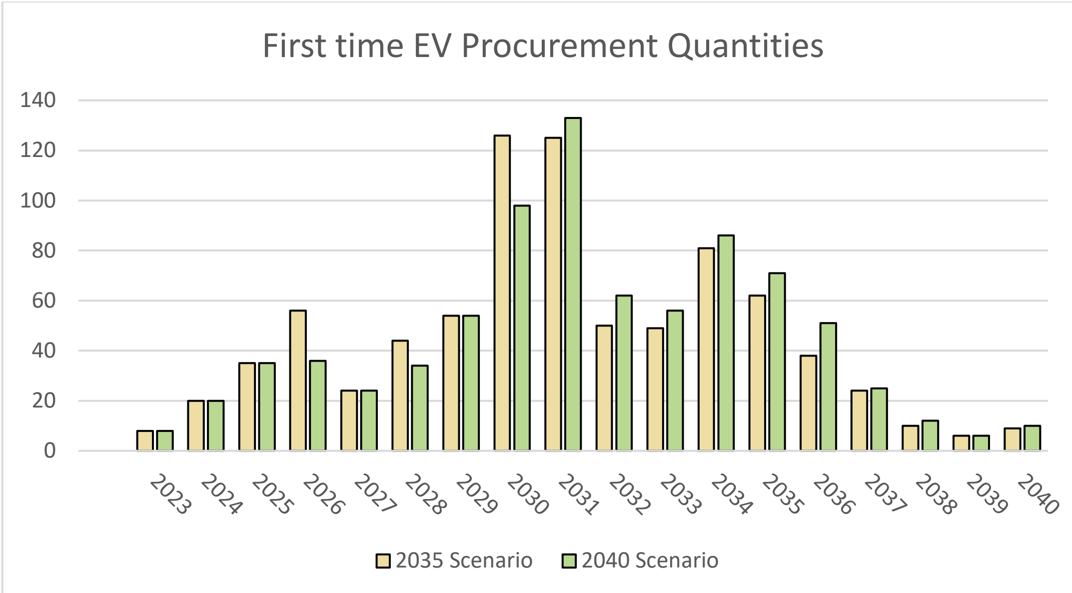

Figure 3. First Time EV Procurement Quantities

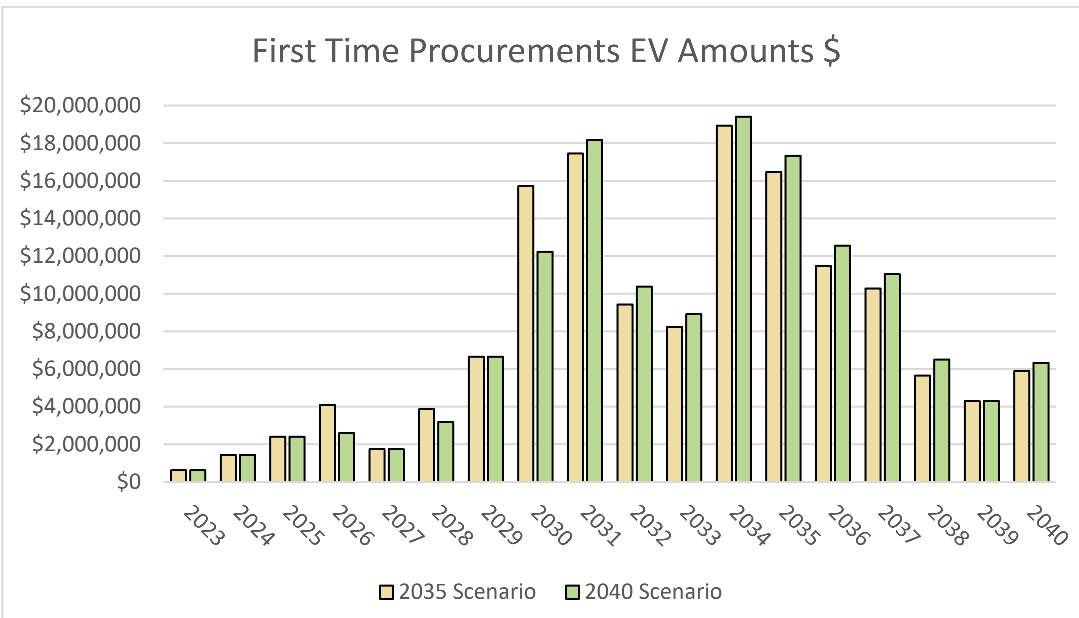

Figure 4. First Time Procurement EV Amounts

Figure 5 and **Figure 6** presents the annual procurements of both EVs and ICEs for each scenario. Note that, even though the annual procurement goal is 100% after 2031 and

2030 respectively, the City may need to purchase a small number of ICE vehicles if no suitable EV replacements exist. This will likely be the case with fire engines.

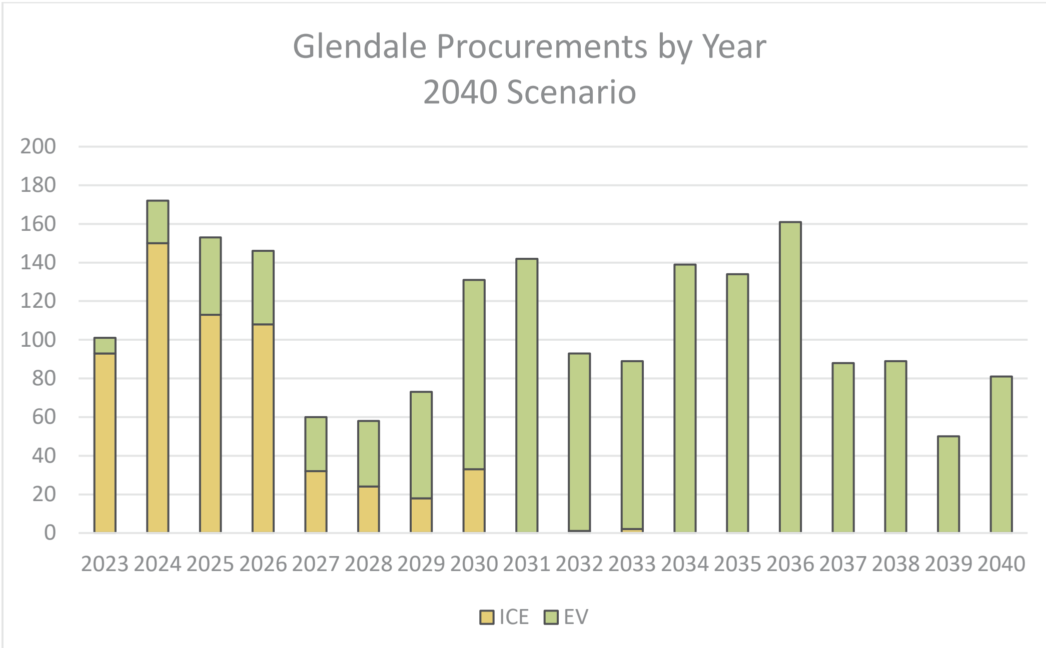

Figure 5. Glendale Procurements by Year, 2040 Scenario

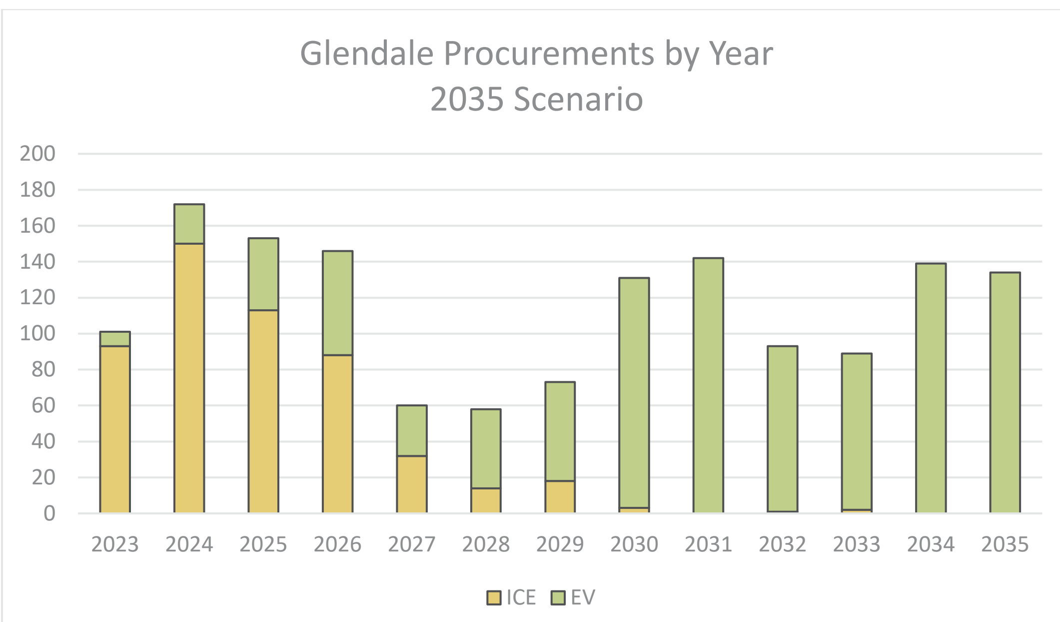

Figure 6. Glendale Procurements by Year, 2035 Scenario

Following these procurement schedules allows the City to transition to 100% EVs in the desired timeline, provided the required vehicles have suitable and feasible EV alternatives by the time of purchase. The annual fleet composition for each scenario is shown in **Figure 7** and **Figure 8**. As a result of the suitability assumptions and procurement schedules, the City's fleet may still include some ICE vehicles at the end of the planned transition period.

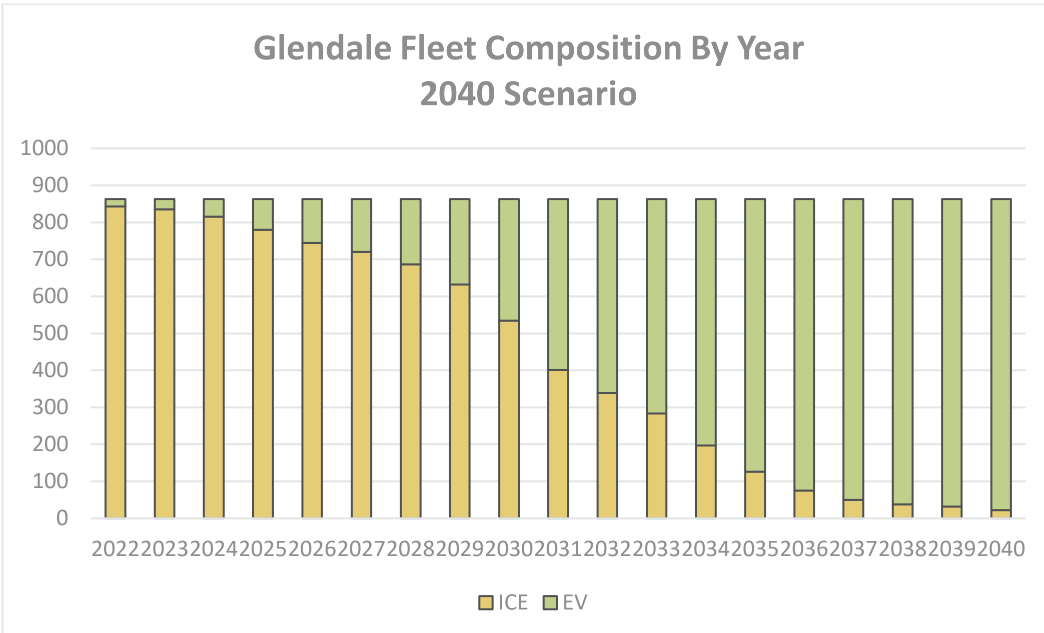

Figure 7. Glendale Fleet Composition by Year, 2040 Scenario

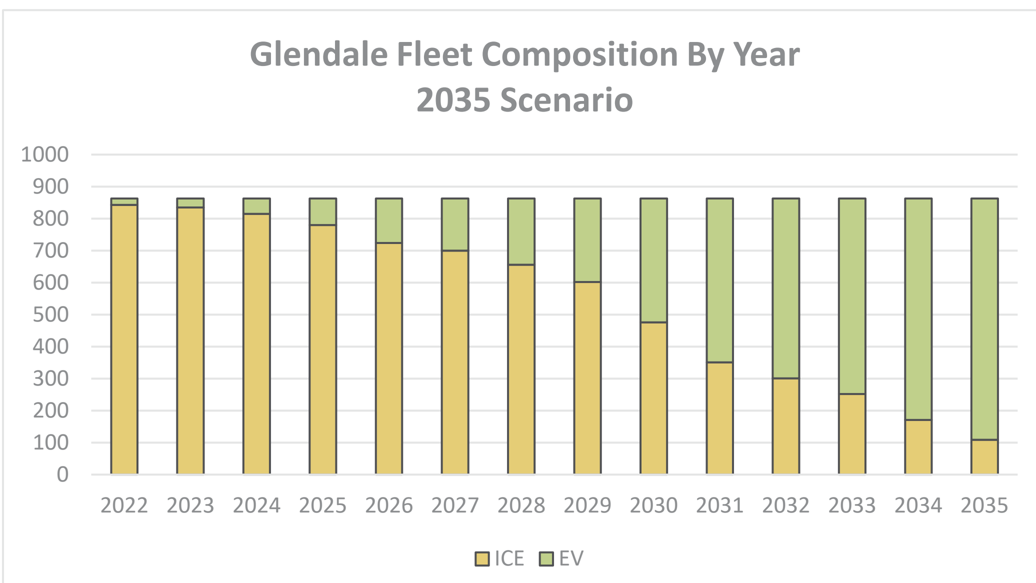

Figure 8. Glendale Fleet Composition by Year, 2035 Scenario

The 2040 scenario achieves 85% EVs in 2035 and 97% EVs in 2040. The 2035 scenario achieves 87% by 2035. The reason for this is based on the fleet replacement schedule, which assumes that vehicles are replaced at the end of their useful life, as well as our assumptions regarding vehicle availability and suitability. For example, we assume that fire engines will not have a suitable replacement until after 2035. However, even if there were commercially suitable products on the market, several fire engines are not scheduled for replacement until after 2035 or 2040 due to its 20-year service life.

The cost of EVs can be 50% - 100% higher than the cost of a comparable ICE vehicle. Since the 2035 scenario accelerates EV procurement, the City will bear a higher cost of capital earlier in the transition life cycle. The annual capital investment for each scenario is shown below in **Figure 9** and **Figure 11**. The cumulative capital investment for each scenario is shown below in **Figure 10** and **Figure 12.**

In all cases, we provide a "Baseline Scenario" for comparison. The Baseline scenario represents the replacement of the City's fleet with the same ICE vehicles as currently exists. This helps to demonstrate the incremental costs associated with the transition to EVs.

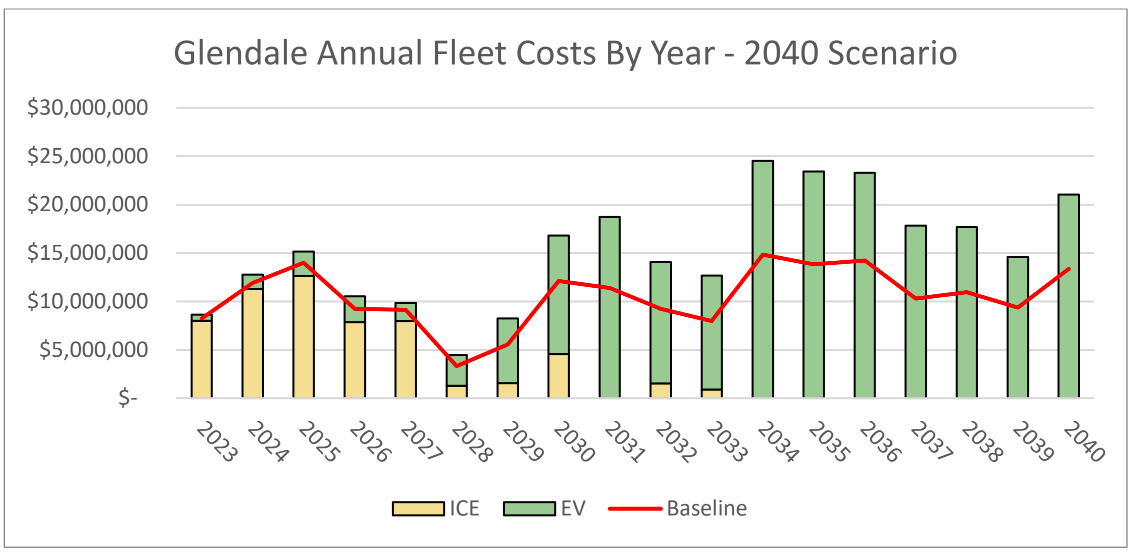

Figure 9. Glendale Annual Fleet Costs by Year, 2040 Scenario

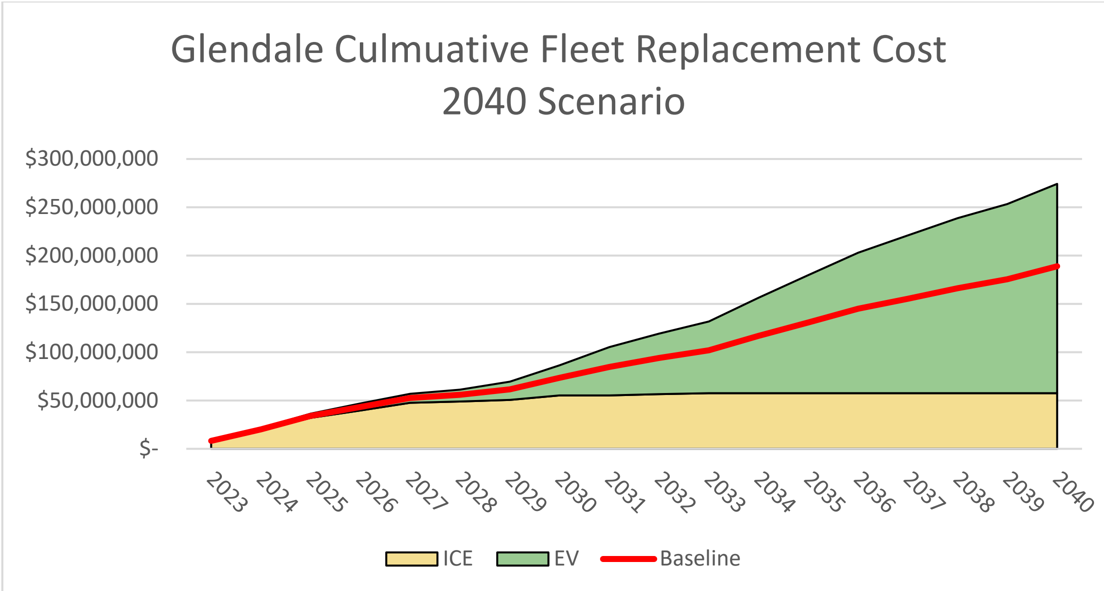

Figure 10. Glendale Cumulative Fleet Cost, 2040 Scenario

The cumulative fleet replacement costs in the 2040 EV Transition scenario is estimated at $274.3 million, an $85.3 million increase over the Baseline scenario.

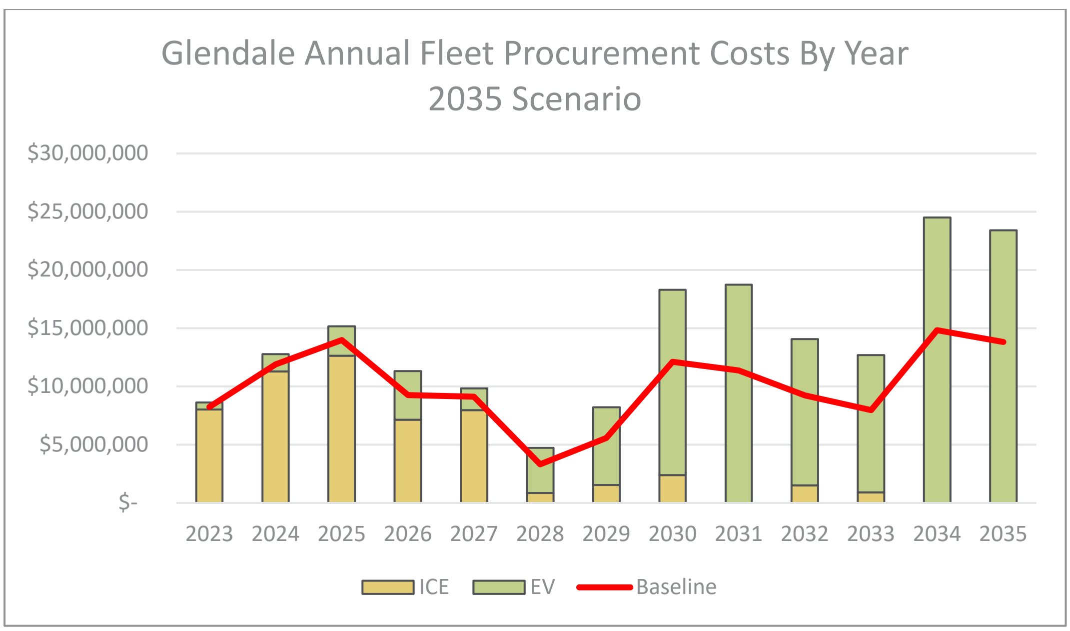

Figure 11. Glendale Annual Fleet Costs by Year, 2035 Scenario

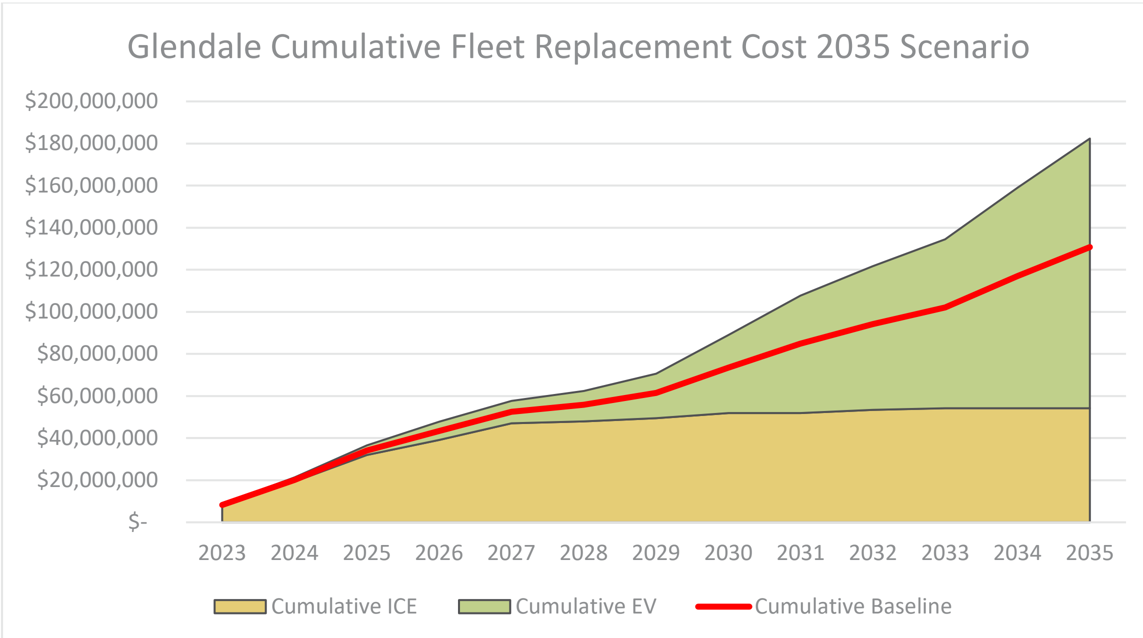

Figure 12. Glendale Cumulative Fleet Costs by Year, 2035 Scenario

The cumulative fleet replacement costs in the 2035 EV Transition scenario is estimated at $276.8 million, an $87.8 million increase over the Baseline scenario.

Infrastructure Transition Assessment

In addition to purchasing EVs, it will be necessary to upgrade electrical infrastructure at each facility where the City parks their vehicles overnight to accommodate the required charging equipment. At this point, we assume that each vehicle will have a dedicated charger (1:1 vehicle-to-charger ratio). However, with improvements in charging technology, it will be possible to increase the ratio to 2:1 or 4:1 and reduce the infrastructure requirements and related costs.

Based on the assumption of a 1:1 vehicle-to-charger ratio, GWP estimated that each yard will require electrical service upgrades, as shown in **Table 10**. The table provides the GWP estimate for each facility as well as the installed power, in megawatts, required for a 100% EV fleet.

Table 10. Estimated Upgrade Costs by Facility

Facility	Installed Power for 100% EV Fleet (MW)	Estimated Cost (Including engineering hours and construction labor)
Public Works Yard	1.26	$300,000
City Hall Complex	1.12	$300,000
GWP Utility Operations Center	1.58	$250,000
Integrated Waste Yard	0.72	$250,000
Fire Station 21	0.35	$225,000
Police Parking Lot	21.5	$4,100,000
Subtotal	26.53	$5,425,000
Acacia Station Upgrade		$17,000,000
Total		$21,875,000

GWP also recommends upgrading the capacity and operating voltages of the Acacia Substation to continue providing reliable service. The cost of this upgrade is estimated at $17 million (includes upgrades to the Public Works Yard and Integrated Waste Facility) Adding this upgrade brings the total to more than $21.8 million.

In addition to adding more service to each yard, the City will need to build out the infrastructure within the yard to deliver power from the transformers to the chargers. This effort will require design and construction of duct banks, conduit, mounting pads/islands, stub-outs, bollards, etc. This can be built in phases as the number of EVs increase at each yard. We currently assume two design/build phases for each yard. Because the 2035 scenario does not fully transition the fleet to 100% EVs, additional infrastructure costs will be incurred as the remaining vehicles are delivered.

As each new EV is delivered, new chargers will be installed, assuming the 1:1 ratio. Note that we've increased the number of Level 2 chargers by 10% to allow for spare capacity. As a result, annualized investment in charging infrastructure for each scenario is shown below in **Figure 13** and **Figure 14.** The Acacia Station upgrade cost is split between the two facilities that it supplies: the Public Works Yard and Integrated Waste Facility. This upgrade is likely to take several years – the graphs show the upgrade taking place in 2006 - 2007.

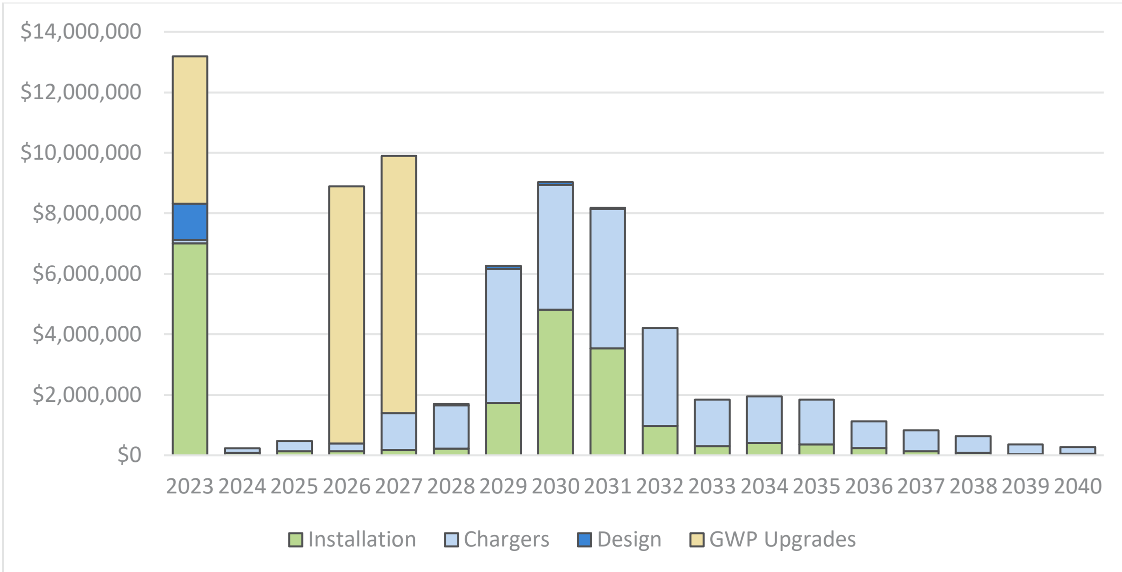

Figure 13. Glendale Infrastructure Cost, 2040 Scenario

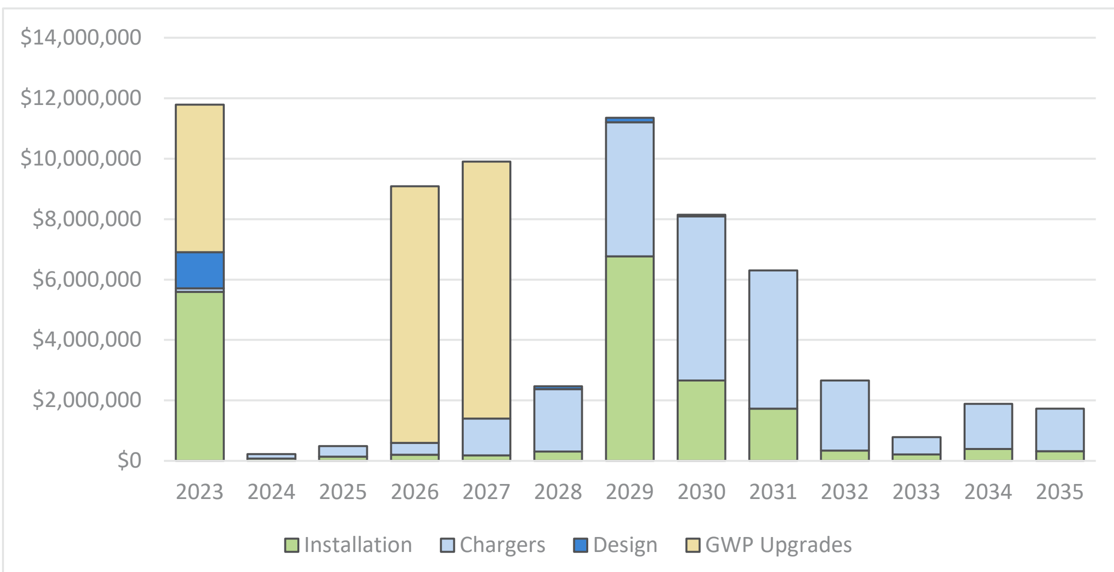

Figure 14. Glendale Infrastructure Cost, 2035 Scenario

Note: these cost estimates are considered a "rough order of magnitude" estimate and not an engineering cost estimate. Also, we've excluded infrastructure upgrade and infrastructure design/build cost at "Other" facilities under the assumption that these costs would be minimal as compared to the six primary facilities because comparatively few vehicles park at these locations. Charger and installation costs for "Other" facilities are included in the estimates.

Fuel Assessment

EVs are generally at least four times as efficient as ICEs. However, while generally favorable, the cost of electricity can sometimes be higher than fossil fuels. Utility rates vary significantly across the county based on generation mix and local demand. With proper planning, fleets can take advantage of low utility rates by charging overnight during off-peak hours. We've estimated the effect of each scenario using electricity as a fuel instead of fossil fuel, as shown below in **Figure 15, Figure 16, Figure 17,** and **Figure 18.**

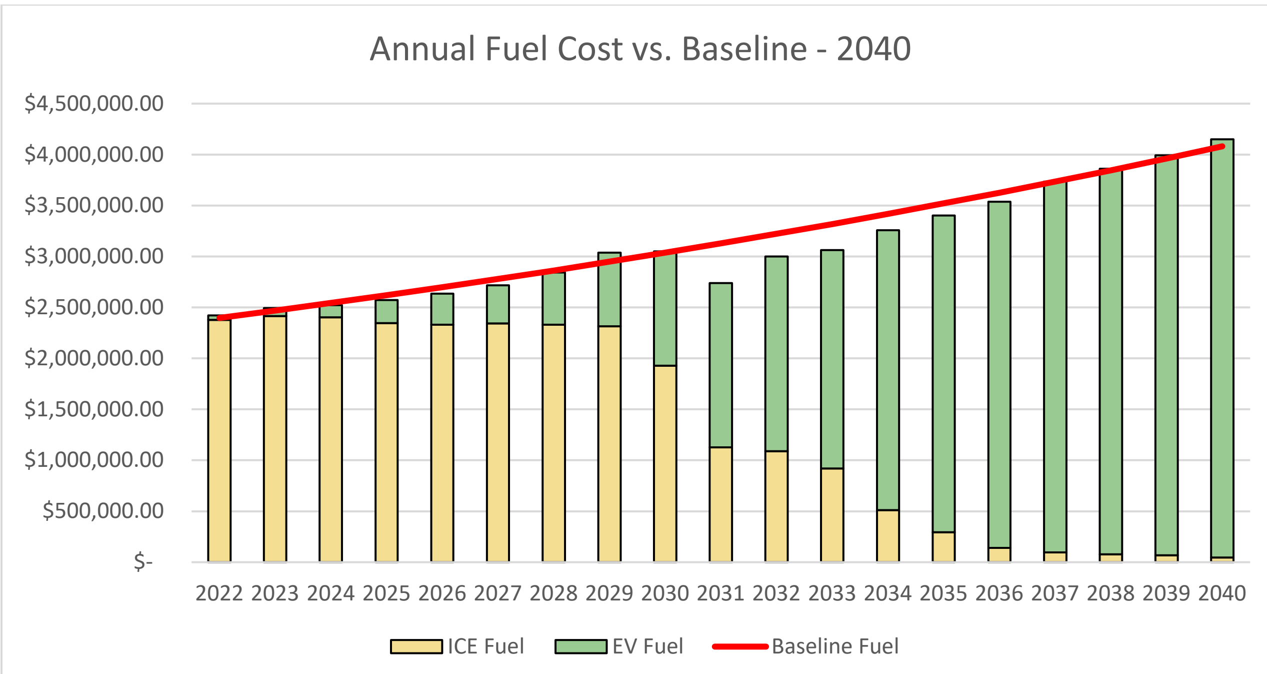

Figure 15. Annual Fuel Cost vs. Baseline, 2040 Scenario

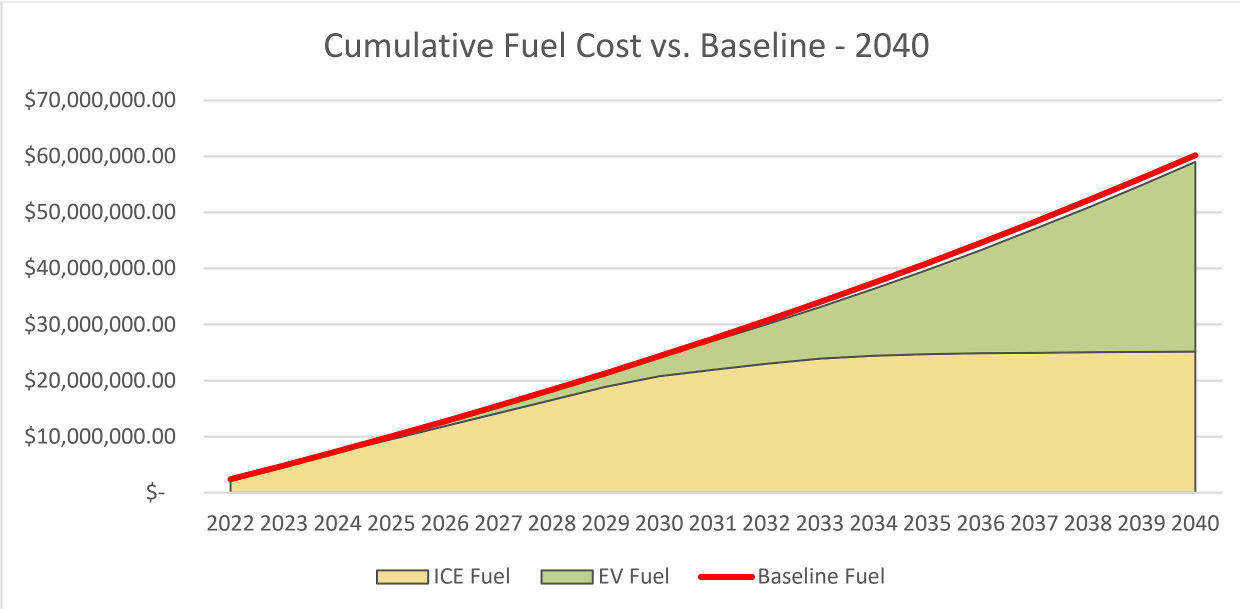

Figure 16. Cumulative Fuel Cost vs. Baseline, 2040 Scenario

Note that is a marginal difference between the Baseline scenario and the EV transition scenario with respect to estimated fuel cost.

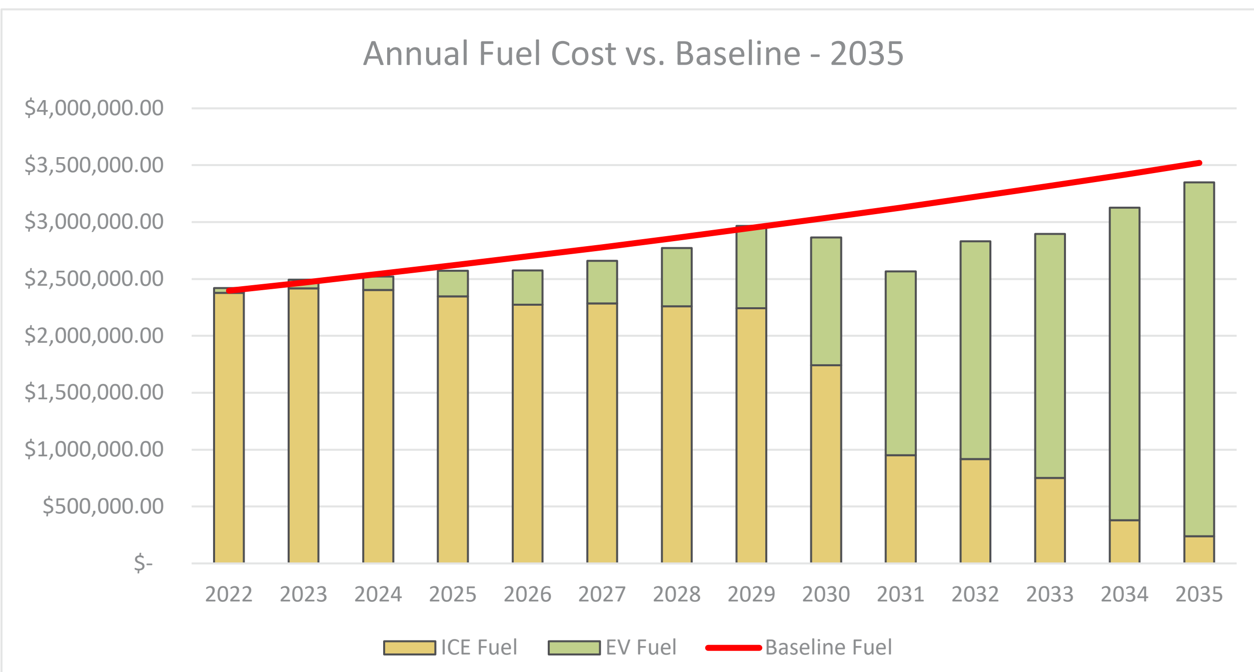

Figure 17. Annual Fuel Cost vs. Baseline, 2035 Scenario

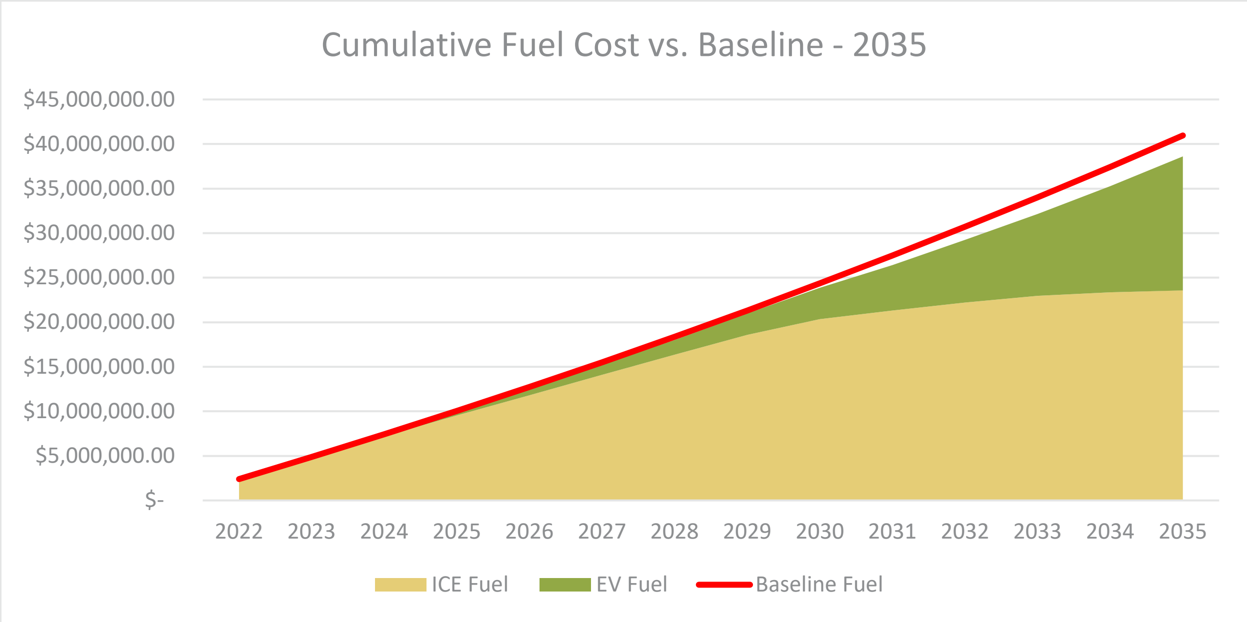

Figure 18. Cumulative Fuel Cost vs. Baseline, 2035 Scenario

Maintenance Assessment

EVs have an advantage over ICE with respect to maintenance due to fewer moving parts, no fluids to replace, and less frequent brake changes due to regenerative braking. Although there is very little data, we estimate that fleets can save approximately 30% on maintenance over the life of the vehicle. The estimated annual maintenance cost compared to baseline vehicles for the 2040 and 2035 Scenarios is provided below in **Figure 19** and **Figure 20** respectively. Cumulative costs for each scenario are provided in **Figure 21** and **Figure 22.**

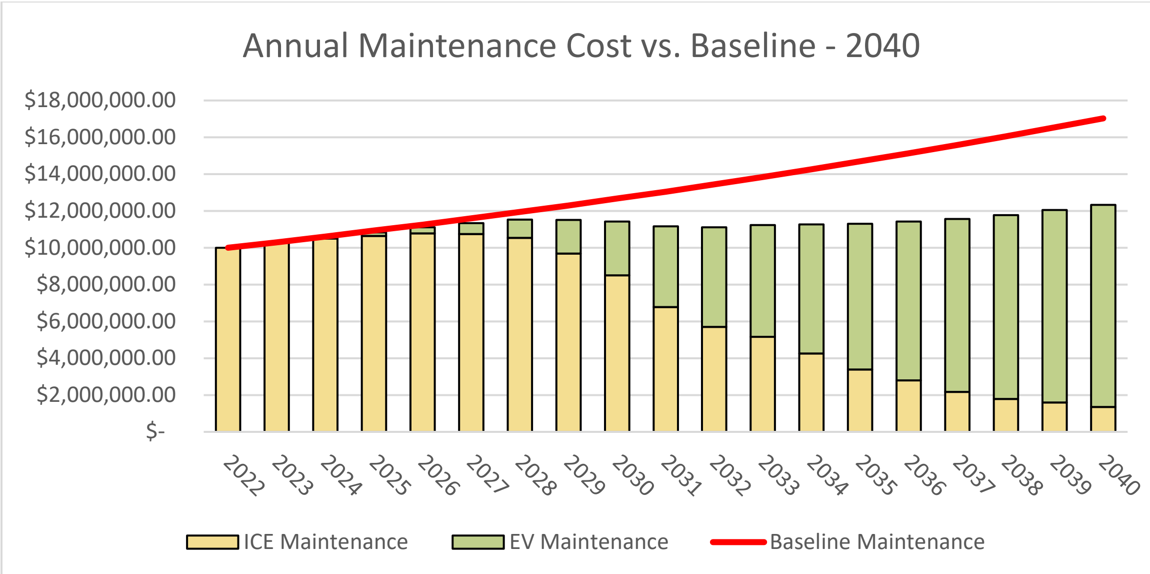

Figure 19. Estimated Annual EV Maintenance Costs Compared to Baseline, 2040

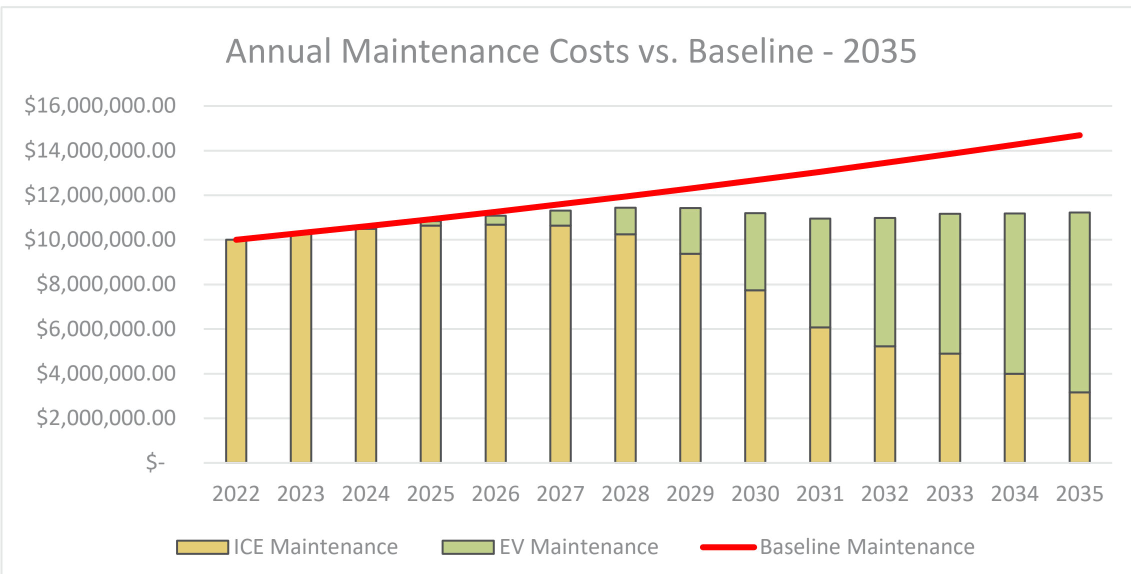

Figure 20. Estimated Annual EV Maintenance Costs Compared to Baseline, 2035

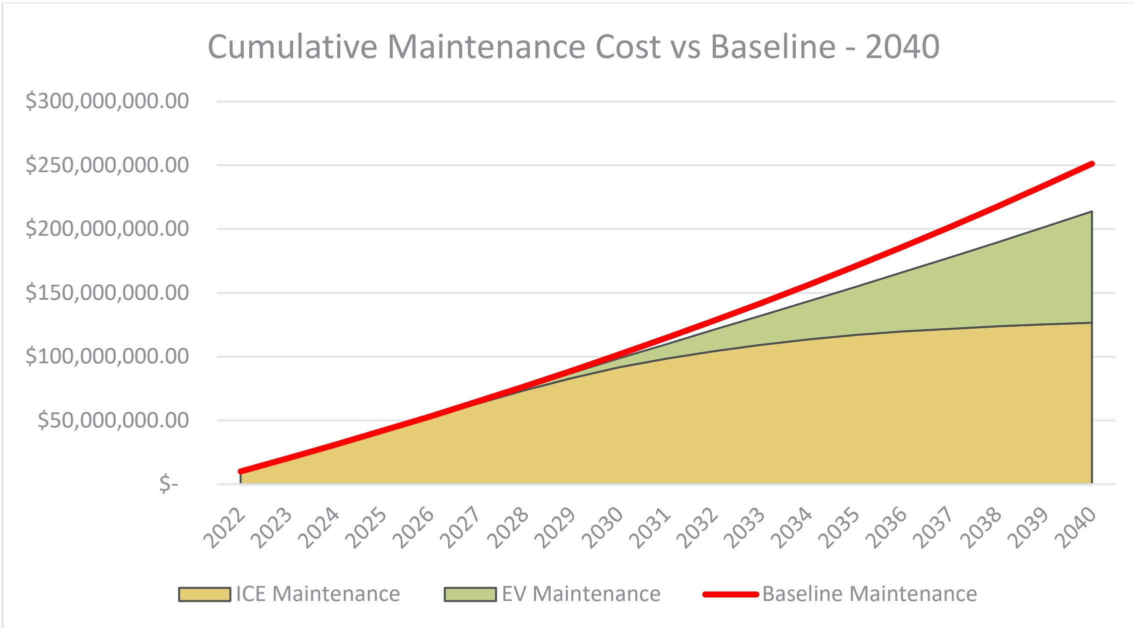

Figure 21. Cumulative EV Maintenance Costs Compared to Baseline, 2040

Cumulative maintenance costs in the 2040 EV scenario is estimated at $213.8 million, a cumulative savings of $37.4 million over the Baseline scenario.

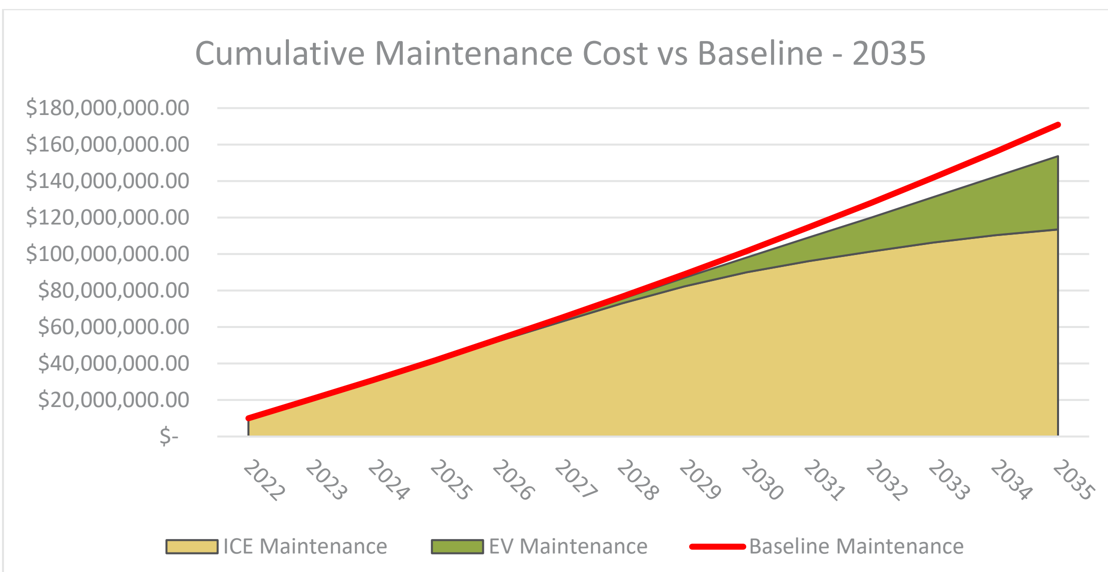

Figure 22. Cumulative EV Maintenance Costs Compared to Baseline, 2035

Cumulative maintenance costs in the 2035 EV scenario is estimated at $212.7 million, a cumulative savings of $38.5 million over the Baseline scenario.

Emissions Assessment

There are substantial financial costs and operational impacts to consider when transitioning to EVs. However, the primary goal is to reduce tailpipe emissions to improve local air quality and reduce the affect that GHGs have on the environment. Net emission reduction is the comparison of current ICE emission compared to emissions related to generation of the electricity required to charge the EVs. While we expect the emissions associated with Glendale's current generation mix to improve over time with the introduction of more renewables on the grid, the estimated emissions reduction of the City's EV transition is shown below in **Figure 23** and **Figure 24**.

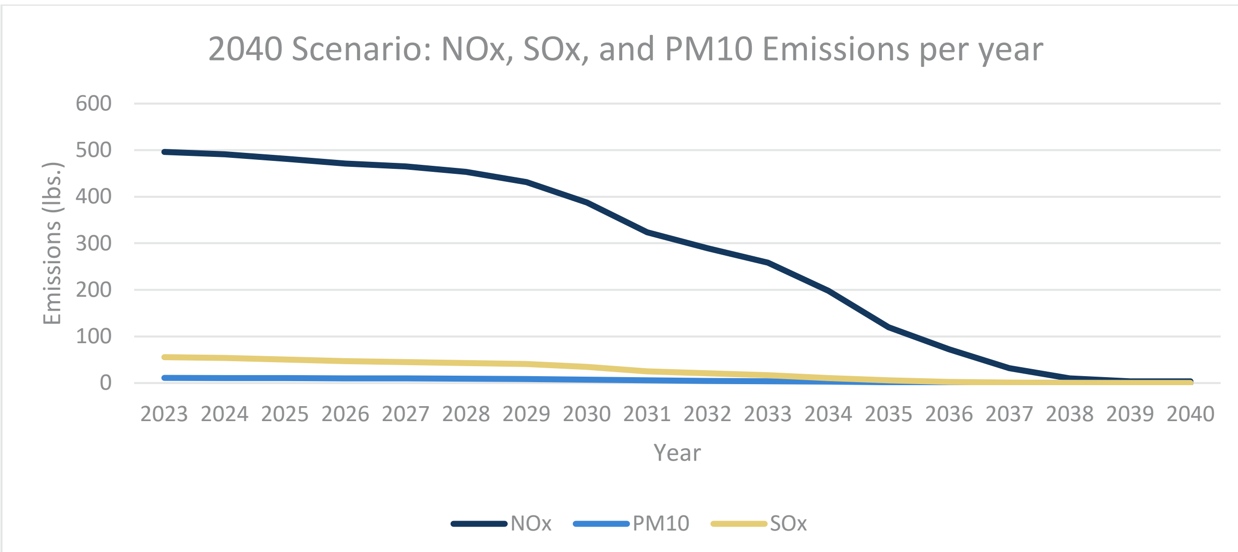

Figure 23. Estimated Emissions of NOx, SOx, PM 10, 2040 Scenario

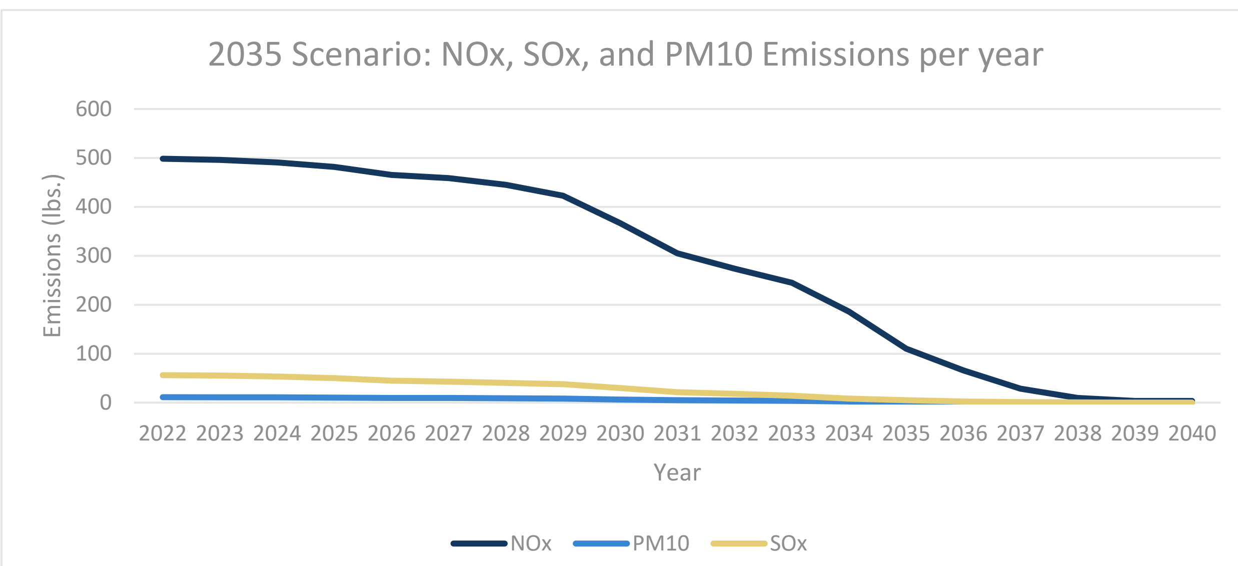

Figure 24. Estimated Emissions of NOx, SOx, PM 10, 2035 Scenario

Total Transition Costs

Total Transition Cost is the total incremental cost of first-time EV replacements plus total EV infrastructure costs. It represents the incremental capital funding required to transition to an all-electric fleet. **Figure 25** provides the total cumulative transition cost for the 2040 scenario which is estimated at $123.5 million.

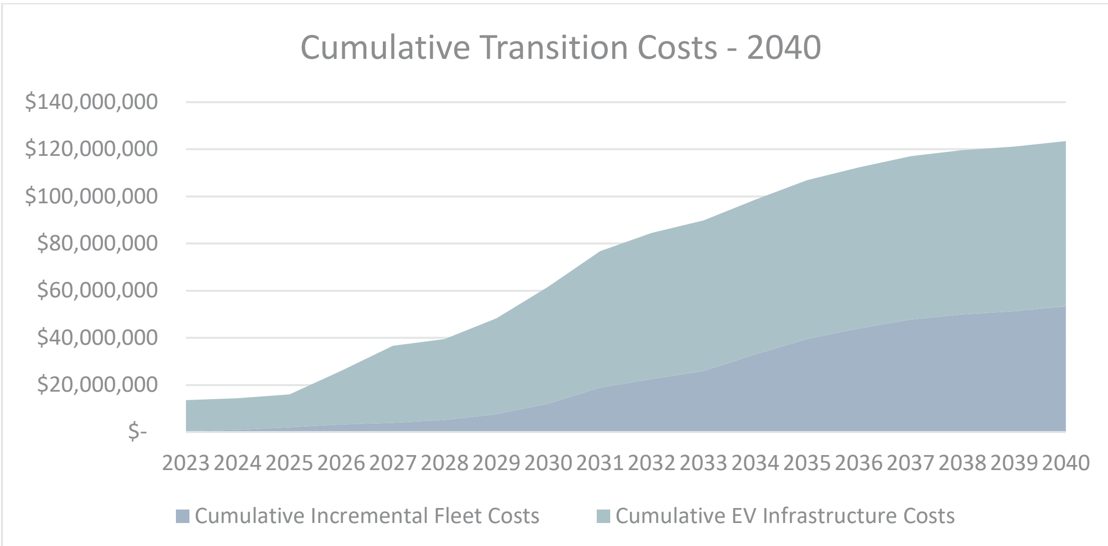

Figure 25. Cumulative Transition Costs, 2040 Scenario

Figure 26 provides the total cumulative transition cost for the 2035 scenario which is estimated at $106.8 million.

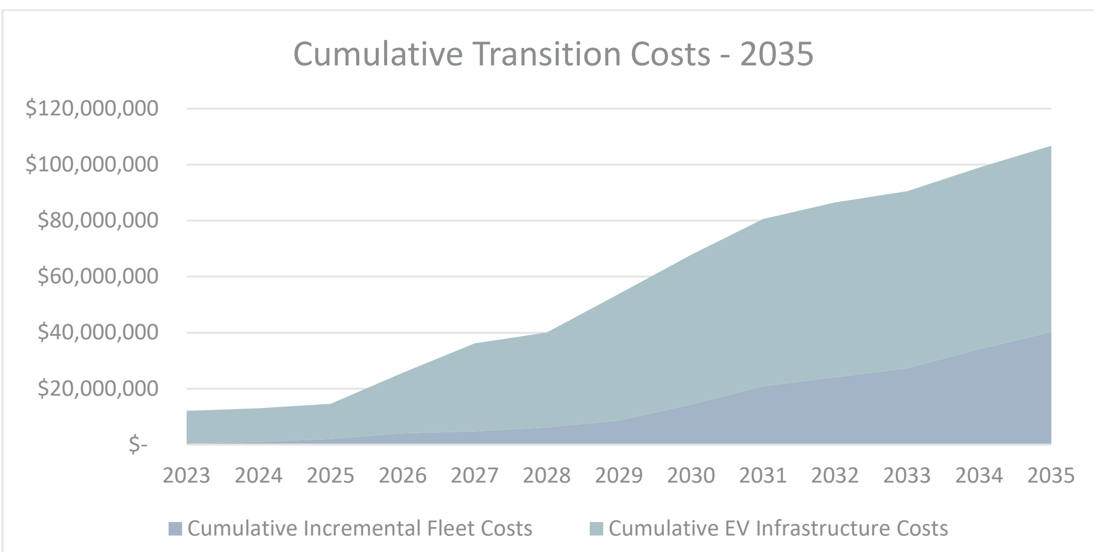

Figure 26. Cumulative Transition Costs, 2035 Scenario

Total Cost of Ownership

The City's TCO for EV Transition considers the total capital investment for the replacement vehicles over the transition period, including both ICEs and EVs, the upgrade of utility service to each facility, the design and construction of charging infrastructure, and the purchase and installation of chargers. The TCO also includes the total fuel and maintenance operating costs over the transition period. Fuel costs include all fuel types over the transition period including electricity, diesel, gasoline, and CNG. Maintenance cost includes maintenance of both ICE and EVs. The goal of the TCO analysis is to assess the impact that EV transition will have on both operating and capital costs for the entire fleet. While fuel and maintenance costs are likely to be lower, it usually does not offset the incremental capital costs. The TCO for each scenario is shown in **Figure 27** and **Figure 28** respectively.

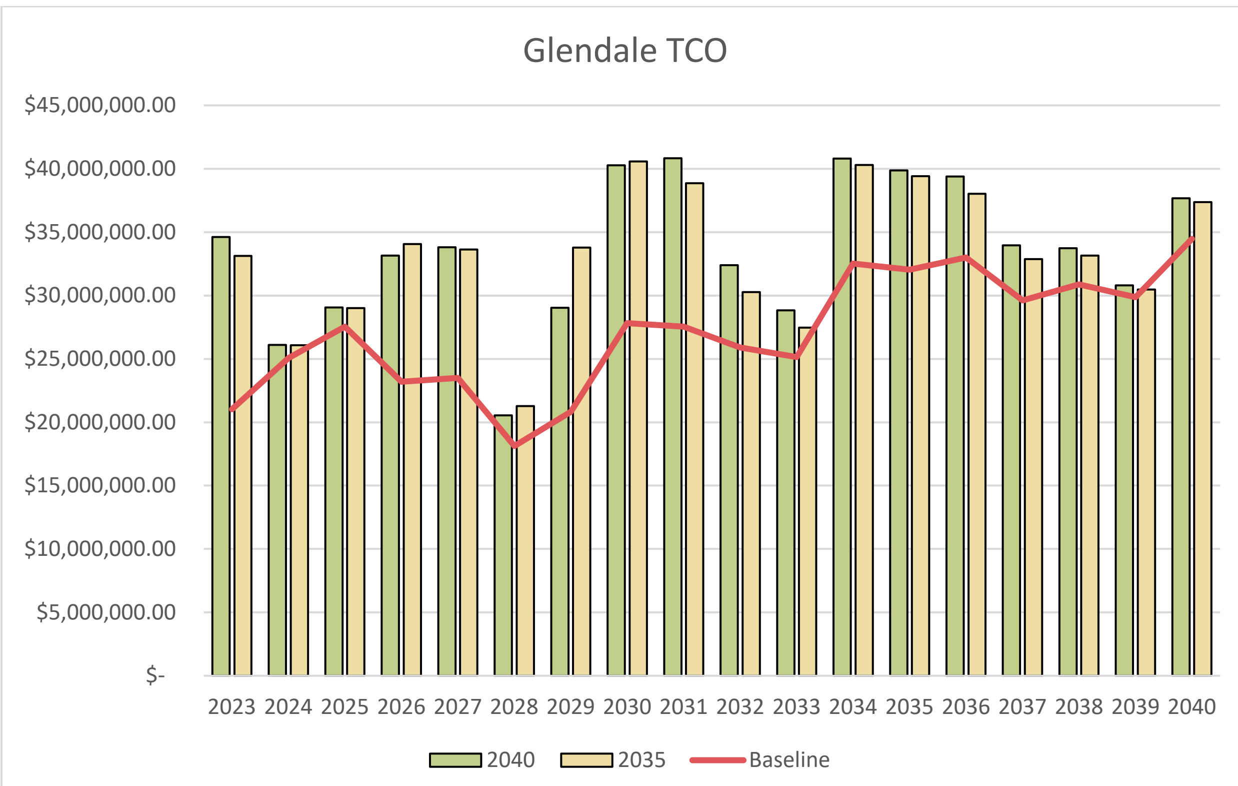

Figure 27. Annual Total Cost of Ownership by Scenario

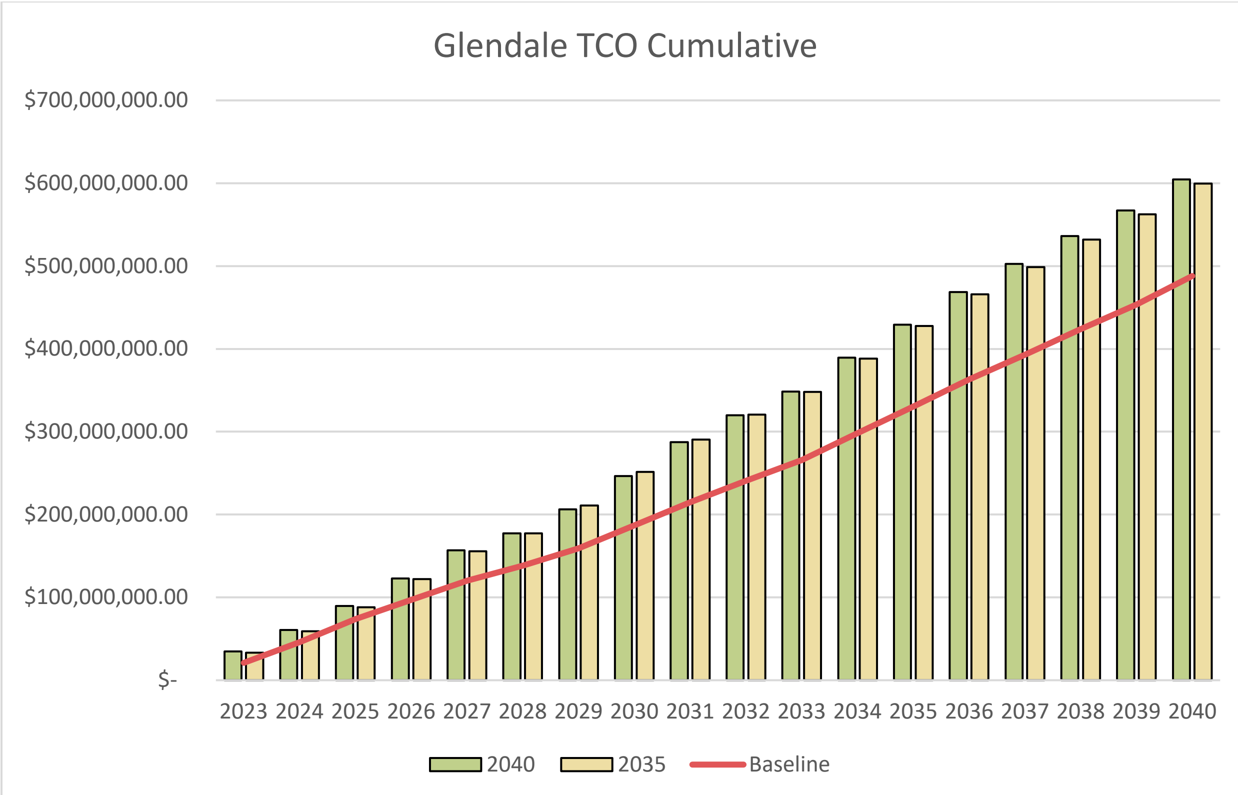

Figure 28. Cumulative Total Cost of Ownership by Scenario

Funding Opportunities

The City of Glendale has several zero-emission vehicle and infrastructure funding opportunities they can pursue to help fund the transition, including:

- HVIP
- VW Environmental Mitigation Trust Funding
- LCFS ZEV Infrastructure Crediting
- Electric Vehicle (EV) Rebate Program:
- National Electric Vehicle Infrastructure Formula Program
- Discretionary Grant Program for Charging and Fueling Infrastructure ($2.5 billion):
- The EPA's DERA Program funds grants and rebates
- Clean Vehicle Rebate Project (CVRP)
- Southern California Incentive Project (SCIP)

Recommendations & Considerations

1. Engage an engineering firm to develop a phased infrastructure design and plan for each facility. The plan should consider staging to minimize disruption to operations and should consider the impact that charging technology improvements may have on the future design.
2. Develop an impact and risk assessment for power outages. This information can be used to develop risk mitigation strategies and a resilience plan and may also shape the EV procurement plan.
3. Focus on currently available light-duty vehicles first. Allow time for the market to develop medium and heavy-duty vehicles.
4. Emergency response vehicles should be deferred until late in the transition cycle. The operational impacts of EVs on EMS services are not well understood at this time and require more research before considering an investment.
5. Update the EV transition plan every two years to consider changes in vehicle operations and requirements, changes in costs, as well as improvements in technology.

The transition to EV technologies represents a paradigm shift in vehicle procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission transportation sector. Widespread adoption of zero-emission vehicle technology has the potential to significantly reduce greenhouse gas (GHG) emissions.

Introduction

City of Glendale, CA Municipal Fleet Service Overview

According to the city's website, the City of Glendale was incorporated on February 16, 1906 and spans approximately 30.6 square miles with a current population of approximately 203,054 people (US Census 2017 Population Estimates). Glendale is the fourth largest city in Los Angeles County and is surrounded by Southern California's leading commercial districts.

As one of its core functions, Glendale provides well-maintained streets and a variety of transportation services. The City's historic success at attracting employers is partially attributed to the result of its location at the center of four major freeways including

- the I-5 Golden State Freeway
- SR-2 Glendale Freeway
- ST-134 Ventura Freeway
- and the 210 Foothill Freeway

All these provide easy access for residents, workers, and customers from around the region. Glendale also offers its own bus services, the Beeline, with 13 routes connecting customers to Jet Propulsion Laboratory (JPL), the City of Burbank, and the Metrolink Stations in both Burbank and Glendale.

The Bob Hope Airport in Burbank serves the Los Angeles area including Glendale, Pasadena and the San Fernando Valley. It is the only airport in the greater Los Angeles area with a direct rail connection to downtown Los Angeles. The City of Glendale is located about 30 minutes from Los Angeles International Airport (LAX). LAX is a commerce leader and designated as a world-class airport for its convenient location, modern facilities, and superior sea/air/land connections.

Glendale prides itself on the quality of services it provides to the community. It is a full-service City which includes a water and electric utility. The City operates its own power plant, although the majority of power is currently imported from other areas. Water comes primarily from the Metropolitan Water District, along with a small portion from local wells.[1]

[1] City of Glendale overview taken from https://www.glendaleca.gov/government/about-us

City Fleet Overview

As of October 2021, The City owns and operates a fleet of 1,018 vehicles. Eliminating trailers, non-vehicular equipment, and parade antiques from the analysis, the City's fleet consists of 863 vehicles, which is the basis for the analysis. City vehicles are categorized as Light-, Medium-, and Heavy-Duty (based on GVWR classification), Pursuit, and Non-Road vehicles. **Figure 29** shows a breakdown of Glendale's fleet by category. Light-duty vehicles make up the largest portion of the fleet (50%) followed by pursuit vehicles at 16%, heavy duty vehicles at 14%, non-road vehicles at 11%, and medium duty vehicles at 9%.

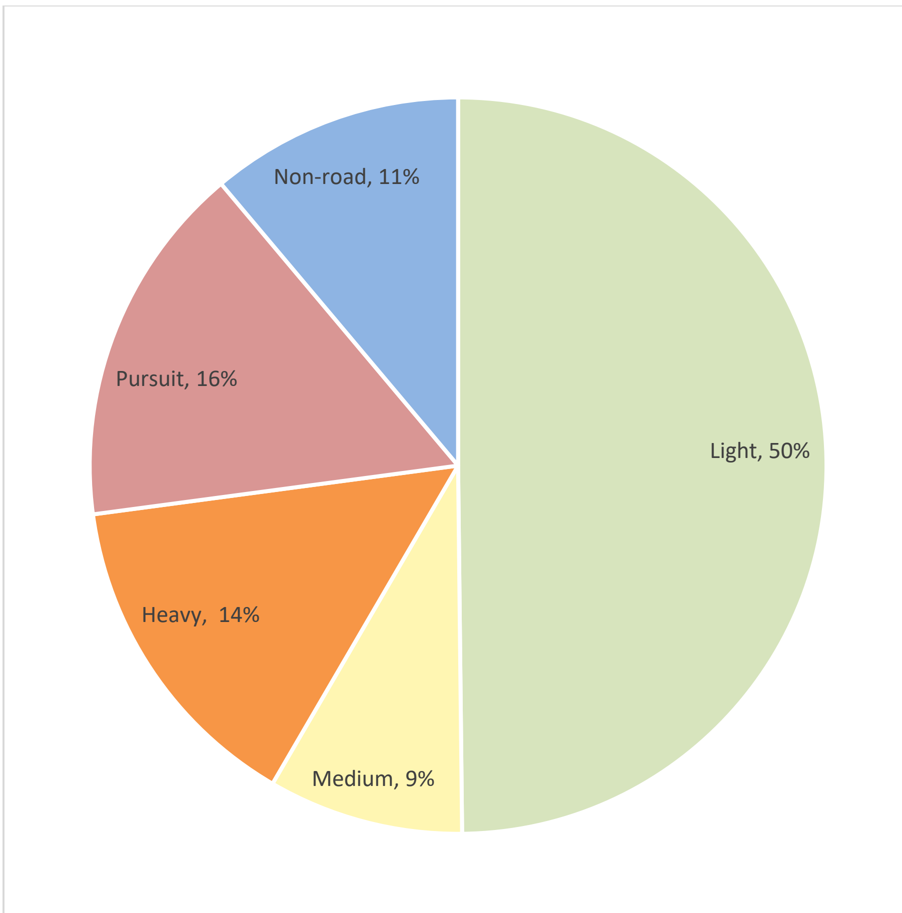

Figure 29. Glendale Fleet by Vehicle Type

City Facility Overview

This analysis focused on the vehicles parked at select primary facilities. The remainder of vehicles not captured at these facilities are generally parked at libraries or other City facilities, where typically only one or two vehicles are parked. For the purposes of this analysis, CTE assumed that the installation of charging infrastructure for those facilities will not require utility upgrades and can be done with little or no disruption to current operations. **Table 11** summarizes the number of vehicles at each of the facilities under consideration.

Table 11. *Fleet Profile at Primary Facilities*

Facility Name	Total Vehicles
Public Works Yard	123
City Hall Complex	109
GWP Utility Operations Center	161
Integrated Waste Yard	68
Fire Station 21	29
Police Parking Lot	227
Other Vehicles	146
Total Fleet	**863**

Public Works Yard

The Public Works Yard houses vehicles from multiple departments and includes vehicles from all types except pursuit. The number of vehicles at the Public Works Yard are summarized by vehicle class in **Table 12.** An aerial view of the facility is shown in **Figure 30,** with the property boundaries outlined in red.

Note that most departments that park vehicles at the Public Works Yard do not have assigned parking spots. When planning for fleet electrification, some vehicle assignments may need to be made to ensure that the vehicles are parked at the appropriate charger (i.e., Level 2 AC charger, DC fast charger).

Table 12. Fleet Profile at the Public Works Yard

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
61	23	26	13	-	123

Figure 30. Public Works Yard aerial view

City Hall Complex

The City Hall Complex houses vehicles from multiple departments that are primarily light-duty. The number of vehicles at the City Hall Complex are summarized by vehicle class in **Table 13.** An aerial view of the facility is shown in **Figure 30**, with the property boundaries outlined in red. The City Hall Complex encompasses multiple parking areas, including a garage that has both public parking and parking for City vehicles

Table 13. Fleet Profile at City Hall Complex

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
104	2	-	3	-	109

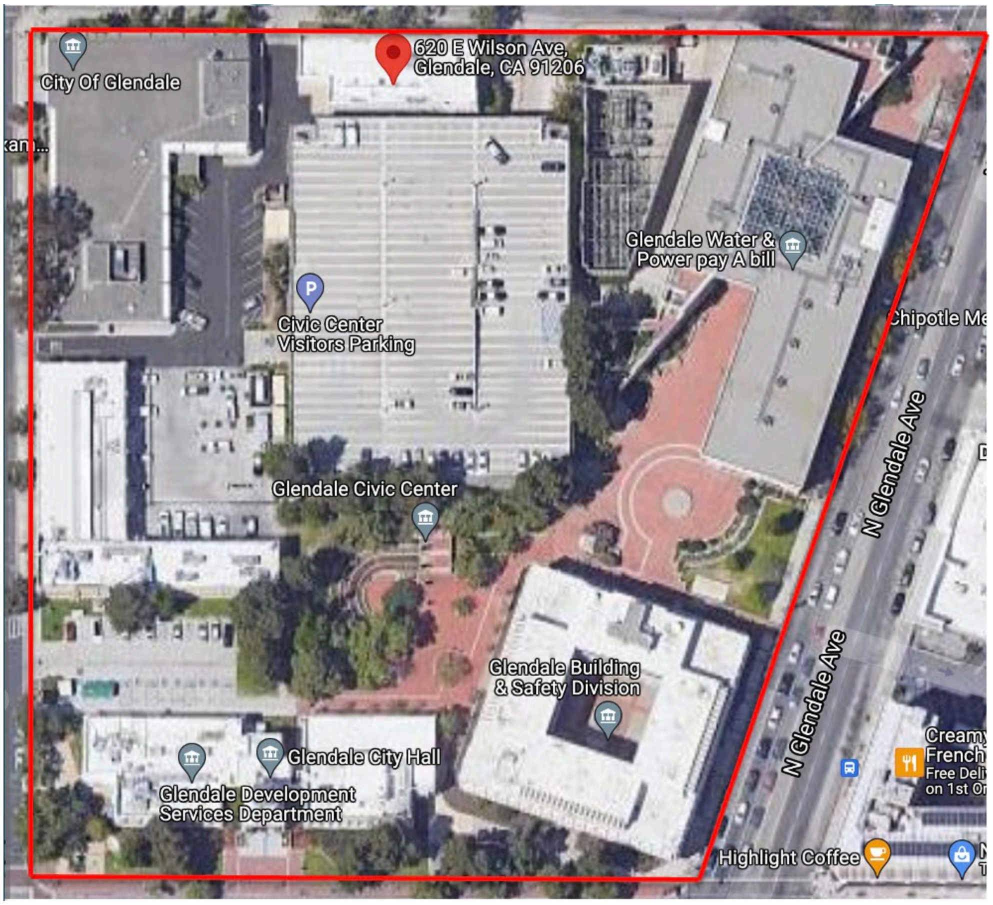

Figure 31. City Hall Complex aerial view

Glendale Water and Power Utility Operations Center

The Glendale Water and Power (GWP) Utility Operations Center houses GWP vehicles. The number of vehicles at the GWP Utility Operations Center are summarized by vehicle class in **Table 14.** An aerial view of the facility is shown in **Figure 32**, with the property boundaries outlined in red.

Note the GWP Utility Operations Center is undergoing a repowering initiative that will entail a large amount of construction throughout the facility beginning in 2023. Construction activities may include the demolition of multiple structures. Any facility work to install chargers supporting the electrification of GWP's vehicles will need to coordinate ongoing construction activities to avoid facility conflicts. The City estimates that the work will take about 3-4 years.

Table 14. *Fleet Profile at GWP Utility Operations Center*

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
90	24	24	23	-	161

Figure 32. GWP Utility Operations Center aerial view

Integrated Waste Yard

The Integrated Waste Yard houses vehicles from multiple departments with the majority being light and heavy-duty vehicles. The number of vehicles at the Integrated Waste Yard are summarized by vehicle class in **Table 15.** An aerial view of the facility is shown in **Figure 33**, with the property boundaries outlined in red.

Table 15. Fleet Profile at Integrated Waste Yard

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
20	0	48	-	-	68

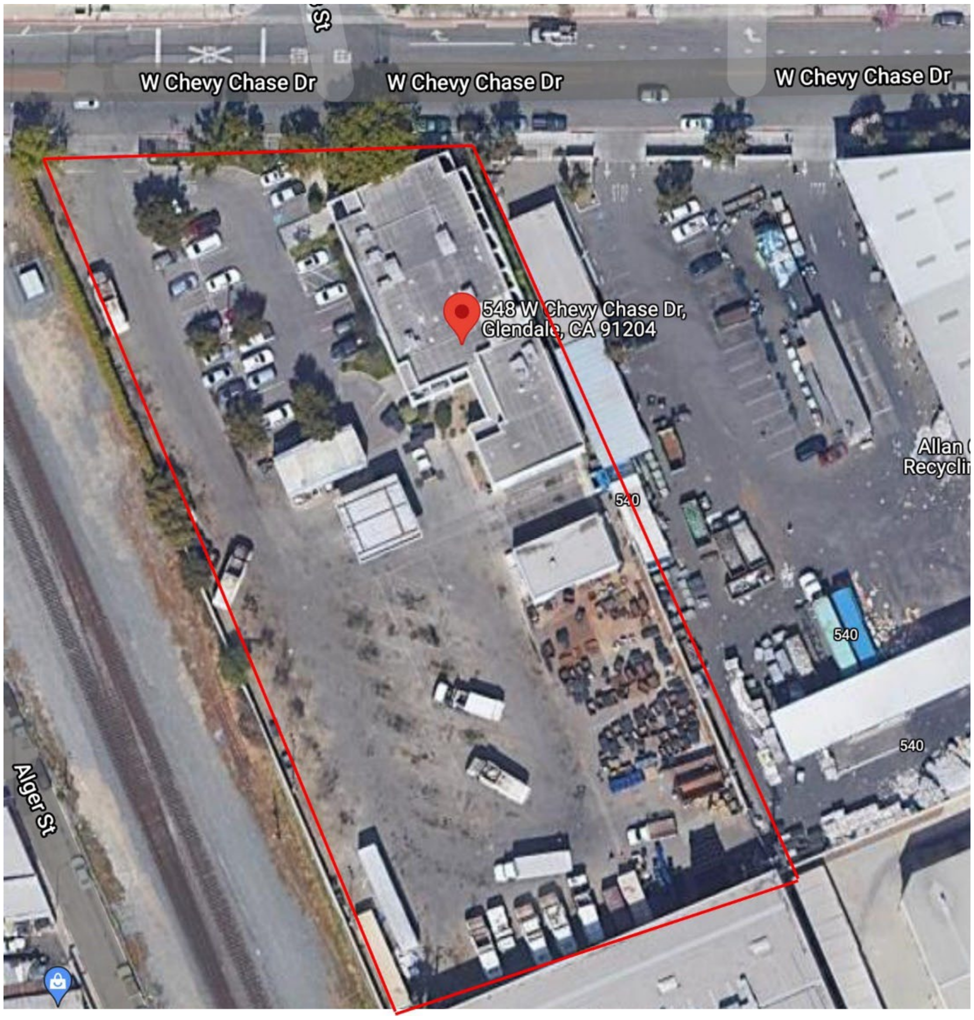

Figure 33. Integrated Waste Yard Aerial View

Fire Station 21

Fire Station 21 houses emergency response vehicles from the fire department, including the City's fire engines. The number of vehicles at Fire Station 21 are summarized by vehicle class in **Table 16.** An aerial view of the facility is shown in **Figure 34**, with the property boundaries outlined in red.

Table 16. Fleet Profile at Fire Station 21

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
18	6	5	-	-	29

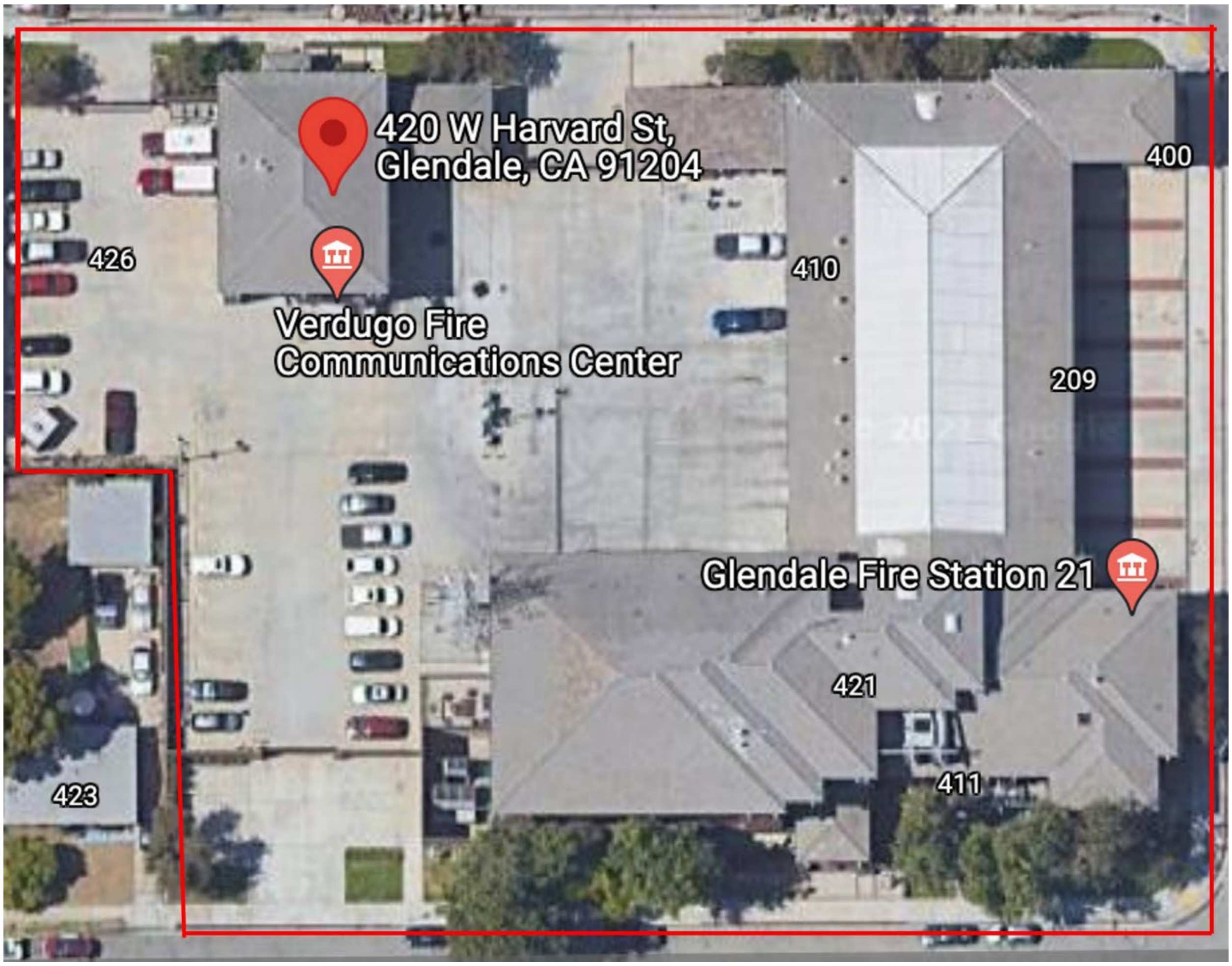

Figure 34. Fire Station 21 Aerial View

Police Department Parking Lot

Police Department Parking Lot houses pursuit and emergency response vehicles from the police department. The number of vehicles at the Police Parking by vehicle class are summarized in **Table 17.** An aerial view of the facility is shown in **Figure 35** with the property boundaries outlined in red.

Table 17. Fleet Profile at Police Parking Lot

Light Duty	Medium Duty	Heavy Duty	Non-Road	Pursuit	Total
83	4	-	4	136	227

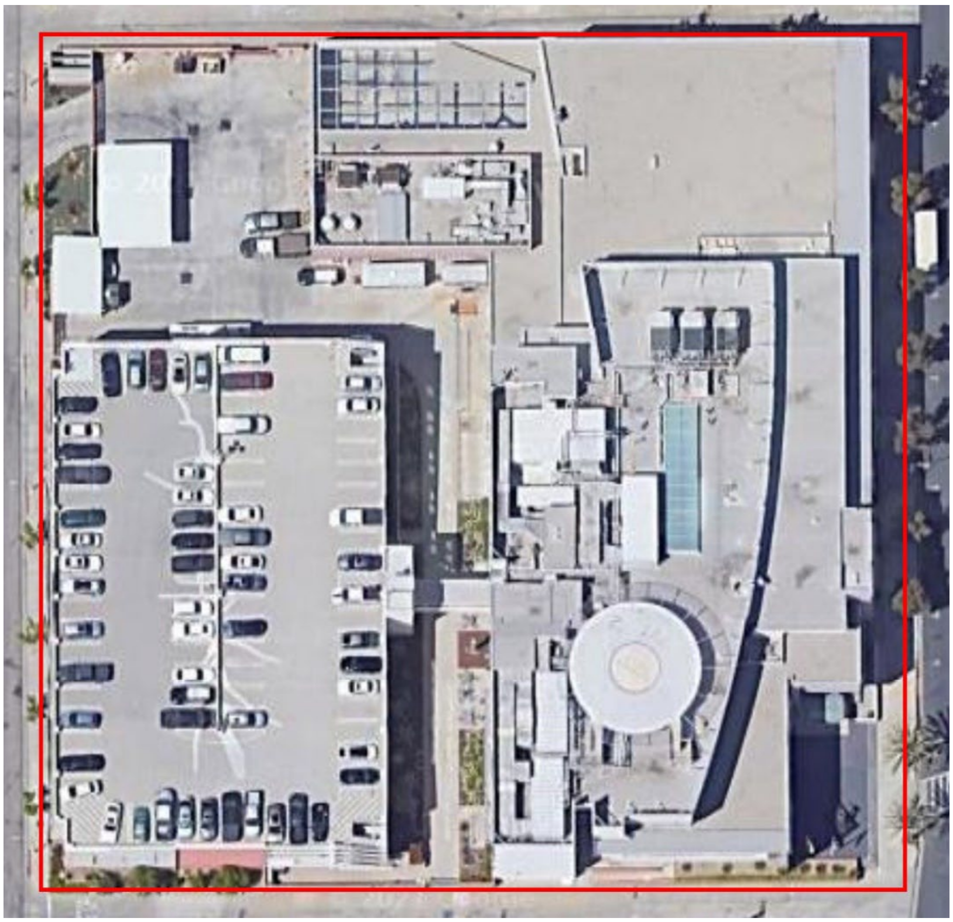

Figure 35. Police Parking Lot Aerial View

Analysis Overview

CTE conducted multiple assessments to evaluate the optimal approach for transitioning the City of Glendale's fleet to 100% EV.

The **Feasibility Assessment** evaluates the feasibility of replacing each vehicle in the City's fleet with an EV model in a 1:1 ratio, considering the current capabilities of EVs on the market. The Feasibility Assessment estimated an average duty cycle based on average daily miles and an estimated energy efficiency by vehicle type. Duty cycles of any vehicles that could not be replaced in a 1:1 ratio with an EV are evaluated and operational strategies that could be implemented to achieve a feasible duty cycle are identified. If operational changes are not sufficient to achieve a suitable duty cycle, electrification of that vehicle type may be delayed.

The **Fleet Assessment** develops a projected timeline for replacement of current vehicles with EVs consistent with the City's plan to transition their fleet by 2035 or 2040. This assessment considers a "Suitability Score" for each vehicle type that indicates the commercial viability of currently available EVs of that vehicle type each year. Vehicles with a higher Suitability Score are prioritized for transition over vehicles with a lower Suitability Score. The Fleet Assessment also includes a projection of fleet capital costs over the entire transition timeline.

The **Facilities Assessment** determines the necessary infrastructure at each facility to support the EV fleet based on the results of the Feasibility Assessment and Fleet Assessment. The Facilities Assessment shows the estimated power and energy loads throughout the fleet transition, which will inform any required utility upgrades to meet the infrastructure needs. The Facilities Assessment also includes a projection of the costs of the charging equipment, installation, and utility upgrades.

The **Funding Assessment** compiles results from the previous assessments to provide a comprehensive view of the vehicle and infrastructure costs for the transition over the transition period. The assessment includes guidance on operations and maintenance (O&M) cost planning and a summary of available funding opportunities that can be used to fund vehicle or infrastructure purchase.

The **Benefits Assessment** summarizes the total greenhouse gas (GHG) emissions and pollution reductions realized from transitioning the fleet to 100% EVs throughout the transition timeline to quantify the environmental, public health, and local air quality benefits from the fleet transition.

Feasibility Assessment

An essential element in developing an EV Transition Plan is feasibility, which, in this context, is the measure of the likely range of an EV under strenuous conditions as compared to the required daily duty cycle. In other words, does the EV have enough battery energy to operate a full day, with air conditioning or heating, before returning to its designated parking area for an overnight charge.

Key assumptions in this assessment include:

- Fleets typically charge overnight during off-peak hours when the cost of energy is lowest, thus each EV needs enough energy to complete a full daily duty cycle.
- EV efficiency and range is impacted by topography, traffic speed and conditions, and climate. Thus, it is important to determine the efficiency and range that account for these factors when determining feasibility.

Table 18 summarizes the expected feasible range vehicle type based on the expected operating conditions (topography, speed, and climate) in Glendale. The "Achievable" range is the daily mileage that is feasible under most conditions. The "Uncertain" range is the daily mileage that may be feasible under some conditions (light traffic, minimal A/C or heater use). The "Unachievable" range is considered not feasible under any normal conditions. We recommend using the Achievable range for planning purposes.

Table 18. Expected Feasibility Range by Vehicle Type

Vehicle Type		Achievable	Uncertain	Unachievable
Light Duty	SUV (Subaru Solterra*)	0 – 150 miles	150-175 miles	>175 miles
	Sedan (Nissan Leaf S*)	0 – 100 miles	100 – 125 miles	>125 miles
	Pickups (Lordstown Endurance*)	0 - 175 miles	175 – 225 miles	> 225 miles
Medium-Duty	Vans (MT50e All-Electric Chassis*)	**0 – 96 miles**	**96 -120 miles**	**>120 miles**
	Dump Trucks (BYD 6F Chassis*)	0 - 75 miles	75 – 125 miles	>125 miles
Heavy Duty	Trucks (BYD 8TT*)	**0 – 125 miles**	**125 – 150 miles**	**>150 miles**
	Dump (Peterbilt 520EV*)	0 – 50 miles	50 -75 miles	>75 miles
Pursuit	Sedans (Tesla Model 3*)	**0 – 195 miles**	**195 – 224 miles**	**>224 miles**
	Motorcycles (Model FX*)	0 – 50 miles	50 -75 miles	>75 miles

** Vehicle shown is the basis for the "Achievable" range calculation.*

Based the City's duty cycle for every vehicle in the fleet, EV adoption is highly feasible, except for Pursuit Motorcycles, as indicated in **Table 19** below. Medium-Duty Dump Trucks and Heavy-Duty Refuse Trucks are moderately feasible. We expect feasibility to improve over time with advances in EV technologies and improvements in battery energy density.

Table 19. EV Feasibility for Glendale Fleet

Vehicle Type		Achievable	Uncertain	Unachievable
Light Duty	SUV	98%	1%	1%
	Sedans	96%	2%	2%
	Pickups	98%	1%	1%
	Vans	98%	1%	1%
Medium-Duty	Vans	95%	1%	4%
	Dump Trucks	95%	4%	1%
Heavy Duty	Trucks	98%	1%	1%
	Refuse Trucks	87%	3%	10%
Pursuit	Sedans	98%	1%	1%
	Motorcycles	30%	23%	47%

Operational Challenges Considering Current EV Capabilities

Most vehicles in the City's fleet stay within the city limits, have duty cycles that are feasible for a 1:1 EV transition, are only used during business hours, and can charge overnight. However, some use cases will require additional planning and consideration before transitioning to an EV to ensure that the required duty cycles can be met without affecting operations or public safety.

GWP Utility Operations Center Vehicles

Some GWP vehicles may be called upon to provide interstate mutual aid and may be staged at a site for multiple days to support a disaster response. The City will need to ensure that there are methods for charging these vehicles to travel long distances, and to maintain a charge on vehicles that are staged at disaster or job sites for prolonged periods of time.

On-call GWP staff and GWP supervisors will also take vehicles home with them. The City will have to evaluate either a possible change in the policy to not permit staff to take the vehicles home, or to install chargers at GWP staff members' homes to ensure the vehicles can charge overnight.

First Responder Vehicles

Additional consideration must be given to the transition of first responder vehicles, including pursuit and fire department vehicles. These vehicles must be always ready to complete a full duty cycle, therefore accounting for charging time and limited vehicle range can cause planning concerns for transition these types of vehicles to EVs.

Resilience during power-outages must also be considered for any facilities with first responder vehicles. Backup power generation will be required to ensure that EV charging can occur even during a power outage.

Police Department Vehicles

The City's pursuit vehicles "hot swap" during shift changes, where vehicles change hands in about a 15-minute period at the police station. It is common for most of the pursuit vehicles to never turn off. To maintain these operations, the vehicles would need the ability to completely charge in a 15–20-minute window, with a DC fast charger in each parking stall. This charging approach will create high demand charges, as a large power demand will only be required during each 15–20-minute shift change.

Officers that are assigned motorcycles also take their motorcycles home with them at the end of their shift, with many officers driving long distances to get home. The City will have to evaluate either a possible change in the policy to not permit officers to take the motorcycles home, or to install chargers at officer's homes to ensure the vehicles can charge overnight. Officers may also need to charge again before starting their shift, if driving long distances from their homes.

Fire Department Vehicles

Major fire apparatus components such as pumps and aerial ladders are powered by the vehicle engine while the unit is stationary. Glendale noted that their Fire Department vehicles are often called upon to provide interstate mutual aid and have deployed vehicles to Oregon. Before transitioning all of the Fire Department vehicles, the City would need to ensure that there was a fast charging corridor to allow these vehicles to continue to provide mutual aid. The City's Fire Department also exclusively procures vehicles from Pierce; who currently does not offer EVs.

Fleet Assessment

Fleet Transition Approach

Figure 36 summarizes the approach used to develop a plan to transition the City's fleet by 2035 or 2040. Details on the EV Procurement Schedule and Suitability Scores are described in further detail below.

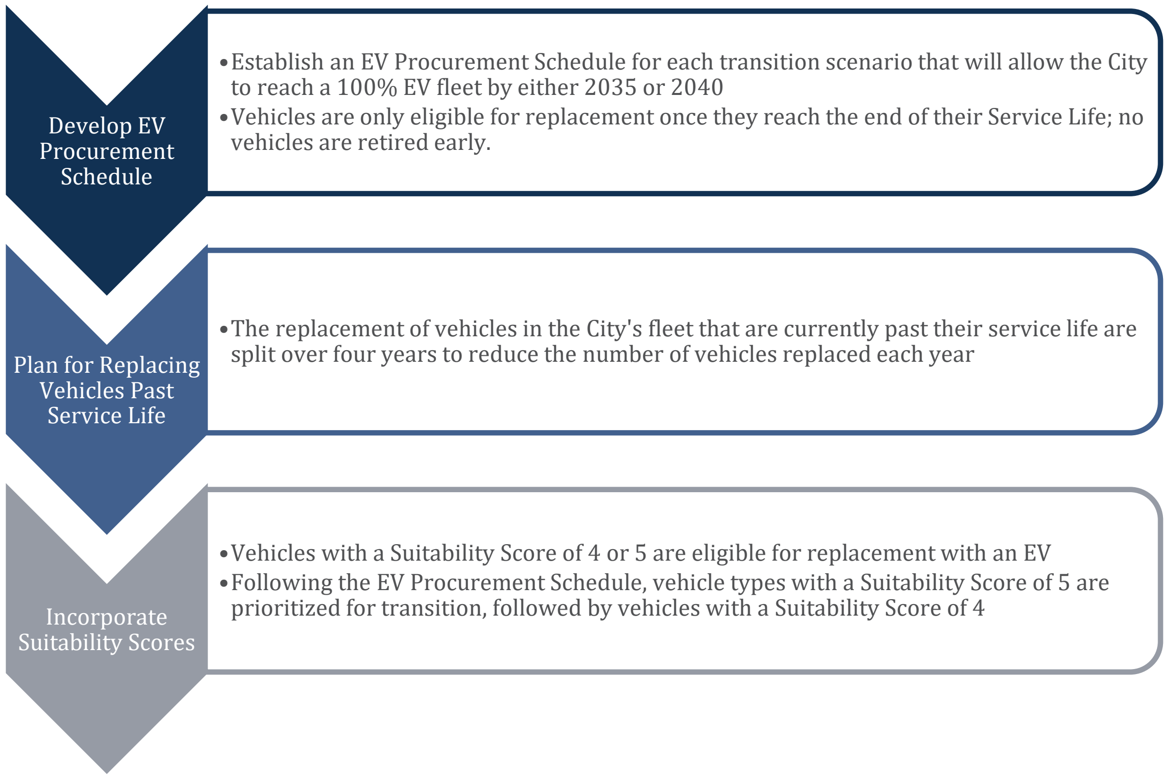

Figure 36. Fleet Transition Methodology

EV Procurement Schedule

The timing of replacing ICE vehicles with EVs is based on four primary factors:

- Asset Replacement Schedule: is the vehicle ready for replacement based on age, mileage, or hours?
- Duty Cycle Feasibility: can the replacement EV feasibly meet the daily duty cycle?
- Vehicle Availability and Suitability: is the EV commercially available and is it a suitable replacement
- Glendale Transition goals: What procurement strategy allows the City to reasonably achieve a 100% zero emission fleet over time?

The fleet transition assessment assumes that vehicles in the City's fleet will be replaced at the end of their planned useful life. **Table 20** shows the number of vehicles currently approved for replacement each fiscal year.

Table 20. Glendale Replacement Schedule Overview

Fiscal Year	# Of Vehicles Approved for Replacement	Original Budget
18-19	150	$13,694,500
19-20	100	$8,159,500
20-21	50	$4,793,000
21-22	65	$10,715,621
22-23	75	$8,731,300

CTE developed an EV Procurement Schedule that will allow the City to achieve a 100% EV fleet by either 2035 or 2040. **Table 20** summarizes the procurement schedule for the 2035 and 2040 transition scenarios.

Vehicles are eligible for replacement once they have reached the end of their useful service life. The transition planning approach does not require any vehicles to be retired early to meet the 100% EV Fleet goals by either the 2035 or 2040 transition scenario. In both scenarios, the City will only be procuring EVs from 2030 on. The EV procurement schedules also split the replacement of vehicles that are currently past their useful service life over four years, to limit the number of vehicle procurements the City would have to initiate in a single year.

The annual percentage of procured vehicles that will be EVs is gradually increased over time, to allow the City to grow their internal capabilities and comfort with EV technology, and to allow EV and charging technology to evolve and improve. Some vehicle types currently do not have an EV option but are expected to be available to procure in the future. The vehicles that are replaced with EVs each year are driven by the Suitability Score of each vehicle type, described in more detail below.

The City should re-evaluate this procurement schedule at least every two years to incorporate learnings from earlier deployments, reflect available funding, and address the latest information on EVs in the market and charging technology.

Table 21. EV Procurement Schedule for Transitioning Fleet to 100% EVs

Year	2035 Scenario % of Procured Vehicles that will be EVs	2040 Scenario % of Procured Vehicles that will be EVs	% of Vehicles Past their Useful Service Life that will be Replaced
2023	10%	10%	
2024	10%	10%	25%
2025	25%	25%	25%
2026	50%	25%	25%
2027	50%	50%	25%
2028	75%	50%	
2029	75%	75%	
2030	100%	75%	
2031	100%	100%	
2032	100%	100%	
2033	100%	100%	
2034	100%	100%	
2035	100%	100%	
2036		100%	
2037		100%	
2038		100%	
2039		100%	
2040		100%	

Suitability Scores

The City of Glendale operates a wide variety of vehicle types, some of which are not currently available in an EV model, and others that are still in the prototyping or development stages. Early adopters of EV technology face higher levels of risk during vehicle deployments, as the vehicles may encounter unforeseen maintenance or performance issues if they have not been thoroughly road tested in a variety of conditions.

To manage risks associated with deploying new vehicle technology, CTE assigned a "Suitability Score" to each vehicle type in the City's fleet each year. The Suitability Scores consider criteria that indicates whether or not a vehicle is "Commercially Viable" for purchase, and the number of deployments.

The Commercial Viability criteria used for this analysis is summarized in **Table 22.** Based on results of a market analysis (Appendix A), CTE evaluated each vehicle type against these criteria to determine which vehicles are currently Commercially Viable.

Table 22. Commercially Viability Criteria

Criteria	Definition
> 1 Make Available	Vehicle options from more than one OEM available
Readily Available	Light Duty Vehicles: Ready for purchase, can drive off the lot. Medium and Heavy Duty Vehicles: Can immediately go into production schedule when purchase order is awarded.
Available for CA Municipality purchase	Available to be procured by CA Municipality.
No additional customizations	Delivered to Glendale meeting technical specifications, does not require additional non-standard upfitting by Glendale to be put into service.
Cost Effective	**Less than twice the cost of current vehicle type in conventional fuel equivalent.**

Suitability Scores range from 1 "Not yet available for purchase" to 5 "Very High Suitability (Widespread Adopters)." Only vehicles with a Suitability Score of a 4 or 5 are eligible for transition in a given year. Definitions for each level of Suitability Score are shown in **Table 23**.

Table 23. Suitability Score Definitions

	Score	Definition
Vehicles Eligible for Transition	5	**Very High Suitability – (Widespread Adopters)** Meets all commercial availability criteria, can likely be a 1:1 replacement with proper charging infrastructure, vehicle options from more than 5 OEMs available
	4	**High Suitability (Limited Adopters)** - Meets all commercial availability criteria, can likely be a 1:1 replacement with proper charging infrastructure, vehicle options from more than 1 OEM available
	3	**Medium Suitability (Early Adopter)** - Meets all commercial availability criteria except for "Cost Effective." Available for

	Score	Definition
Vehicles Not Eligible for Transition		purchase, few commercial deployments, but past the prototyping stage. May not be 1:1 replacement
	2	**Low Suitability (First Customer) -** Can be ordered but may not be able to be immediately entered into production. In pilot/prototyping stage of development
	1	**Not yet available for purchase**

Based on the market analysis, commercially available criteria, and projections about how EV technology is expected to advance over the transition timeline, each vehicle type was assigned a Suitability Score for each year through 2030. By 2030, CTE assumes that all vehicle types that the City operates will achieve a Suitability Score of 5, with the exception of fire engines. Due to the uncertainty in the EV market, CTE does not have enough evidence to indicate that an electric fire engine will be suitable for transition within the transition timeline.

Using this method, each Vehicle Category by GVWR class is assigned a suitability score for each year of the transition period. **Table 20** is a sample of the Suitability Score used for the Glendale analysis.

Table 24. Suitability Score by Year and Vehicle Type

Vehicle & GVWR Class	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Light Duty - 1	5	5	5	5	5	5	5	5	5	5	5	5	5
Light Duty - 2	3	3	3	4	4	5	5	5	5	5	5	5	5
Light Duty - 3	2	3	3	3	4	4	5	5	5	5	5	5	5
Medium Duty - 4	2	3	3	3	4	4	5	5	5	5	5	5	5
Medium Duty - 5	1	1	1	2	3	4	5	5	5	5	5	5	5
Medium Duty - 6	1	1	1	2	3	4	5	5	5	5	5	5	5
Heavy Duty - 7	1	1	1	2	3	4	5	5	5	5	5	5	5
Heavy Duty - 8	1	1	1	2	3	4	5	5	5	5	5	5	5
Pursuit - 1	3	3	4	4	4	4	4	5	5	5	5	5	5
Pursuit - 2	1	1	3	3	4	4	4	5	5	5	5	5	5
Non-Road - Backhoes, loaders, etc.	1	1	1	2	2	3	4	5	5	5	5	5	5
Heavy - Specialty, Fire Engines, etc.	1	1	1	1	1	1	1	2	2	3	3	4	5

The Suitability Scores are based on criteria guided by market research and industry trends, and do not directly consider the financial strength or prospects of any given vehicle manufacturer. Historically, new OEMs have come to market with EVs only to go out of business a few years later. Vehicle maintenance could be an issue if the OEM goes out of business before the end of the service life of the purchased vehicle. The City should thoroughly vet the financial strength of an OEM, as well as ensure that there is an established maintenance network prior to procuring vehicles.

Vehicle Transition Timeline

100% EV Fleet by 2040

Fleet Composition over Transition Period

Table 25 provides the actual number of ICE vehicles and EVs in the fleet throughout the transition timeline for the 2040 scenario. **Figure 37** presents the data graphically. The City is expected to still have 22 ICE vehicles in the fleet in 2040 due to the suitability of specific vehicles and the long procurement schedule.

Table 25. Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	843	20
2023	835	28
2024	815	48
2025	780	83
2026	744	119
2027	720	143
2028	686	177
2029	632	231
2030	534	329
2031	401	462
2032	339	524
2033	283	580
2034	197	666
2035	126	737
2036	75	788
2037	50	813
2038	38	825
2039	32	831
2040	22	841

Figure 37. Fleet Composition Over Time, 2040 Transition Scenario

Annual Vehicle Procurements

Table 26 outlines the number of ICE vehicles and EVs procured in the fleet throughout the transition timeline for the 2040 scenario. **Figure 38** shows the data graphically.

Table 26. Number of ICE vehicles and EV procurements per year, 2040 Transition Scenario

Year	ICE	EV
2023	93	8
2024	150	22
2025	113	40
2026	108	38
2027	32	28
2028	24	34
2029	18	55
2030	33	98
2031	0	142
2032	1	92
2033	2	87
2034	0	139
2035	0	134
2036	0	161
2037	0	88
2038	0	89
2039	0	50
2040	0	81

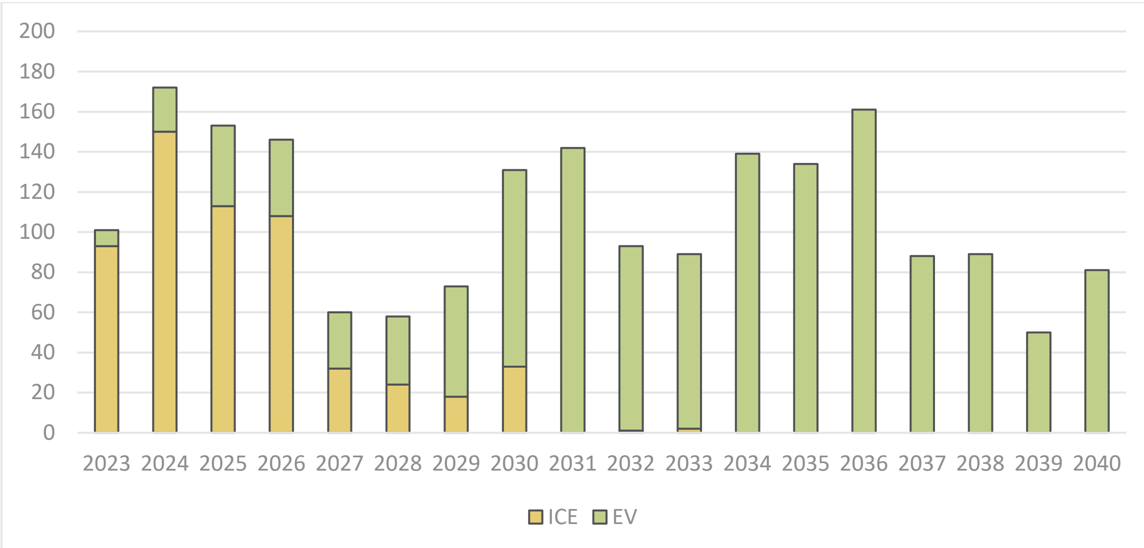

Figure 38. Annual Vehicle Procurements by Vehicle Type, 2040 Transition Scenario

Figure 39 shows the vehicle costs per year throughout the transition timeline in the 2040 scenario. The costs of procuring both ICE vehicles and EVs are included.

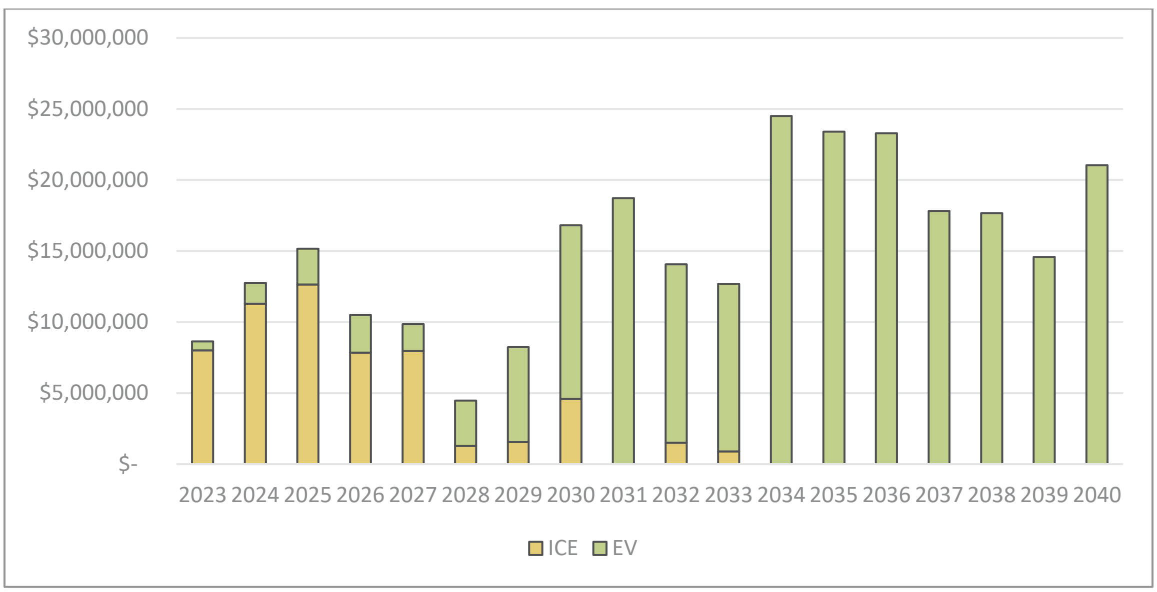

Figure 39. Cost of Vehicle Procurements by Year, 2040 Transition Scenario

Transition Timelines by Facility

The fleet composition over time for the primary facilities are shown in the sections below.

Public Works Yard

Table 27 provides the number of ICE vehicles and EVs in the Public Works Yard fleet throughout the transition timeline for the 2040 scenario. **Figure 40** shows the data graphically. **Figure 41** shows the annual purchases for the 2040 Scenario.

Table 27. Public Works Yard Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	122	1
2023	122	1
2024	120	3
2025	114	9
2026	107	16
2027	104	19
2028	103	20
2029	102	21
2030	95	28
2031	83	40
2032	74	49
2033	67	56
2034	51	72
2035	24	99
2036	19	104
2037	11	112
2038	9	114
2039	8	115
2040	5	118

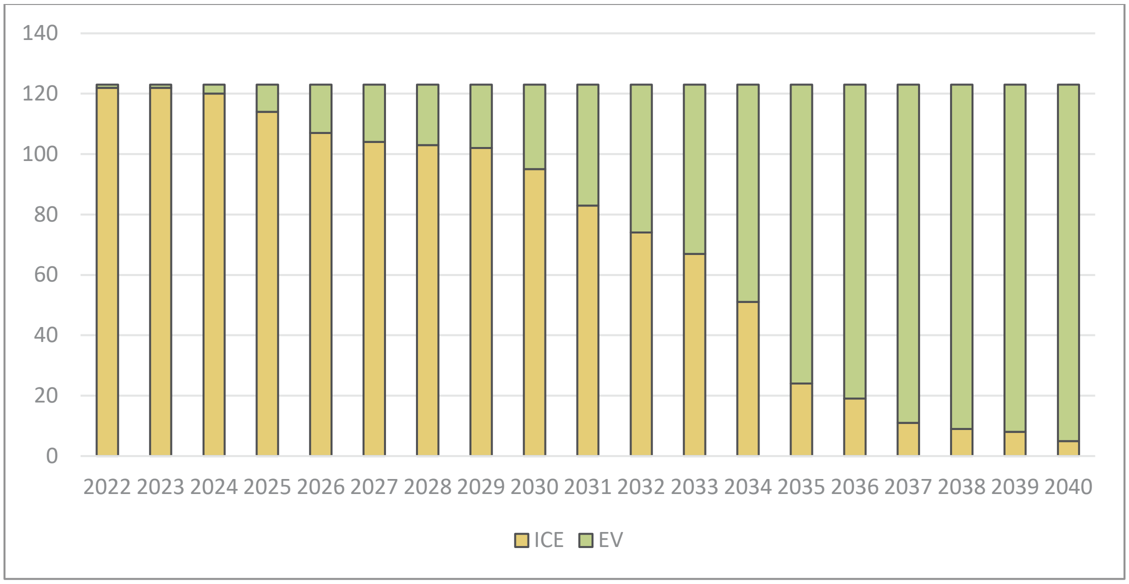

Figure 40. Public Works Yard Fleet Composition Over Time, 2040 Transition Scenario

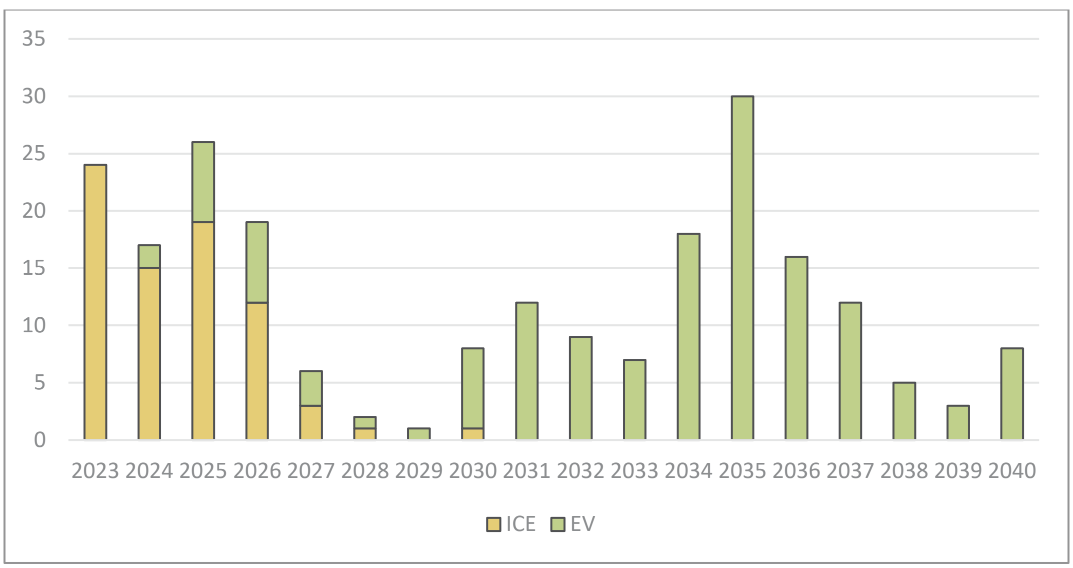

Figure 41. Public Works Yard Fleet Annual Purchases, 2040 Transition Scenario

Figure 42 Provides the yearly cost for purchasing both ICE and EVs for the Public Works Yard under the 2040 Transition Scenario.

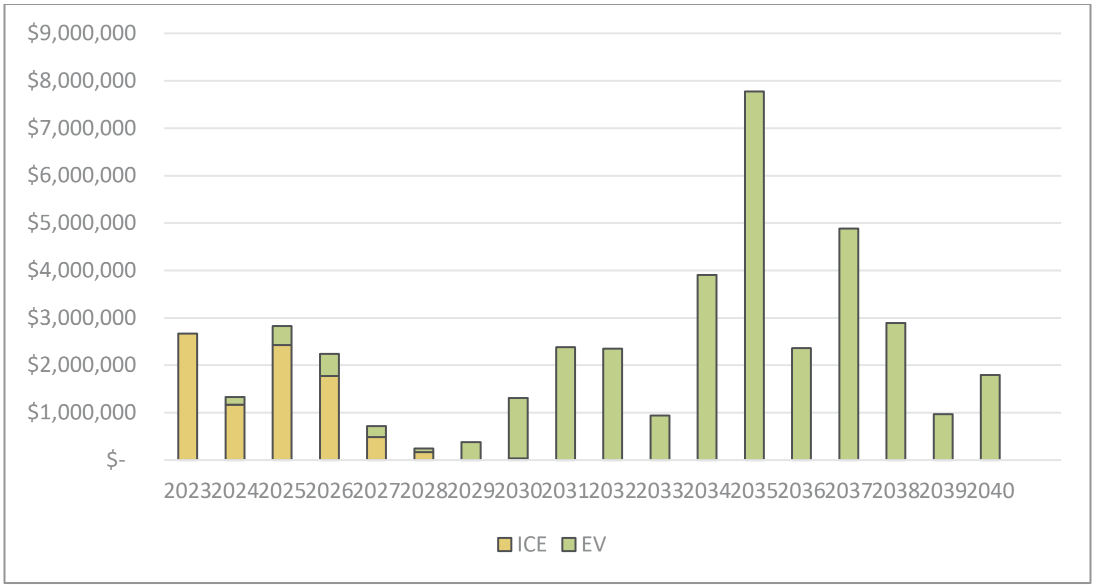

Figure 42. Public Works Yard Cost of Vehicle Procurements by Year, 2040 Transition Scenario

City Hall Complex

Table 28 provides the number of ICE vehicles and EVs in the City Hall Complex fleet throughout the transition timeline for the 2040 scenario**. Figure 43** shows the fleet composition data graphically. **Figure 44** shows the annual purchases for the 2040 Scenario.

Table 28. City Hall Complex Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	103	6
2023	99	10
2024	95	14
2025	89	20
2026	86	23
2027	82	27
2028	80	29
2029	78	31
2030	59	50
2031	38	71
2032	38	71
2033	28	81
2034	14	95
2035	8	101
2036	2	107
2037	1	108

Year	ICE	EV
2038	0	109
2039	0	109
2040	0	109

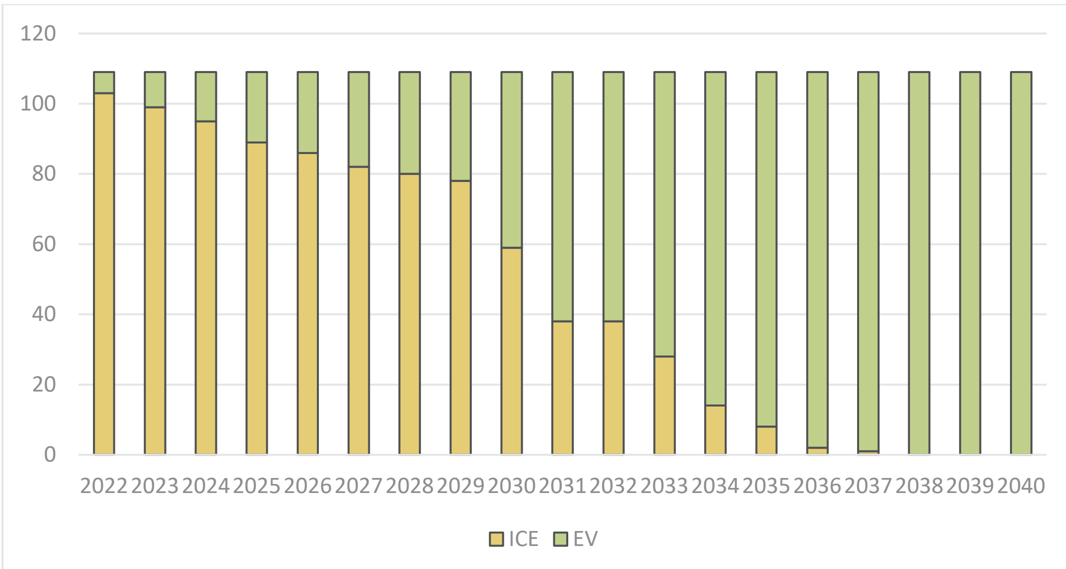

Figure 43. City Hall Complex Fleet Composition Over Time, 2040 Transition Scenario

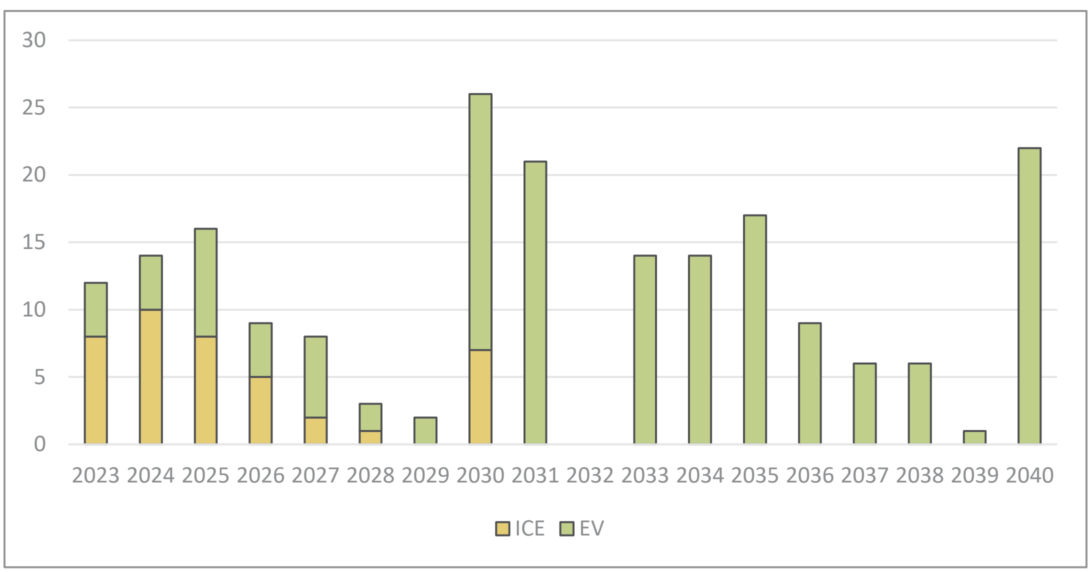

Figure 44. City Hall Complex Annual Purchases, 2040 Transition Scenario

Figure 45 Provides the yearly cost for purchasing both ICE and EVs for the City Hall Complex under the 2040 Transition Scenario.

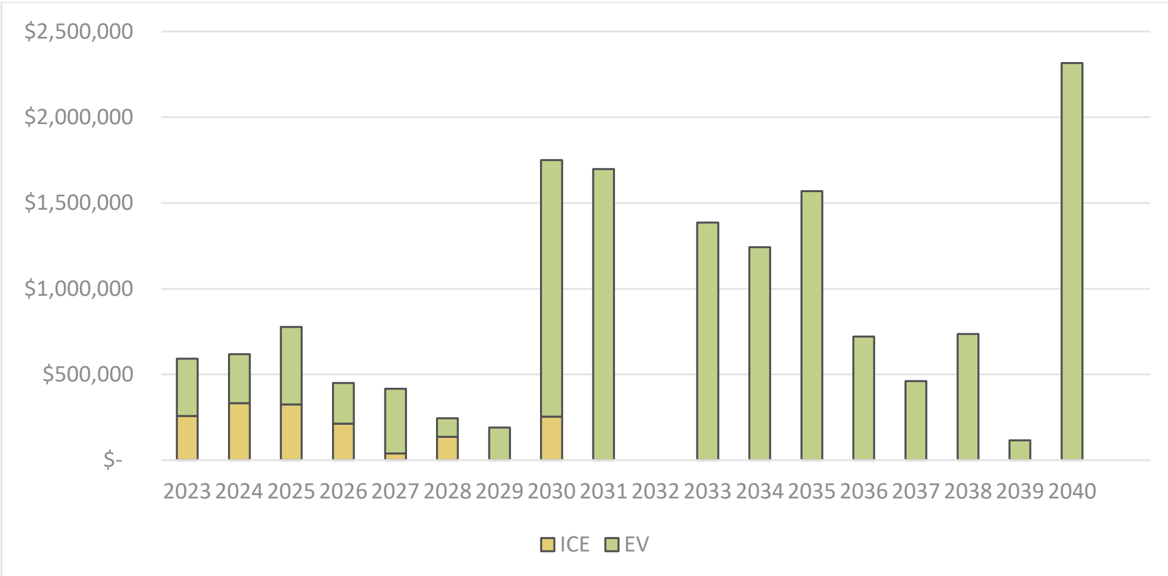

Figure 45. City Hall Complex Cost of Vehicle Procurements by Year, 2040 Transition Scenario

GWP Utility Operations Center

Table 29 lists the number of ICE vehicles and EVs in the GWP Utility Operations Center fleet throughout the transition timeline for the 2040 scenario. **Figure 46** shows the fleet composition over time graphically. **Figure 47** shows the annual purchases for the 2040 Scenario.

Table 29. GWP Utility Ops Center Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	153	8
2023	152	9
2024	148	13
2025	147	14
2026	138	23
2027	135	26
2028	132	29
2029	128	33
2030	119	42
2031	87	74
2032	82	79
2033	70	91
2034	53	108
2035	45	116

Year	ICE	EV
2036	24	137
2037	13	148
2038	8	153
2039	5	156
2040	1	160

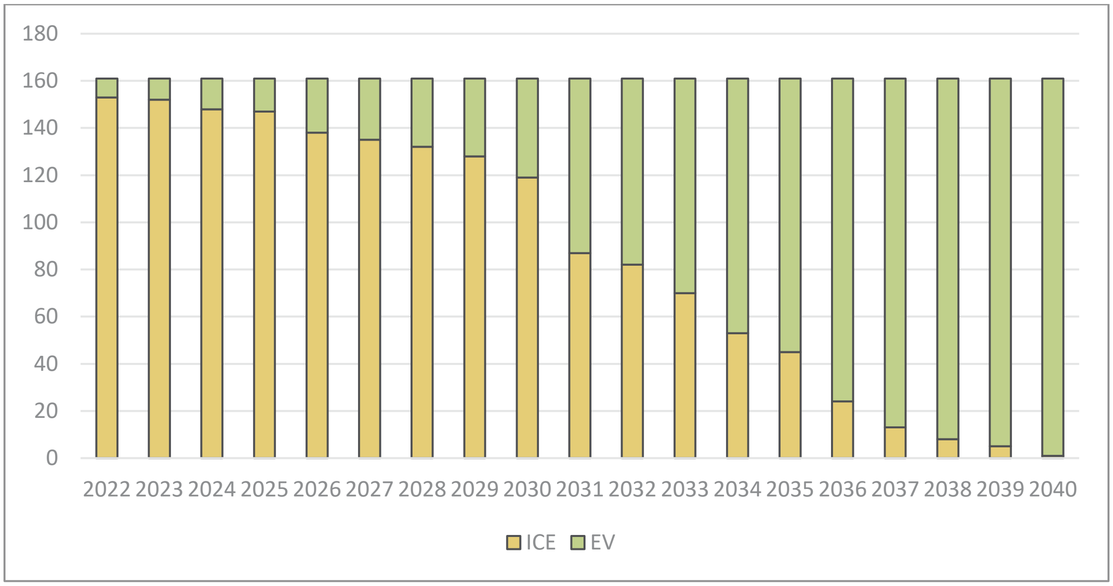

Figure 46. GWP Utility Ops Center Fleet Composition Over Time, 2040 Transition Scenario

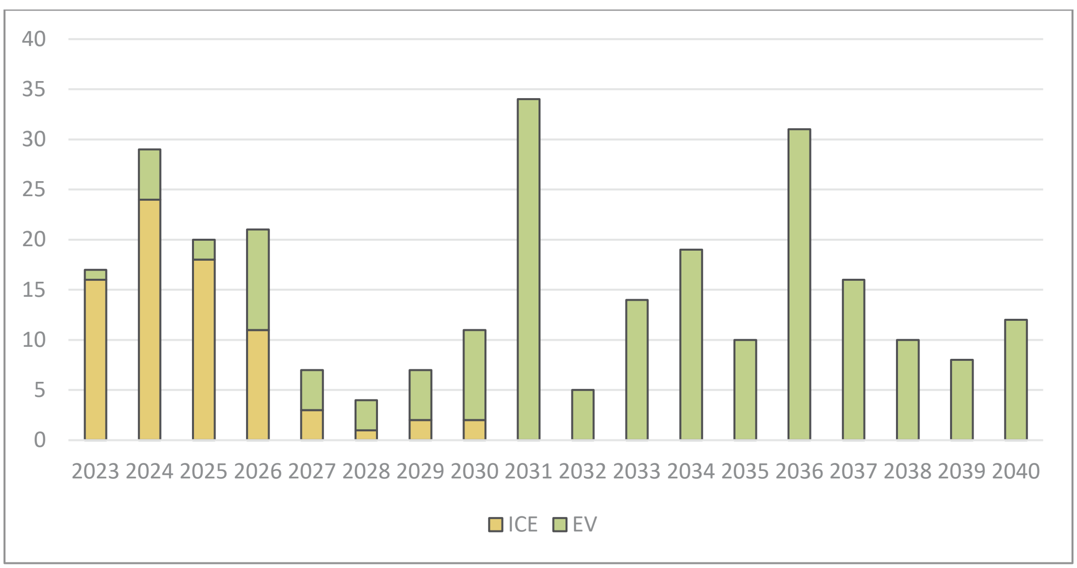

Figure 47. GWP Utility Ops Center Annual Purchases, 2040 Transition Scenario

Figure 48 Provides the yearly cost for purchasing both ICE and EVs for the GWP Utility Operations Center under the 2040 Transition Scenario.

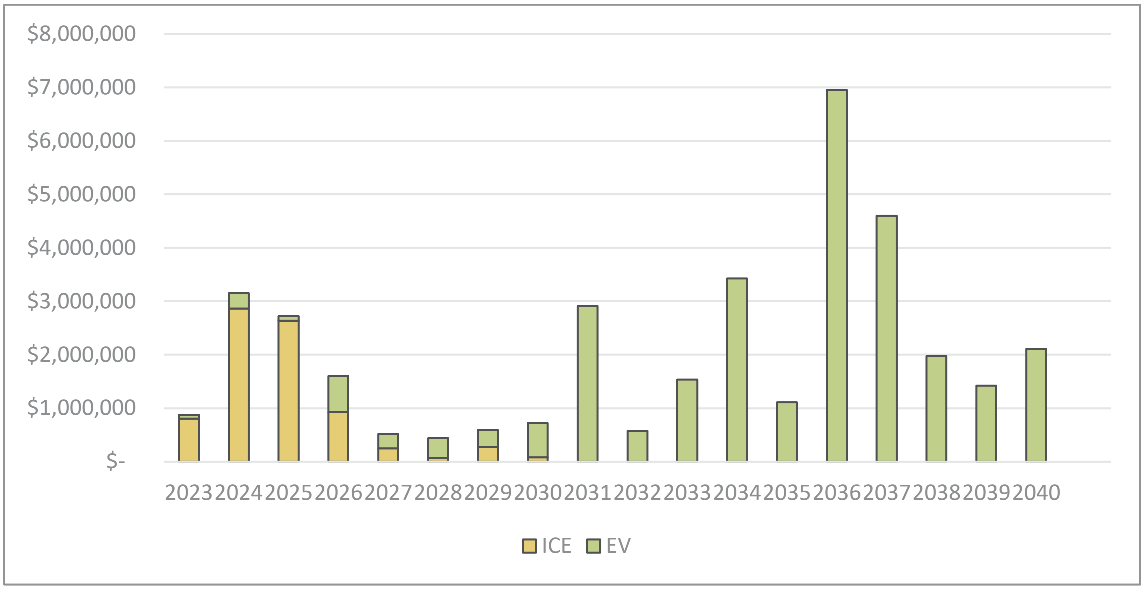

Figure 48. GWP Utility Ops Center Cost of Vehicle Procurements by Year, 2040 Transition Scenario

Integrated Waste Yard

Table 30 provides the number of ICE vehicles and EVs in the Integrated Waste Yard fleet throughout the transition timeline for the 2040 scenario. **Figure 49** shows the fleet composition graphically. **Figure 50** shows the annual purchases for the 2040 Scenario.

Table 30. Integrated Waste Yard Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	68	0
2023	68	0
2024	68	0
2025	63	5
2026	61	7
2027	61	7
2028	59	9
2029	55	13
2030	44	24
2031	31	37

Year	ICE	EV
2032	26	42
2033	21	47
2034	13	55
2035	6	62
2036	2	66
2037	1	67
2038	0	68
2039	0	68
2040	0	68

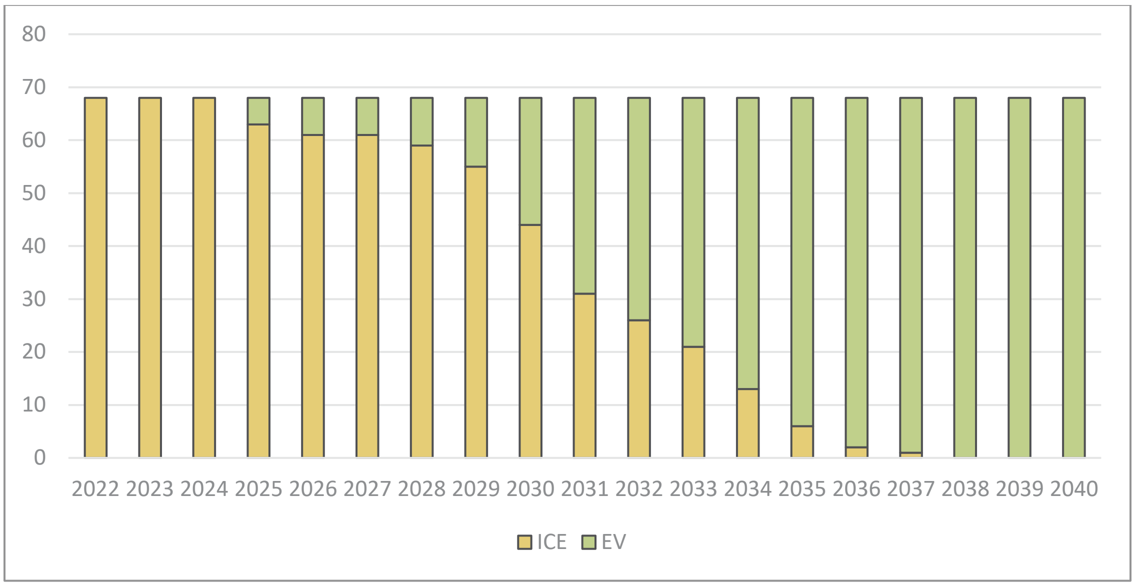

Figure 49. Integrated Waste Yard Fleet Composition Over Time, 2040 Transition Scenario

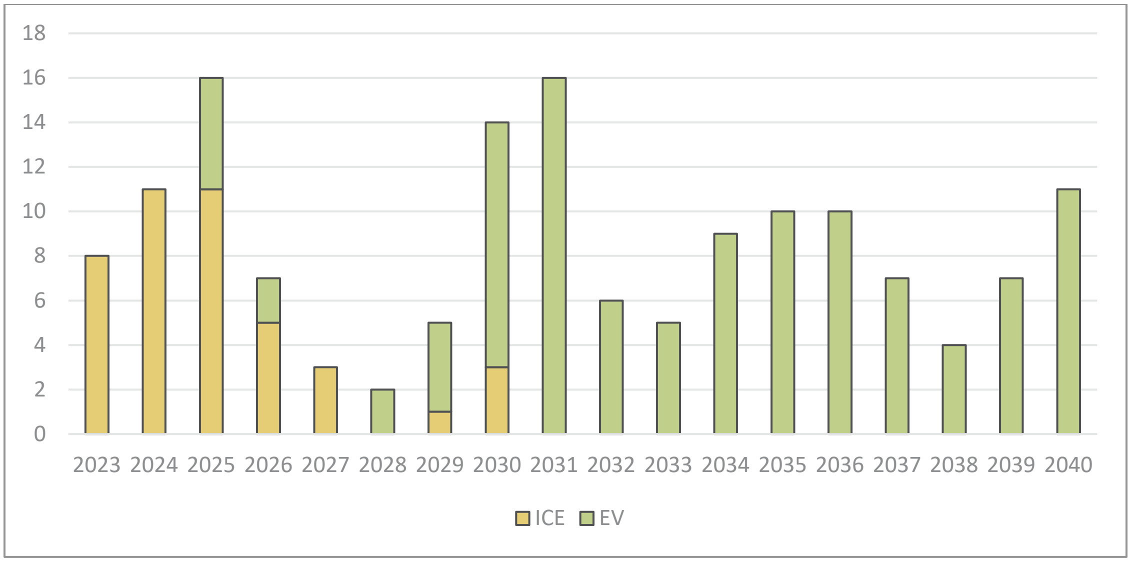

Figure 50. Integrated Waste Yard Annual Purchases, 2040 Transition Scenario

Figure 51 Provides the yearly cost for purchasing both ICE and EVs for the Integrated Waste Yard under the 2040 Transition Scenario.

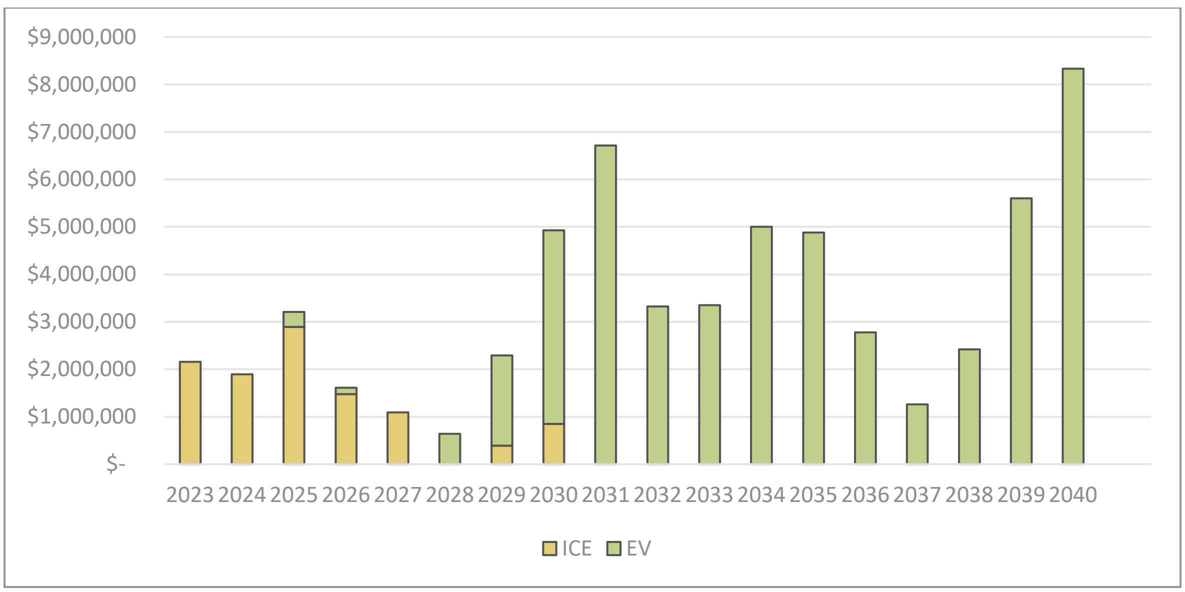

Figure 51. Integrated Waste Yard Cost of Vehicle Procurements by Year, 2040 Transition Scenario

Fire Station 21

Table 31 provides the number of ICE vehicles and EVs in the Fire Station 21 fleet throughout the transition timeline for the 2040 scenario. **Figure 52** shows the fleet composition over time graphically. **Figure 53** shows the annual purchases for the 2040 Scenario.

Table 31. Fire Station 21 Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	29	0
2023	29	0
2024	28	1
2025	26	3
2026	23	6
2027	23	6
2028	21	8
2029	20	9
2030	17	12
2031	14	15
2032	12	17
2033	10	19
2034	7	22
2035	5	24
2036	4	25
2037	3	26
2038	3	26
2039	3	26
2040	3	26

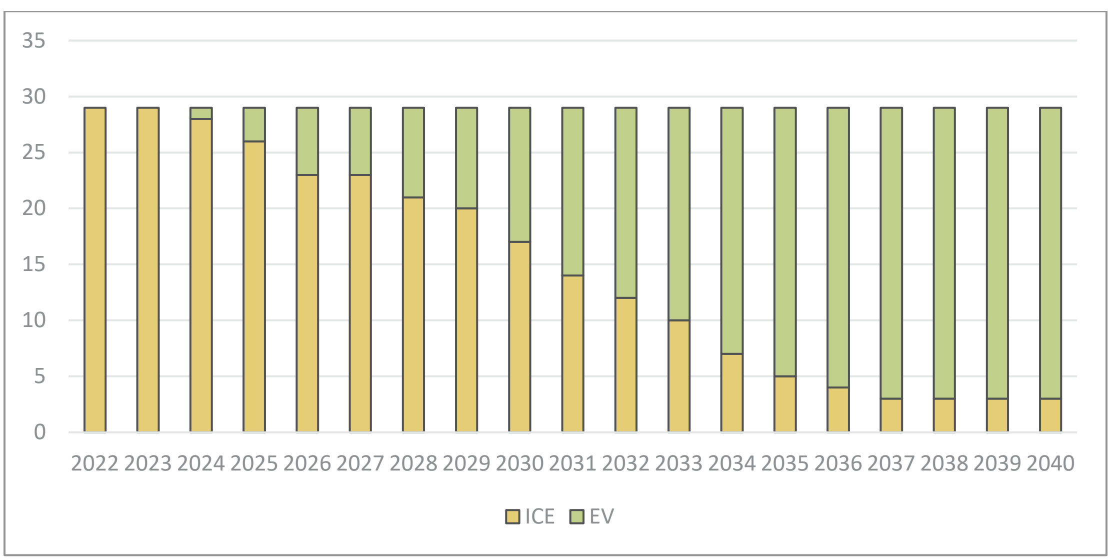

Figure 52. Fire Station 21 Fleet Composition Over Time, 2040 Transition Scenario

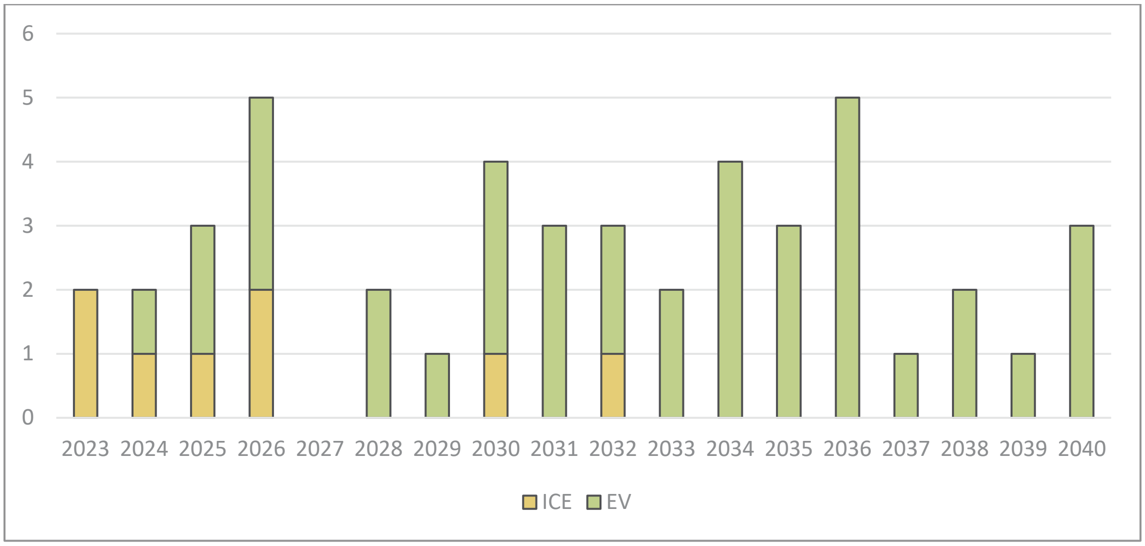

Figure 53. Fire Station 21 Annual Purchases, 2040 Transition Scenario

Figure 54 Provides the yearly cost for purchasing both ICE and EVs for Fire Station 21 under the 2040 Transition Scenario.

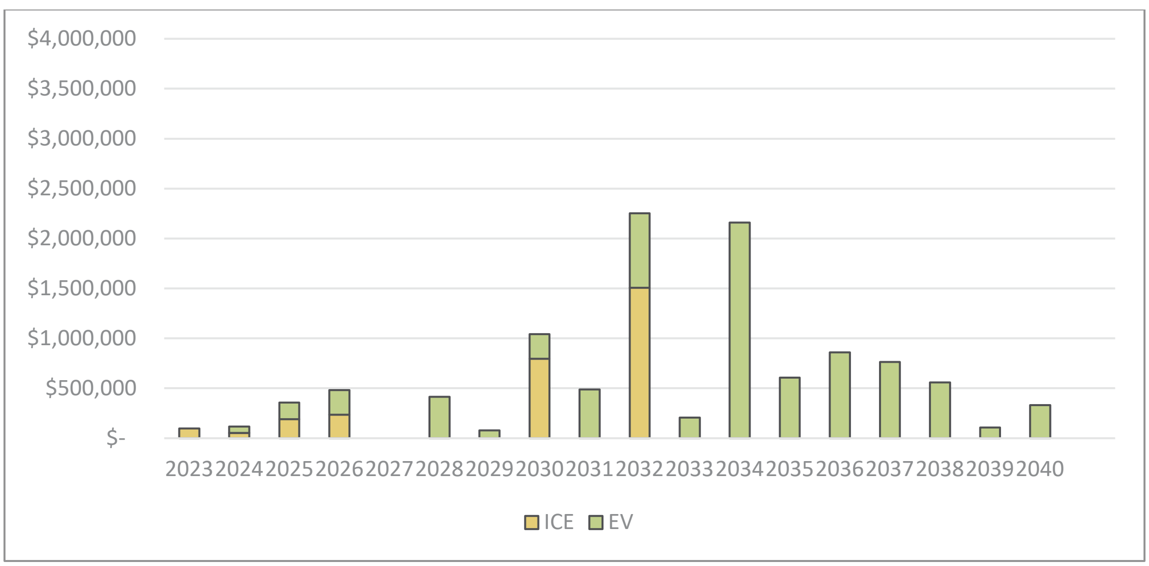

Figure 54. Fire Station 21 Cost of Vehicle Procurements by Year, 2040 Transition Scenario

Police Parking Lot

Table 32 provides the number of ICE vehicles and EVs in the Police Parking Lot fleet throughout the transition timeline for the 2040 scenario. **Figure 55** presents the data graphically. **Figure 56** shows the annual purchases for the 2040 Scenario.

Table 32. Police Parking Lot Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	222	5
2023	220	7
2024	213	14
2025	204	23
2026	197	30
2027	185	42
2028	164	63
2029	126	101
2030	91	136
2031	52	175
2032	16	211
2033	9	218
2034	7	220
2035	3	224
2036	1	226
2037	0	227
2038	0	227
2039	0	227
2040	0	227

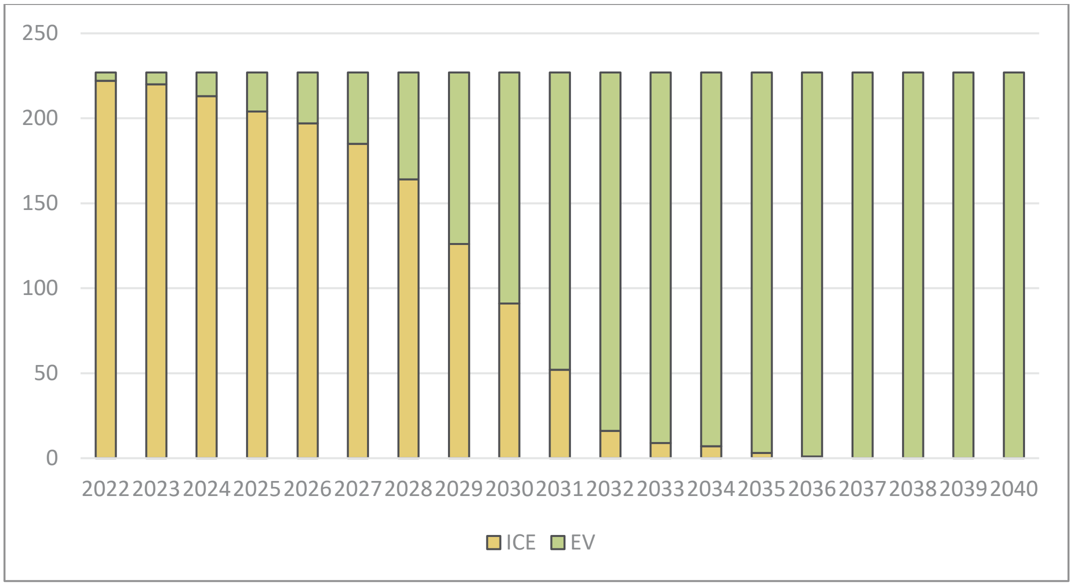

Figure 55. Police Parking Lot Fleet Composition Over Time, 2040 Transition Scenario

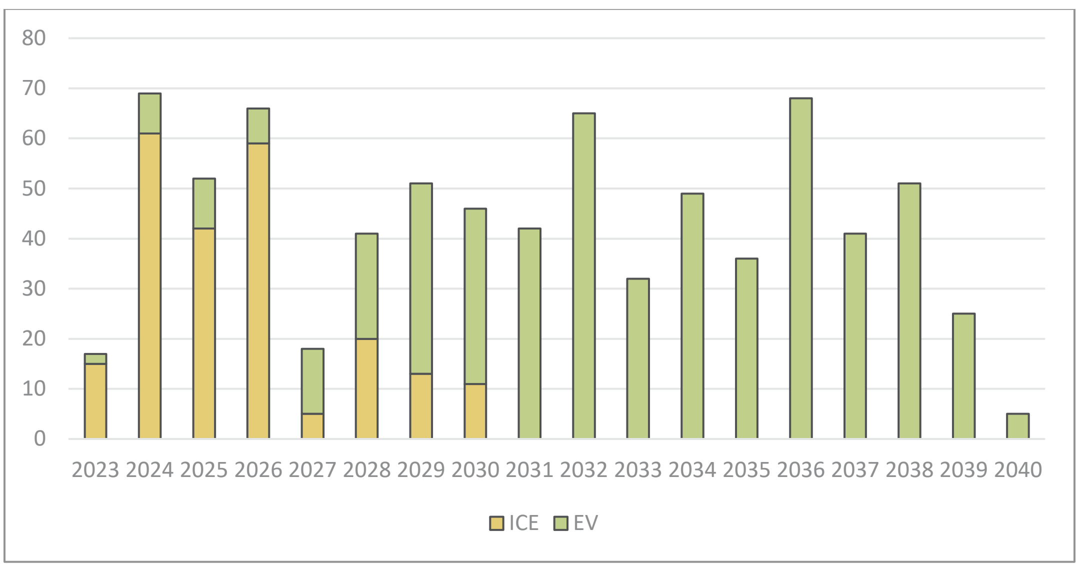

Figure 56. Police Parking Lot Annual Purchases, 2040 Transition Scenario

Figure 57 Provides the yearly cost for purchasing both ICE and EVs for the Police Parking Lot under the 2040 Transition Scenario.

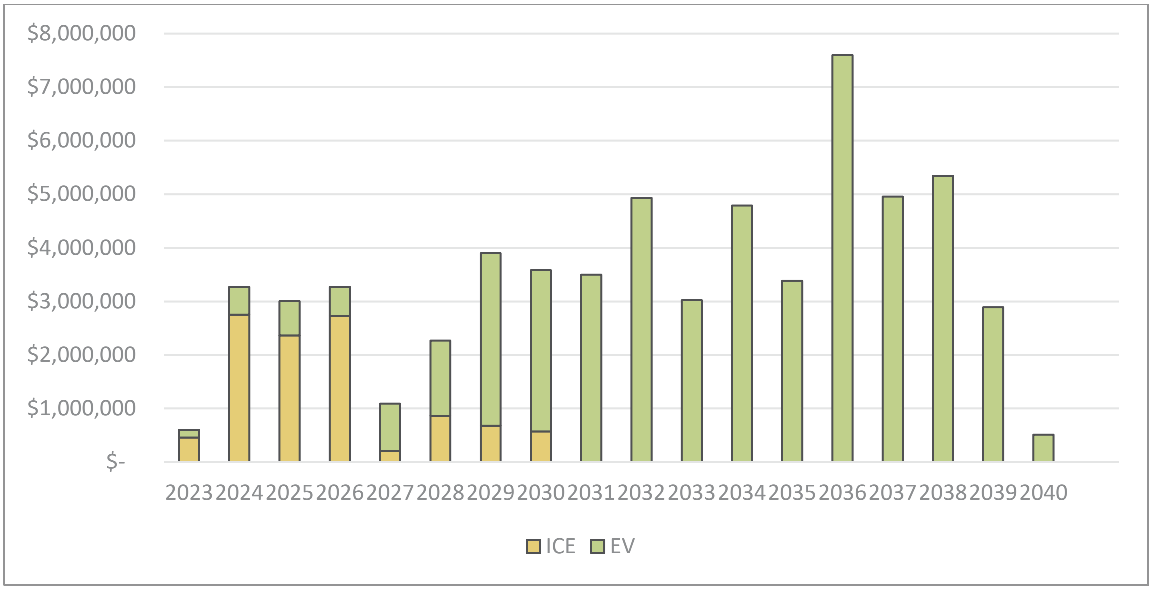

Figure 57. Police Parking Lot Cost of Vehicle Procurements by Year, 2040 Transition Scenario

Other Vehicles

For the City's fleet vehicles housed in locations other than the selected site, **Table 33** lists the EV and ICE fleet composition over time for the 2040 Scenario and **Figure 58** presents the data graphically. **Figure 59** shows the annual purchases by type and **Figure 49** shows the costs.

Table 33. Other Vehicles Number of ICE vehicles and EVs in fleet per year, 2040 Transition Scenario

Year	ICE	EV
2022	146	0
2023	145	1
2024	143	3
2025	137	9
2026	132	14
2027	130	16
2028	127	19
2029	123	23
2030	109	37
2031	96	50
2032	91	55
2033	78	68
2034	52	94
2035	35	111
2036	23	123
2037	21	125

Year	ICE	EV
2038	18	128
2039	16	130
2040	13	133

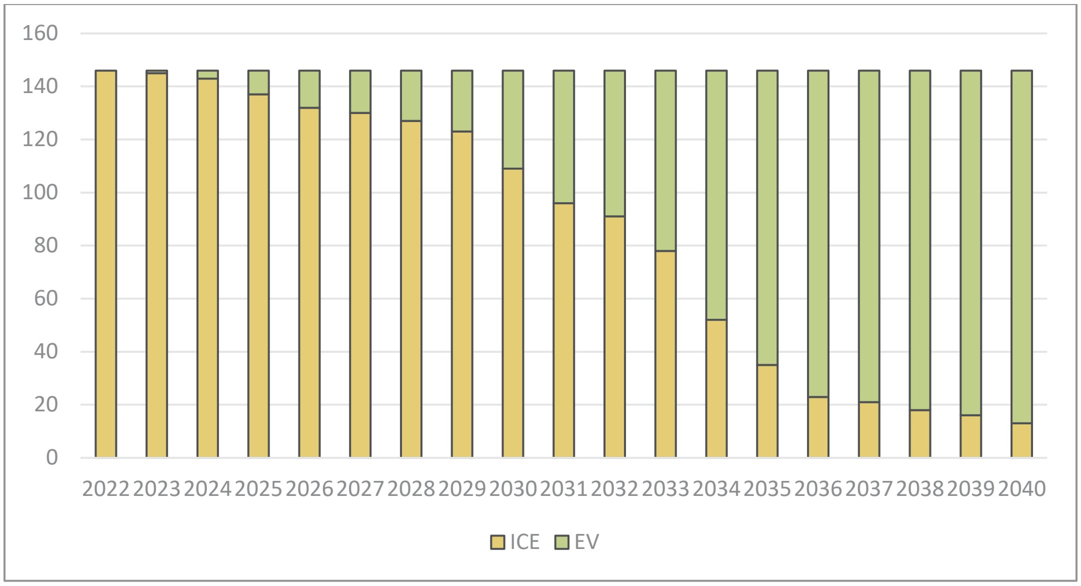

Figure 58. Other Vehicles Composition Over Time, 2040 Scenario

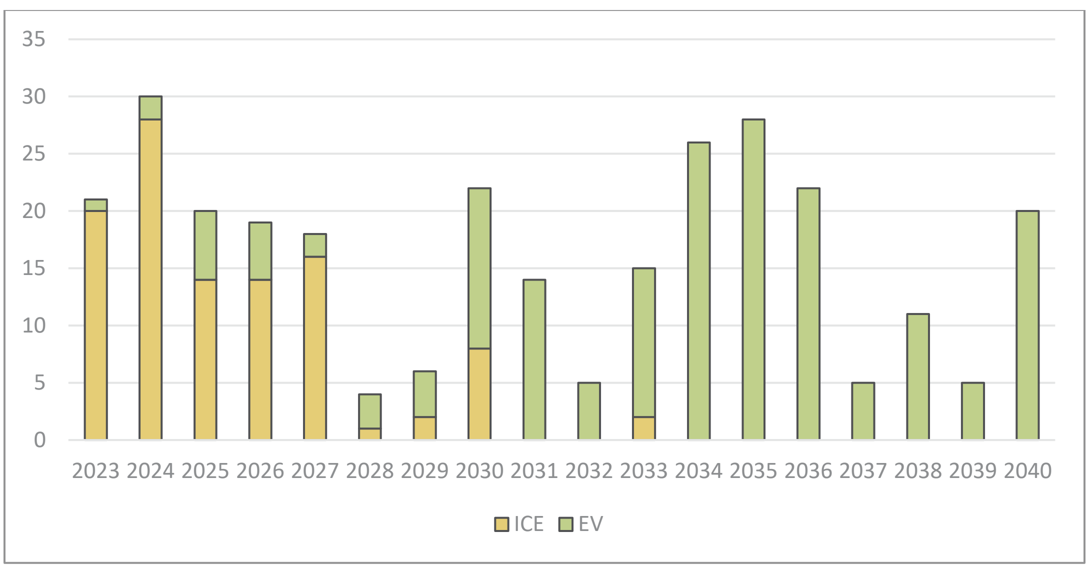

Figure 59. Other Vehicles Annual Purchases, 2040 Scenario

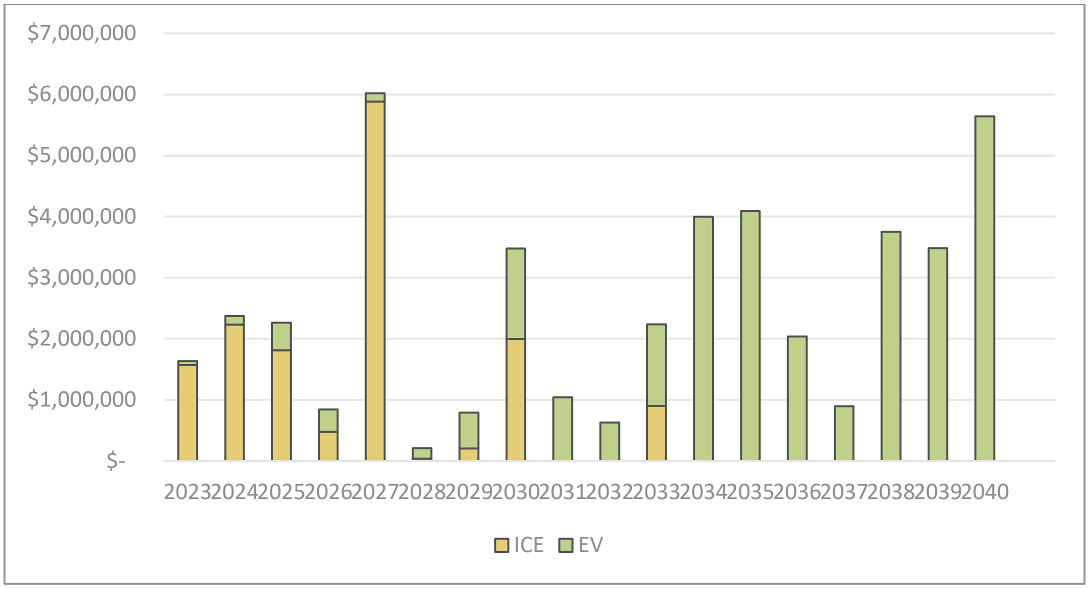

Figure 60. Other Vehicles Purchase Costs 2040 Scenario

100% EV Fleet by 2035

Fleet Composition over Transition Period

Following the procurement goals for the 2040 transition scenario outlined in the previous section, **Table 35** provides annual ICE and EV vehicle purchases over the transition period. **Figure 61** shows these numbers graphically. The City is expected to still have 109 ICE vehicles in the fleet in 2035 due to the suitability of specific vehicles and the long procurement schedule. **Figure 62** shows the annual purchases for the 2035 Scenario.

Table 34. Number of ICE vehicles and EVs in the fleet each year, 2035 Transition Scenario

Year	ICE	EV
2022	843	20
2023	835	28
2024	815	48
2025	780	83
2026	724	139
2027	700	163
2028	656	207
2029	602	261
2030	476	387
2031	351	512
2032	301	562
2033	252	611
2034	171	692
2035	109	754

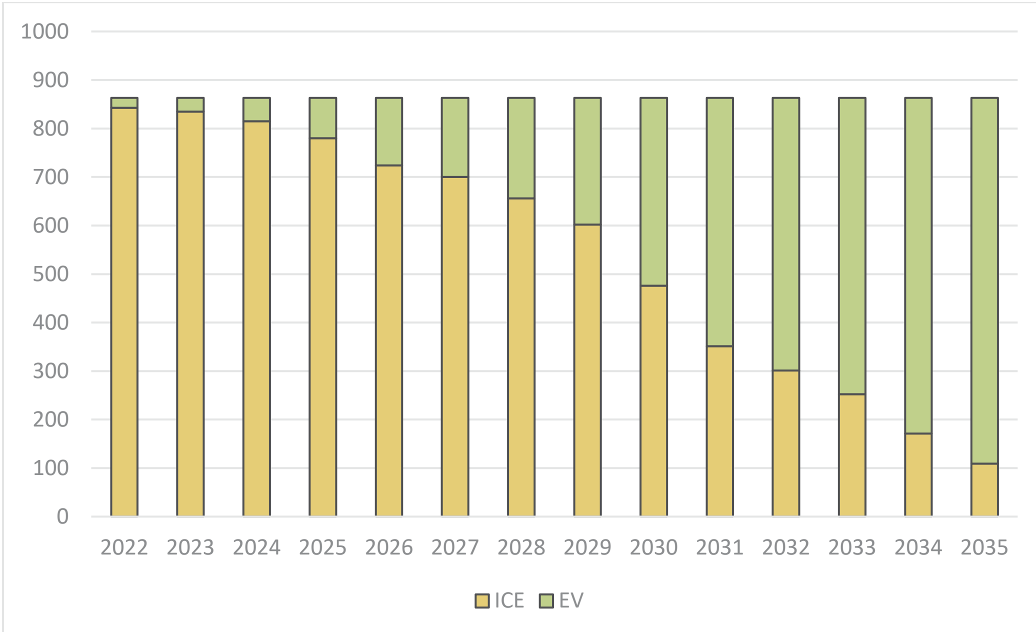

Figure 61. Fleet Composition Over Time, 2035 Transition Scenario

Table 35. Number of ICE vehicles and EVs purchased per year, 2035 Transition Scenario

Year	ICE	EV
2023	93	8
2024	150	22
2025	113	40
2026	88	58
2027	32	28
2028	14	44
2029	18	55
2030	3	128
2031	0	142
2032	1	92
2033	2	87
2034	0	139
2035	0	134

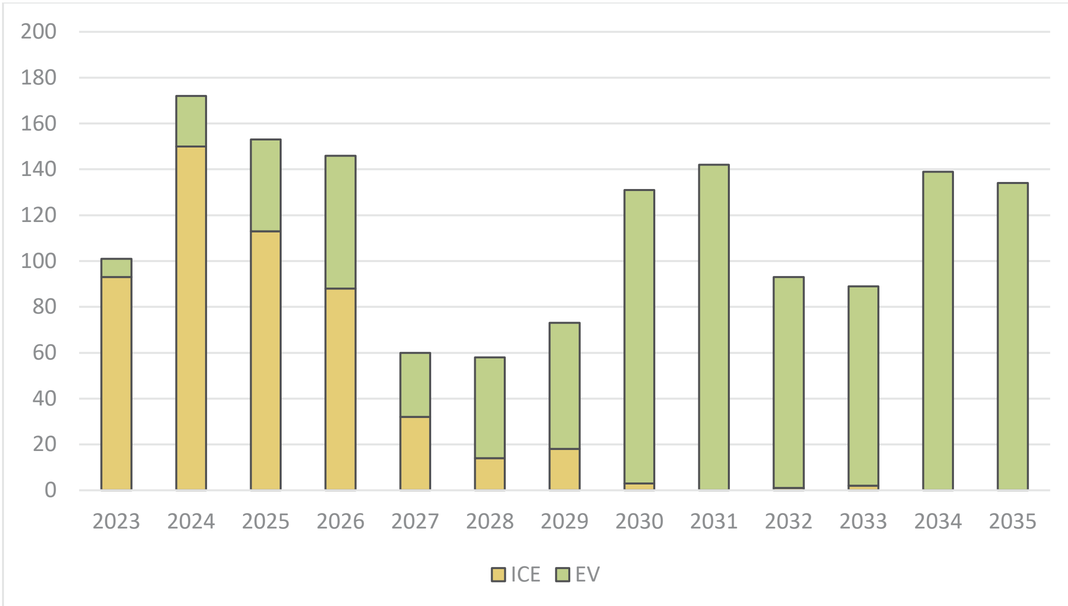

Figure 62. Annual Vehicle Procurements by Vehicle Type, 2035 Transition Scenario

Figure 63 Provides the yearly cost for purchasing both ICE and EVs under the 2035 Transition Scenario.

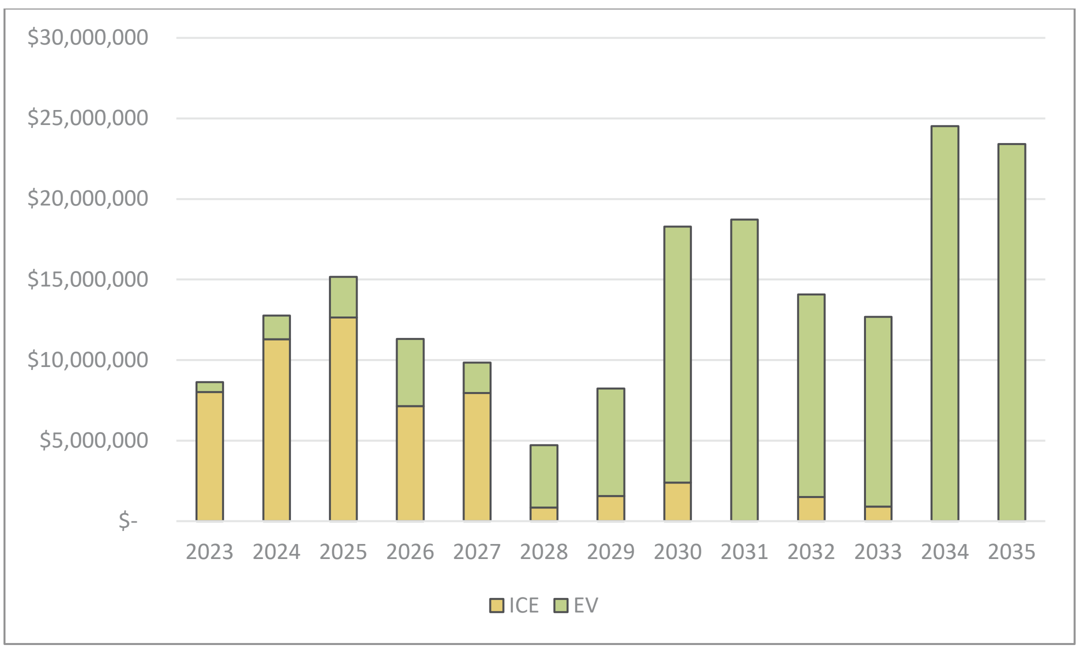

Figure 63. Annual Procurement Cost per Year, 2035 Transition Scenario

Transition Timelines by Facility

The fleet composition over time for the primary facilities are shown in the sections below.

Public Works Yard

Table 36 provides the number of ICE vehicles and EVs in the Public Works Yard fleet throughout the transition timeline for the 2035 scenario. **Figure 64** presents the data graphically. **Figure 65** shows the Public Works Yard annual fleet procurements for the 2035 scenario.

Table 36. Public Works Yard Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	122	1
2023	122	1
2024	120	3
2025	114	9
2026	105	18
2027	102	21
2028	101	22
2029	100	23
2030	92	31
2031	80	43
2032	71	52
2033	64	59
2034	48	75
2035	24	99

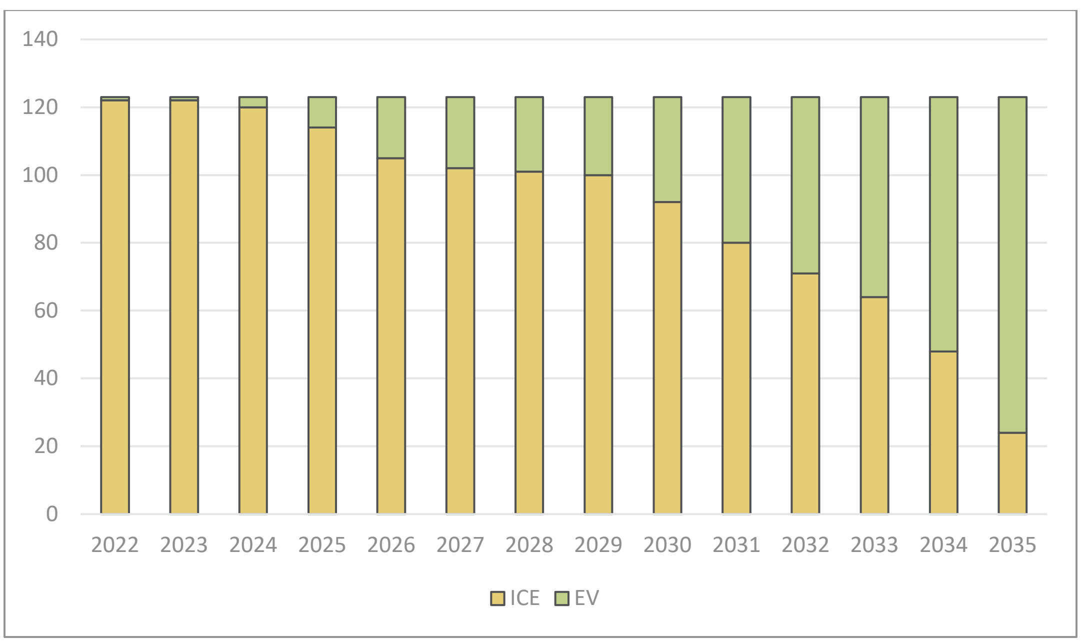

Figure 64. Public Works Yard Fleet Composition Over Time for 2035 Transition Scenario

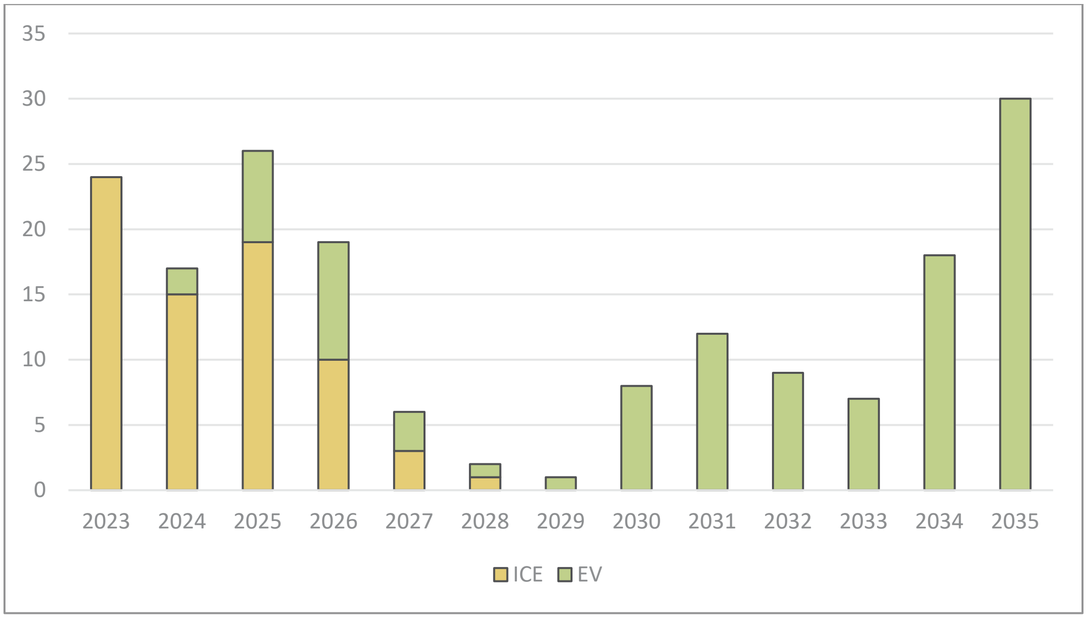

Figure 65. Public Works Yard Fleet Annual Fleet Procurements 2035 Transition Scenario

Figure 66 Provides the yearly cost for purchasing both ICE and EVs for the Public Works Yard under the 2035 Transition Scenario.

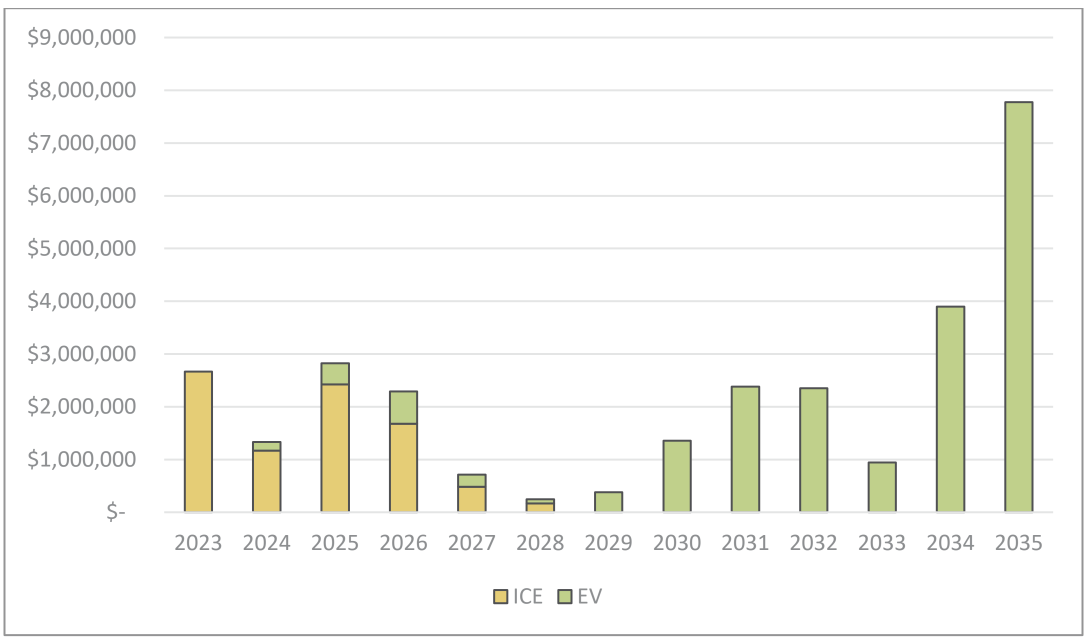

Figure 66. Public Works Yard Cost of Vehicle Procurements by Year, 2035 Transition Scenario

City Hall Complex

Table 37 shows the number of ICE vehicles and EVs in the City Hall Complex fleet throughout the transition timeline for the 2035 scenario. **Figure 67** presents the data graphically. **Figure 68** shows the City Hall Complex annual fleet procurements for the 2035 scenario.

Table 37. City Hall Complex Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	103	6
2023	99	10
2024	95	14
2025	89	20
2026	84	25
2027	80	29
2028	78	31
2029	76	33
2030	50	59
2031	29	80
2032	29	80
2033	19	90
2034	9	100
2035	5	104

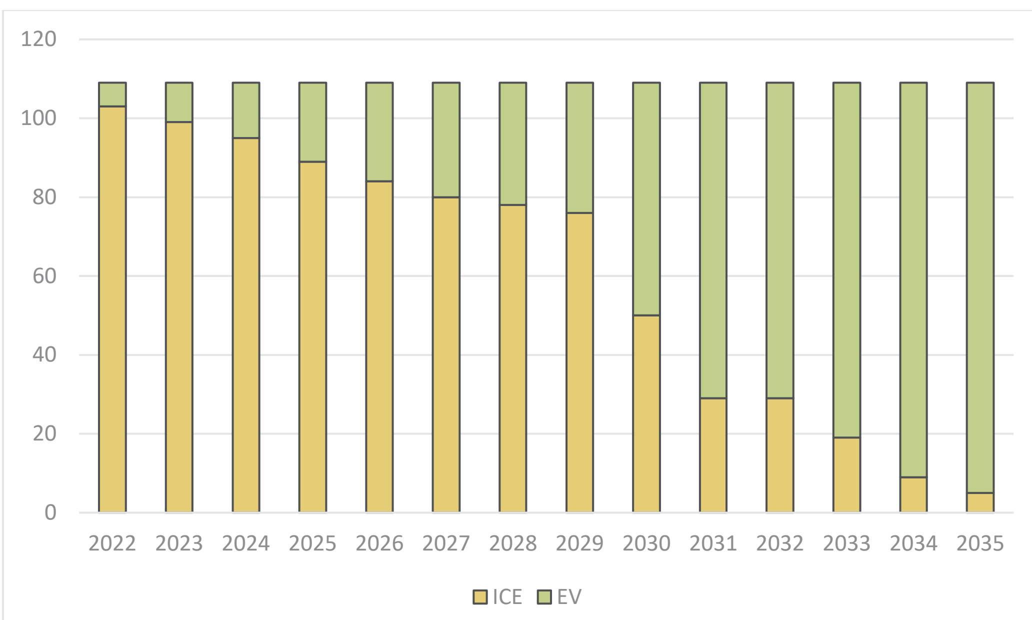

Figure 67. City Hall Complex Fleet Composition Over Time, 2035 Transition Scenario

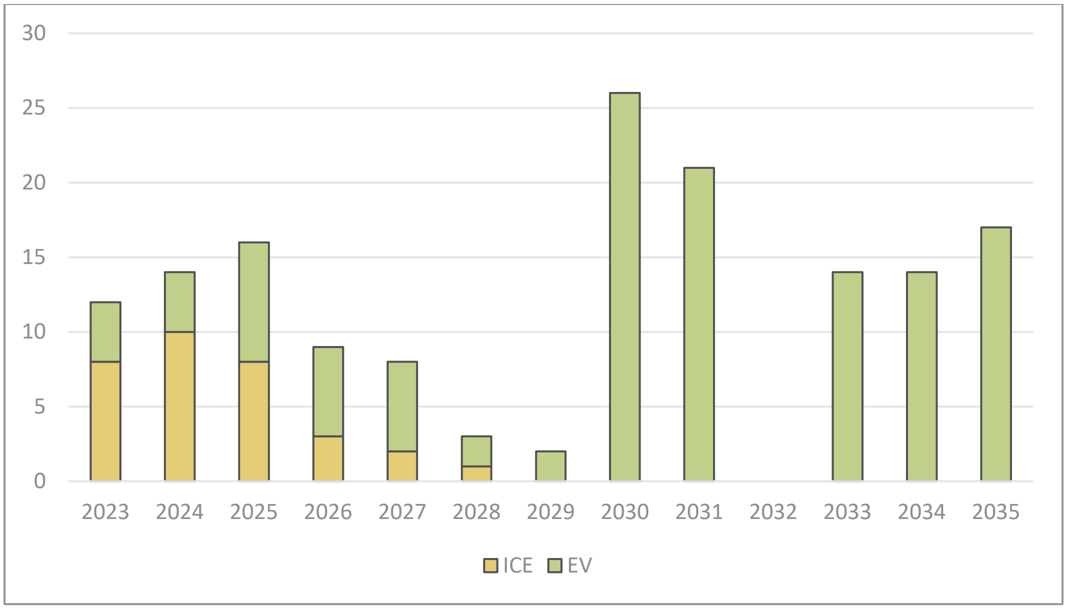

Figure 68. City Hall Complex Number of Procurements by Type, 2035 Transition Scenario

Figure 69 Provides the yearly cost for purchasing both ICE and EVs for the City Hall Complex under the 2035 Transition Scenario.

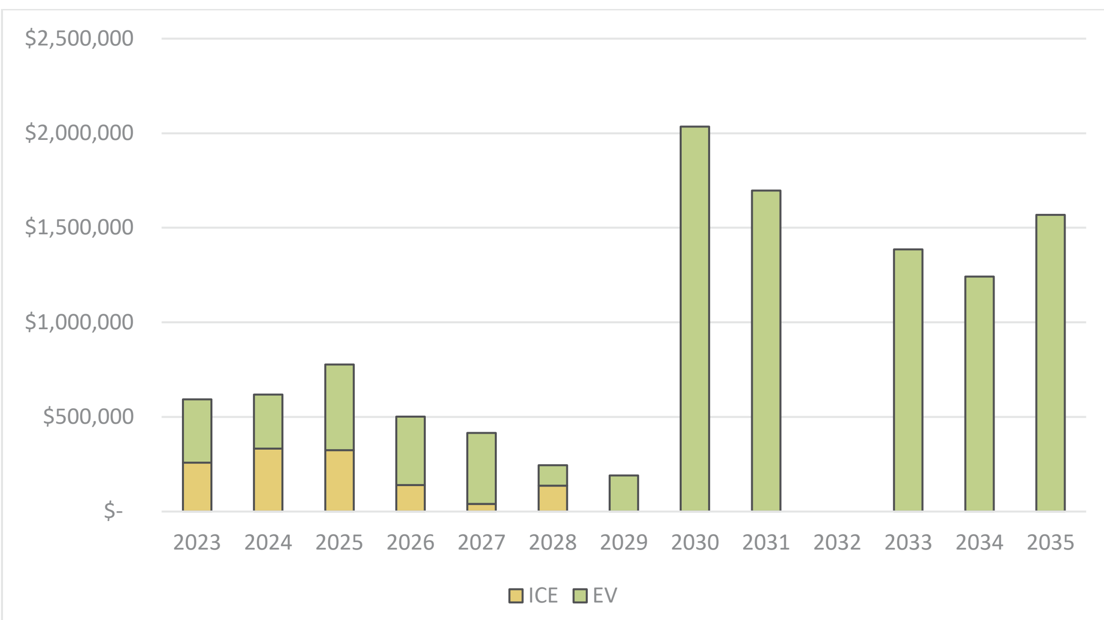

Figure 69. City Hall Complex Cost of Vehicle Procurements by Year, 2035 Transition Scenario

GWP Utility Operations Center

Table 38 shows the number of ICE vehicles and EVs in the GWP Utility Operations Center fleet throughout the transition timeline for the 2035 scenario. **Figure 70** presents the data graphically. **Figure 71** shows the GWP Utility Operations Center annual fleet procurements for the 2035 scenario.

Table 38. GWP Ops Center Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	153	8
2023	152	9
2024	148	13
2025	147	14
2026	133	28
2027	130	31
2028	127	34
2029	123	38
2030	112	49
2031	80	81
2032	75	86
2033	63	98
2034	47	114
2035	39	122

Figure 70. GWP Ops Center Fleet Composition Over Time, 2035 Transition Scenario

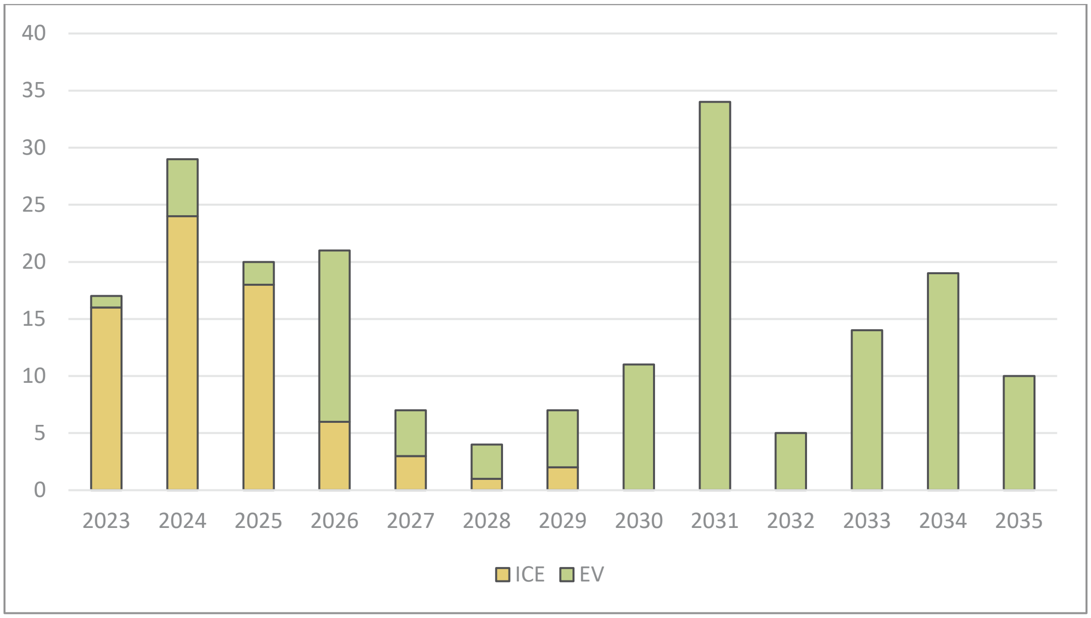

Figure 71. GWP Ops Center Number of Procurements by Type

Figure 72 Provides the yearly cost for purchasing both ICE and EVs for the GWP Utility Operations Center under the 2035 Transition Scenario.

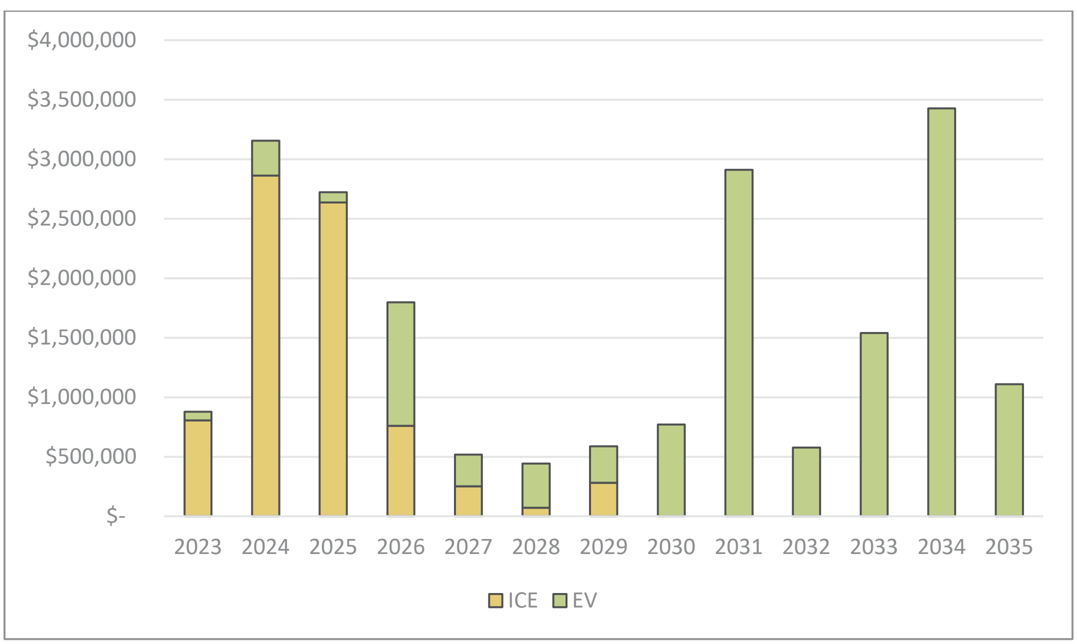

Figure 72. GWP Ops Center Cost of Vehicle Procurements by Year, 2035 Transition Scenario

Integrated Waste Yard

Table 39 shows the number of ICE vehicles and EVs in the Integrated Waste Yard fleet throughout the transition timeline for the 2035 scenario. **Figure 73** presents the data graphically. **Figure 74** shows the Integrated Waste Yard annual fleet procurements for the 2035 scenario.

Table 39. Integrated Waste Yard Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	68	0
2023	68	0
2024	68	0
2025	63	5
2026	61	7
2027	61	7
2028	59	9
2029	55	13
2030	41	27
2031	29	39
2032	24	44
2033	19	49
2034	11	57
2035	4	64

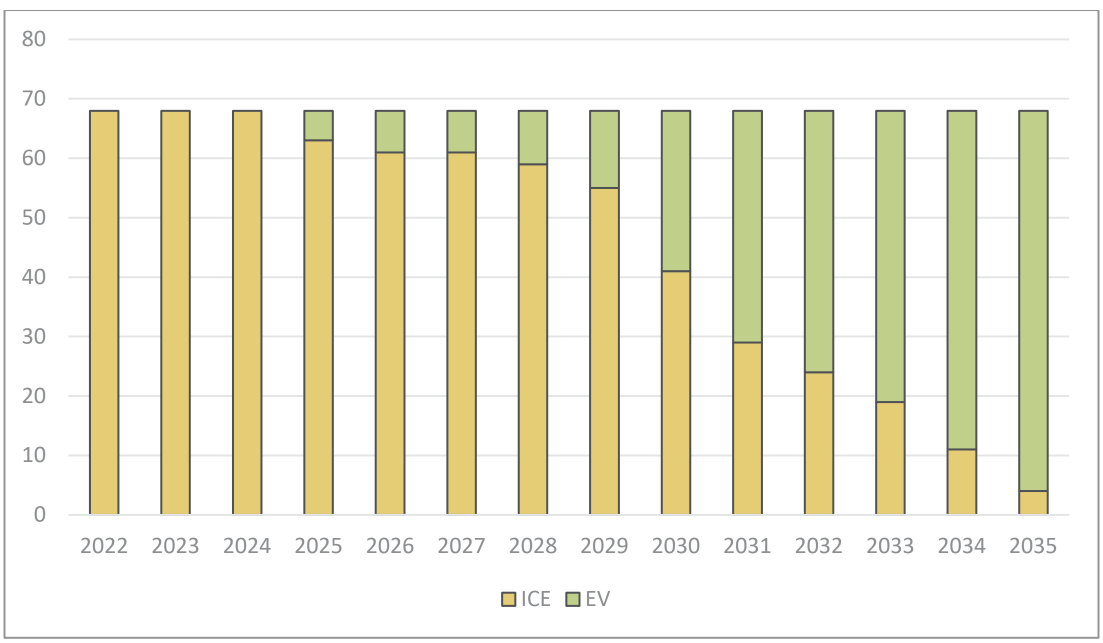

Figure 73. Integrated Waste Yard Fleet Composition Over Time, 2035 Transition Scenario

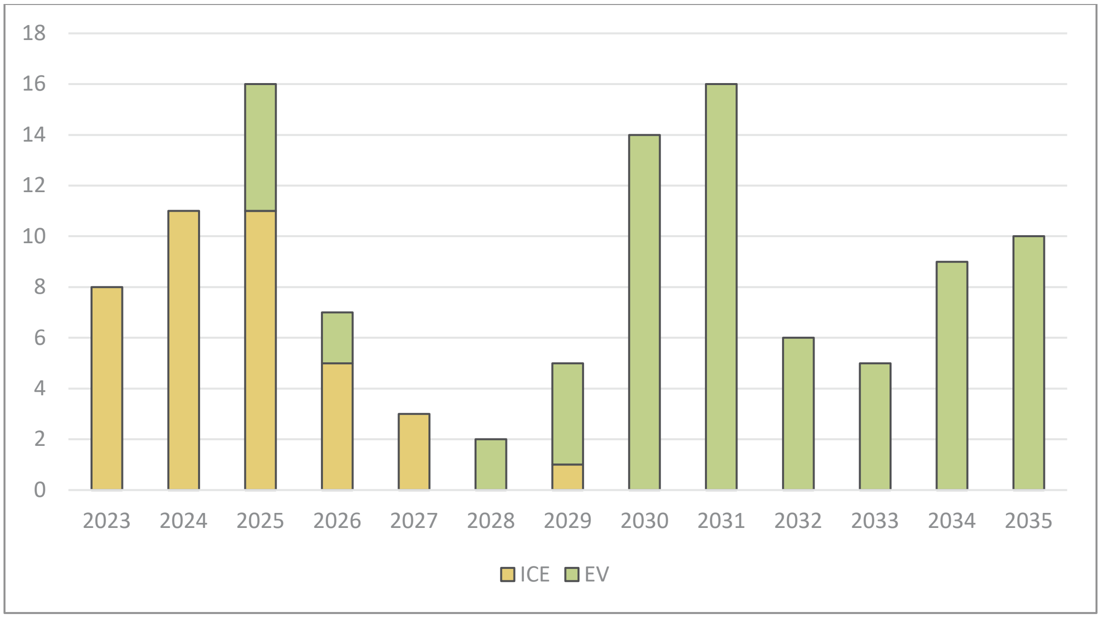

Figure 74. Integrated Waste Yard Number of Procurements by Type

Figure 75 Provides the yearly cost for purchasing both ICE and EVs for the Integrated Waste Yard under the 2035 Transition Scenario.

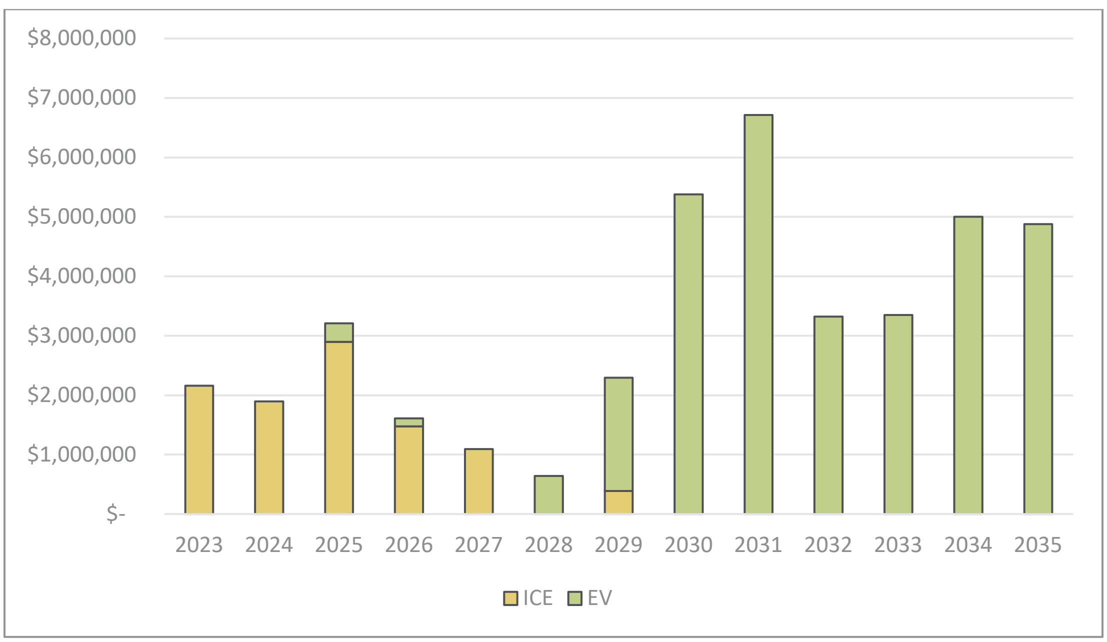

Figure 75. Integrated Waste Yard Cost of Vehicle Procurements by Year, 2035 Transition Scenario

Fire Station 21

Table 40 shows the number of ICE vehicles and EVs in the Fire Station 21 fleet throughout the transition timeline for the 2035 scenario. **Figure 76** presents the data graphically. **Figure 77** shows the Fire Station 21 annual fleet procurements for the 2035 scenario.

Table 40. Fire Station 21 Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	29	0
2023	29	0
2024	28	1
2025	26	3
2026	22	7
2027	22	7
2028	20	9
2029	19	10
2030	16	13
2031	13	16
2032	11	18
2033	9	20
2034	6	23
2035	5	24

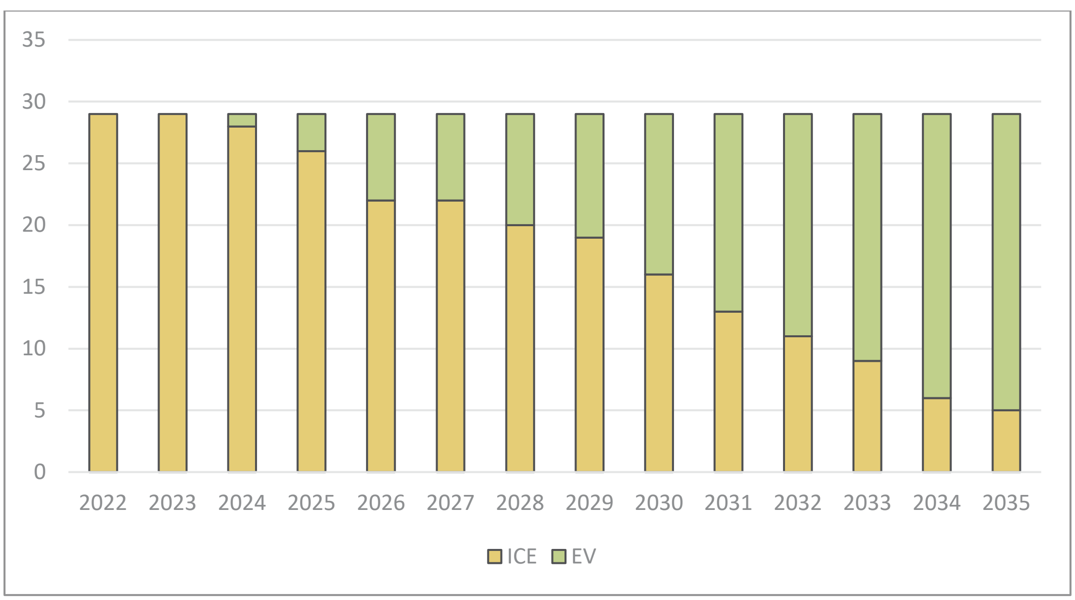

Figure 76. Fire Station 21 Fleet Composition Over Time, 2035 Transition Scenario

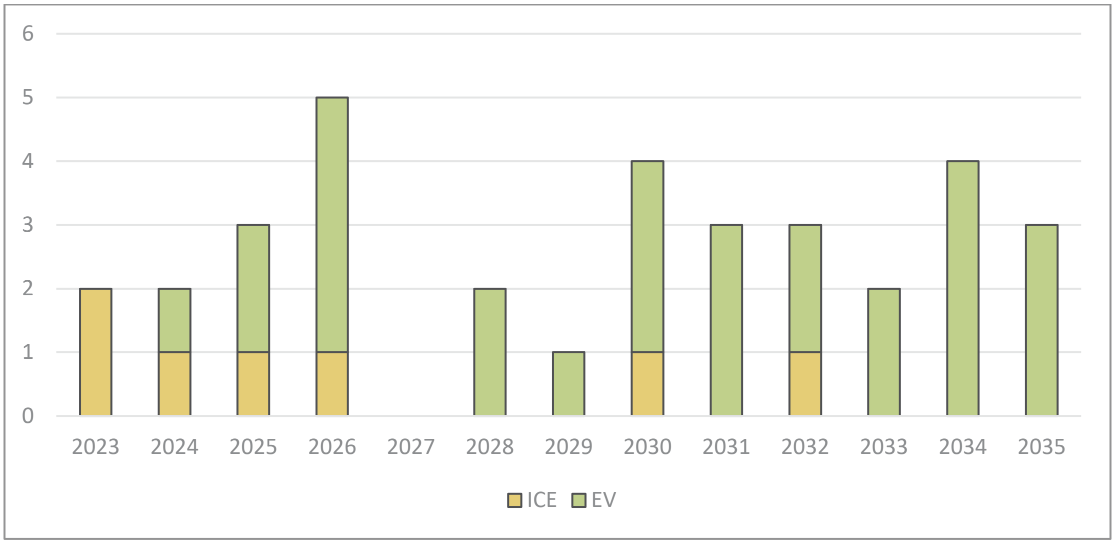

Figure 77. Fire Station 21 Number of Procurements by Type

Figure 78 Provides the yearly cost for purchasing both ICE and EVs for Fire Station 21 under the 2035 Transition Scenario.

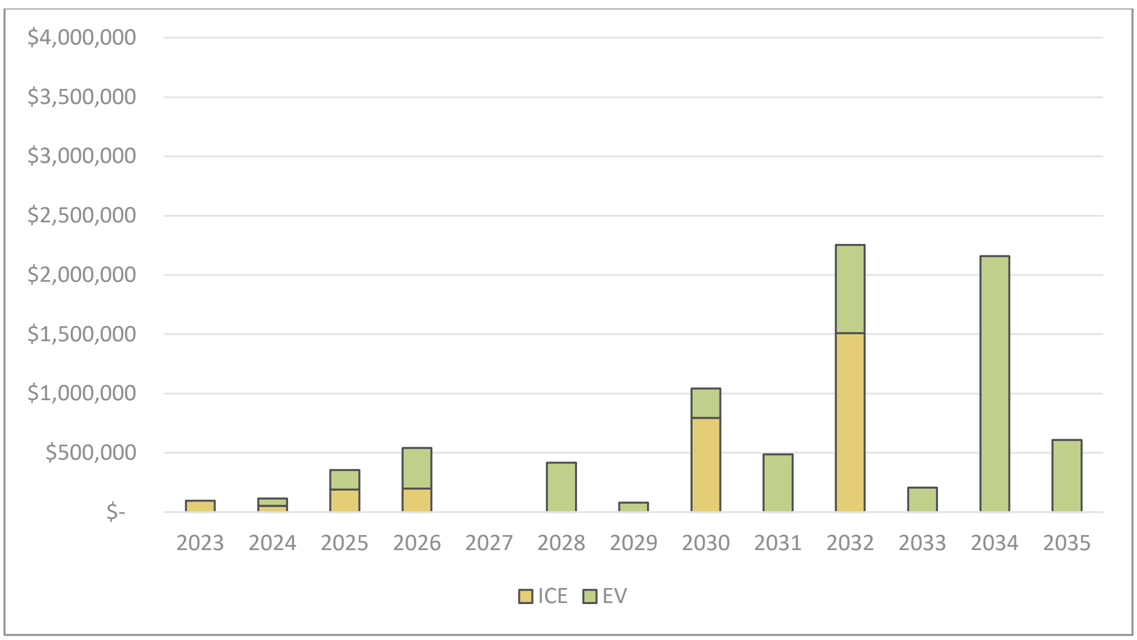

Figure 78. Fire Station 21 Cost of Vehicle Procurements by Year, 2035 Transition Scenario

Police Parking Lot

Table 41 shows the number of ICE vehicles and EVs in the Police Parking Lot fleet throughout the transition timeline for the 2035 scenario. **Figure 79** presents the data graphically. **Figure 80** shows the Police Parking Lot annual fleet procurements for the 2035 scenario.

Table 41. Police Parking Lot Number of ICE vehicles and EVs in fleet per year, 2035 Transition Scenario

Year	ICE	EV
2022	222	5
2023	220	7
2024	213	14
2025	204	23
2026	190	37
2027	178	49
2028	147	80
2029	109	118
2030	65	162
2031	33	194
2032	9	218
2033	9	218
2034	7	220
2035	3	224

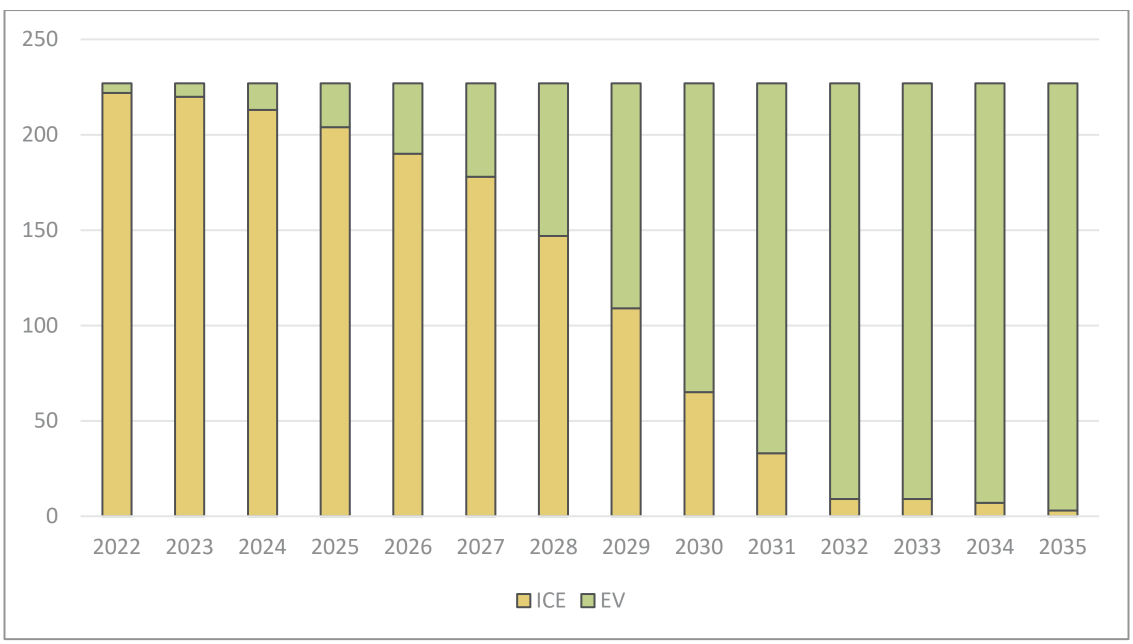

Figure 79. Police Parking Lot Fleet Composition Over Time, 2035 Transition Scenario

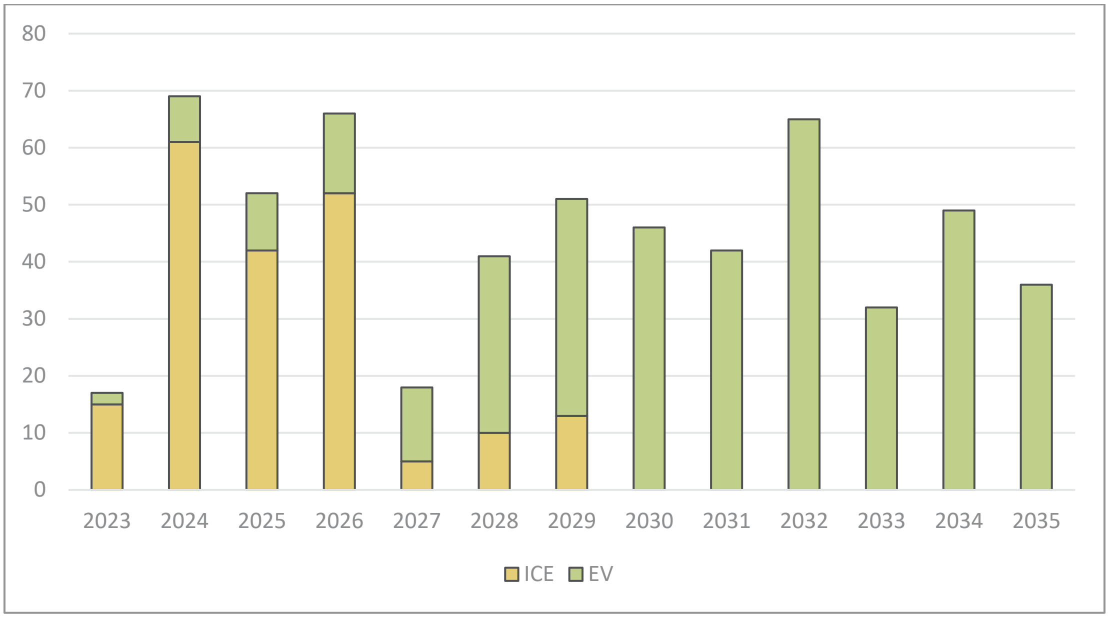

Figure 80. Police Parking Lot Number of Procurements by Type

Figure 81 Provides the yearly cost for purchasing both ICE and EVs for the Police Parking Lot under the 2035 Transition Scenario.

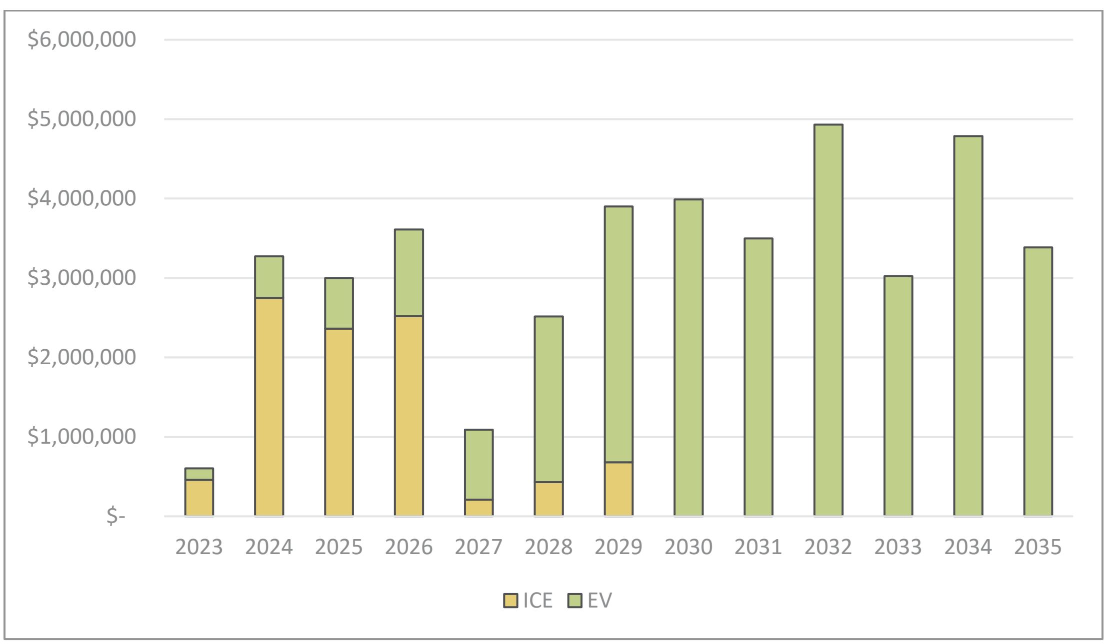

Figure 81. Police Parking Lot Cost of Vehicle Procurements by Year, 2035 Transition Scenario

Other Vehicles

Table 42 shows the number of ICE vehicles and EVs for other vehicles not located at the selected facilities throughout the transition timeline for the 2035 scenario. **Figure 82** presents the data graphically. **Figure 83** shows the other vehicles annual fleet procurements for the 2035 scenario.

Table 42. Other Vehicles Composition Over Time, 2035 Transition Scenario

Year	ICE	EV
2022	146	0
2023	145	1
2024	143	3
2025	137	9
2026	129	17
2027	127	19
2028	124	22
2029	120	26
2030	100	46
2031	87	59
2032	82	64
2033	69	77
2034	43	103
2035	29	117

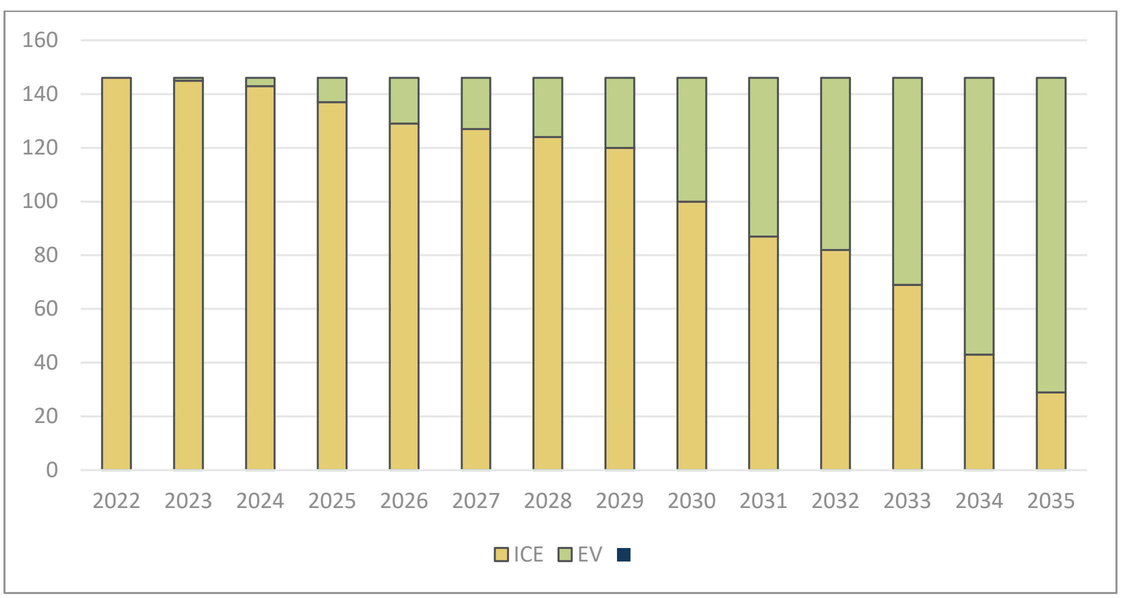

Figure 82. Other Vehicles Composition over Time, 2035 Transition Scenario

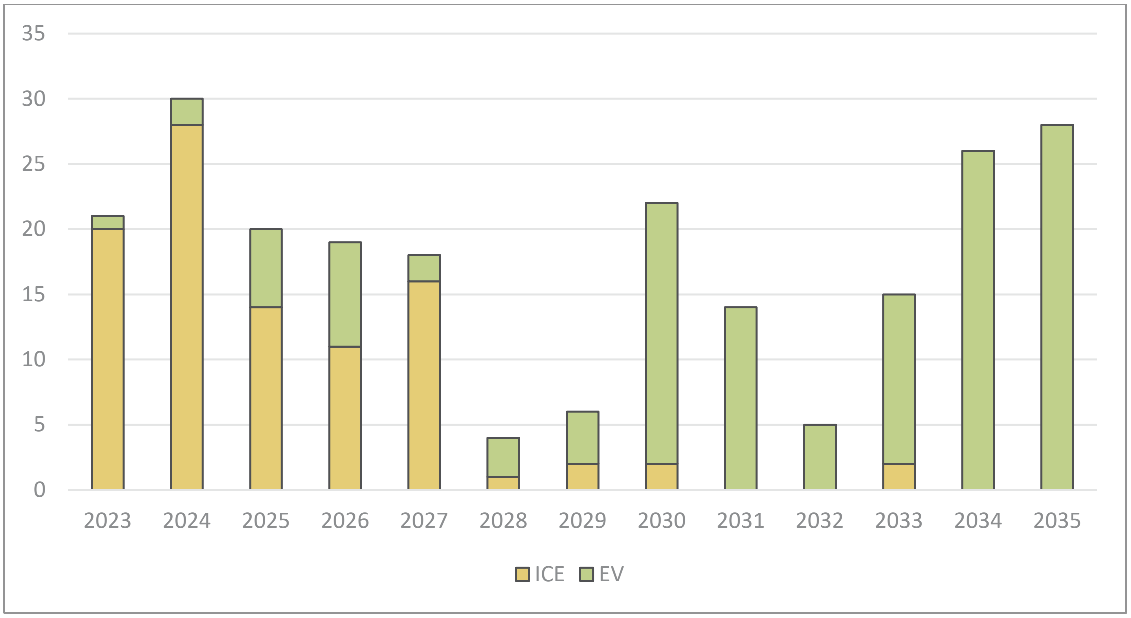

Figure 83. Other Vehicles Number of Procurements

Figure 84 provides the yearly cost for purchasing both ICE and EVs for the Police Parking Lot under the 2035 Transition Scenario.

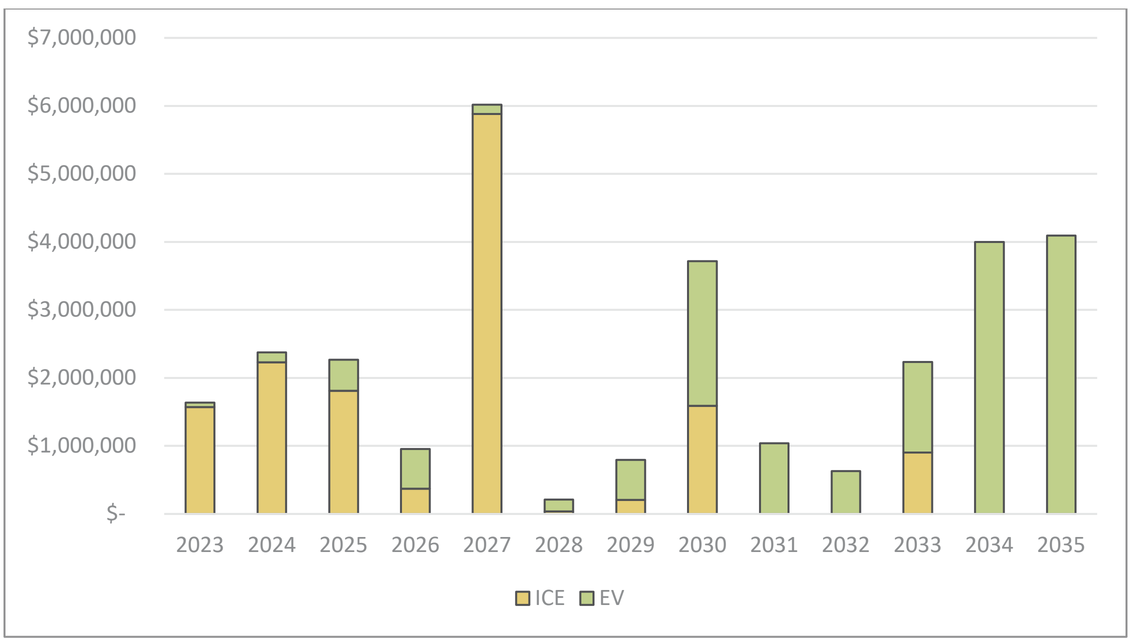

Figure 84. Other Vehicles Cost of Procurement, 2035 Transition Scenario

Facilities Assessment

Scaling the City's fleet to 100% EVs requires significant investment in charging infrastructure. Based on the feasibility and fleet assessments and following the fleet procurement schedule, CTE analyzed the energy requirements for each facility throughout the transition periods. Because the City's fleet is so diverse, the analysis uses higher level categories to determine an average vehicle mileage and efficiency. Not all vehicles will be used every day, therefore the energy estimates are considered a worst-case scenario – with all vehicles operating a full days work before returning to each facility for charging.

Energy and Demand Requirements

CTE evaluated the energy needed by facility based on the results of feasibility assessment and average duty cycle energy consumption by vehicle type. The duty cycles for most vehicle types indicate that individual vehicles do not travel every day and may not require daily charging. The installed power will not likely correspond to the actual utility demand on a normal day. Not all vehicles will be used every day, and they won't all return and be plugged in at the same time. The number of vehicles charging simultaneously may have a large effect on the demand and therefore on operational costs.

The energy needs analysis includes vehicle to charger ratios of 1:1, 2:1, and 4:1. A 1:1 ratio is more efficient for fully charging all vehicles in a minimum timeframe, but 2:1 and 4:1 ratio will be less expensive to install and maintain. Depending on the charger model, the power will be split to charge each vehicle simultaneously or can charge two vehicles sequentially. Both Level 2 and DC fast chargers are available in a 2:1 orientation. Some DC chargers can handle a 4:1 orientation, however that is not currently available for level 2 chargers. Installing 1 level 2 charger for every 4 vehicles might require operational procedures to move vehicles around the yard to ensure every vehicle gets a full charge.

Utility upgrade costs

The City coordinated with GWP to evaluate the required equipment upgrades and costs at each of the priority sites. **Table 43** summarizes the upgrades required at each facility to support a 100% electric fleet, including materials needed and estimated cost.

Table 43. Summary of Required GWP Utility Upgrades at Priority Facilities

Facility	Installed Power for 100% EV Fleet (MW)	Materials Needed	Estimated Cost (Including engineering hours and construction labor)
Public Works Yard	1.26	- 500' underground conduits - 1 pull box - wiring - 1 vault room	$300,000
City Hall Complex	1.12	- 400' substructures and underground conduits - 1 pull box - wiring - 1 vault room	$300,000
GWP Utility Operations Center	1.58	- 300' underground conduits - 1 pull box - wiring - 1 vault room	$250,000
Integrated Waste Yard	0.72	- Upgrade 4 overhead conductors from 2 Copper to 4/0 Copper - 360' underground conduits - 1 pull box - wiring - 1 vault room	$250,000
Fire Station 21	0.35	- 300' underground conduits - 1 pull box - wiring - 1 vault room	$225,000
Police Parking Lot	21.5	- Power transformer at Columbus Substation - 12kV Switchgear - Upgrade the substation Switchyard and Bus work - 69Kv Circuit Breaker - 5000' substructures and conduits from Columbus substation - Ten Vaults - Wiring - Vault rooms	$4,100,000
TOTAL	**26.53**		**$5,425,000**

The Acacia substation serves the load of the Public Works Yard and Integrated Waste Yard, in addition to other City facilities, most notably the Beeline Maintenance Facility. GWP indicated that this is an old substation with 8 transformers that were manufactured in 1963 for a total capacity of 22.54 MW. Considering the additional load from the fleet transition project, the increased use of this substation would reach 98% of the total capacity. To provide reliable service, GWP will need to replace the older equipment and increase the capacity of the Acacia substation. Upgrading the Acacia substation from 22.54 MW at 34.5/4 kV to 50 MW at 69/12.47 kV will cost an estimated $17,000,000 (includes costs to upgrade Public Works Yard and Integrated Waste Yard). Adding in the cost to upgrade the Acacia Substation would bring the total cost to $21,875,000. The City will need to coordinate with GWP throughout the implementation of the transition plan to understand the available power at the site over time, and when utility upgrades will be required.

Infrastructure Assessment Assumptions

CTE used a 1:1 charger to vehicle ratio to calculate the number of chargers needed at each facility. Level 2 chargers with a power level less than 20 kW were planned for all light and medium duty vehicles. Non-emergency heavy-duty vehicles were assigned level 3 DC chargers with a power level of 50 kW and heavy-duty emergency vehicles were assigned high power level 3 DC chargers with a power level of 150 kW. While the police department vehicles are light duty, the use profile for the pursuit vehicles requires faster charging than level 2 chargers can provide. Because of this, the analysis uses level 3 DC (150kW) chargers for the pursuit vehicles at the Police Parking Lot.

CTE added a spare ratio of 10% additional level 2 chargers than vehicles to account for charger downtime and maintenance. At least 2 level 3 (50 kW) chargers are planned at each site to account for challenging duty cycle days that might require a faster charge. CTE includes inflation over time for both the charger and installation costs. The analysis does not include managed charging.

Infrastructure Costs

Equipment and Installation Costs

The equipment and installation estimates are focused on the City's on-road fleet. **Table 44** outlines the number of chargers planned by charger type and site for the 2040 scenario. At a 1:1 ratio of vehicles to chargers, 619 L2 chargers, 103 DC 50kW chargers, and 146 DC high power chargers are estimated to be installed. The number of chargers for the 2035 Scenario is slightly less because the chargers are timed to be installed when EVs of each type are first purchased. Because of suitability, several heavy-duty emergency vehicles are not scheduled for purchase until after 2035. The chargers planned for sites other than the six selected facilities include several fire stations, therefore eight high powered chargers will be required to support the heavy-duty emergency vehicles.

Table 44. Number of Chargers installed by type and site

Facility	L2 <20 kW chargers	DC 50 kW chargers	DC high power 150 kW chargers
Public Works Yard	100	26	0
City Hall Complex	113	2	0
GWP Utility Operations Center	141	24	0
Integrated Waste Yard	22	48	0
Fire Station 21	26	0	2
Police Parking Lot	95	0	136
Other Locations	122	3	8
TOTAL	**619**	**103**	**146**

100% EV Fleet by 2040

Table 45 provides the summary of costs at each facility for the 2040 Scenario, including the Acacia Station upgrade. The cost for the Acacia Station upgrade is split between the two facilities that it supplies, the Public Works Yard and Integrated Waste Yard. The analysis for the other locations includes the cost of chargers and installation needed for vehicles not located at one of the six selected facilities, however it does not include the initial cost of preparing the sites for adding chargers (design, stub outs, conduit, etc.). Total charging infrastructure costs are estimated to be nearly $71 million at a 1:1 ratio. The higher cost compared to the 2035 Scenario is due to inflation. Spreading out the installations through 2040 increases the cost for chargers and installation. This estimate represents a maximum cost scenario. Using a 2:1 ratio of chargers would lower the cost of installation and chargers significantly, saving an estimated $26.6 million.

Table 45. Summary of Charger and Installation Costs at Priority Sites, 2040

Facility	GWP Upgrades	Design	Charging Equipment	Installation	Total Costs by Facility
Public Works Yard	8,500,000	250,000	1,857,210	2,353,572	12,960,782
City Hall Complex	300,000	250,000	853,291	1,720,495	3,123,786
GWP Utility Operations Center	250,000	250,000	2,088,415	2,905,297	5,493,712
Integrated Waste Yard	8,500,000	250,000	2,211,462	1,783,230	12,744,692
Fire Station 21	225,000	250,000	439,995	538,020	1,453,015
Police Parking Lot	4,100,000	250,000	17,538,585	10,587,179	32,475,764
Other Locations			2,097,591	601,999	2,699,591
TOTAL	**21,875,000**	**1,500,000**	**27,086,549**	**20,489,792**	**70,951,341**

Total Cost, 2040 Scenario

Figure 85 provides the annual cost over time throughout the 2040 transition scenario, including the Acacia Station upgrade. For the analysis, CTE assumed the Acacia Station upgrade would occur over two years beginning in 2026. The actual construction timeline will be determined in collaboration with GWP. The first year of the scenario has the highest cost because as all selected facilities incur a full design and installation to prepare for approximately half the planned chargers. The second design build out for the individual facilities is spread over the years from 2031 through 2033. The remainder of this section outlines the cost for the 2040 Scenario by facility.

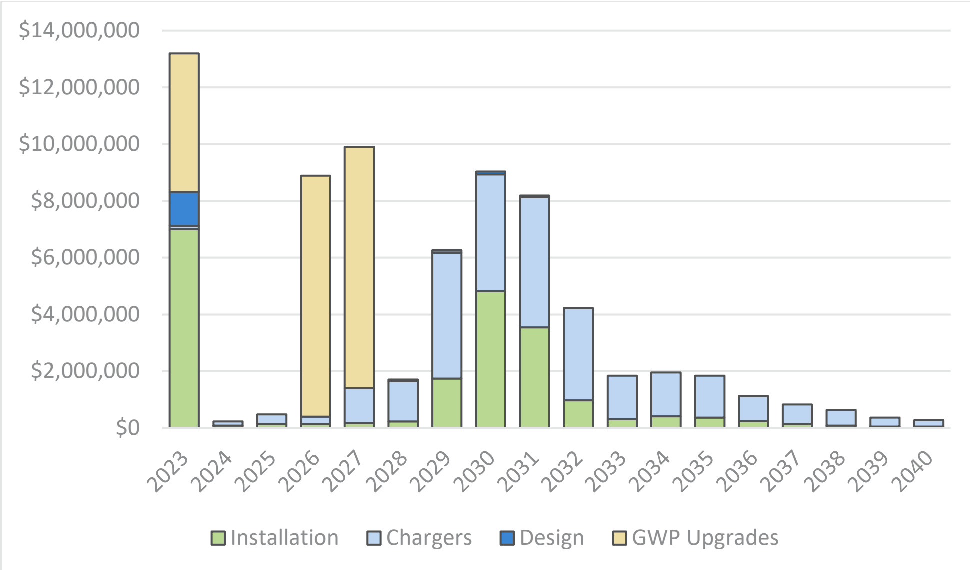

Figure 85. Total Infrastructure Costs for the 2040 Transition Scenario

Public Works Yard

Figure 86 shows the estimated annual infrastructure costs for the Public Works Yard. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2031. The Acacia Station upgrade in 2026-2027 results in significantly higher costs in those years compared to the rest of the transition timeline.

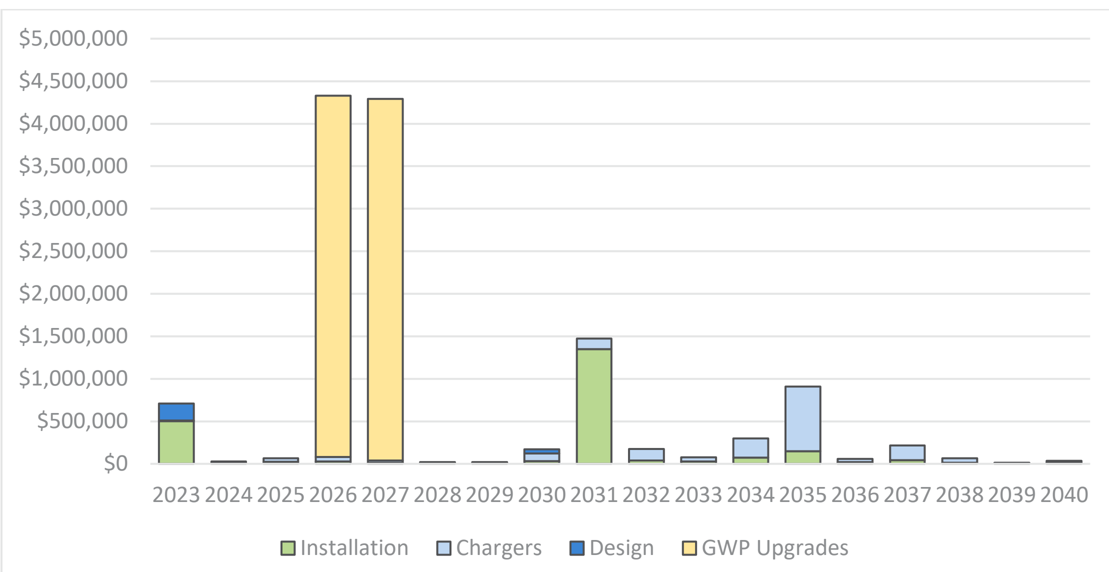

Figure 86. Annual Infrastructure cost for the Public Works Yard, 2040 Transition Scenario

City Hall Complex

Figure 87 shows the estimated annual infrastructure costs for the City Hall Complex. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2032.

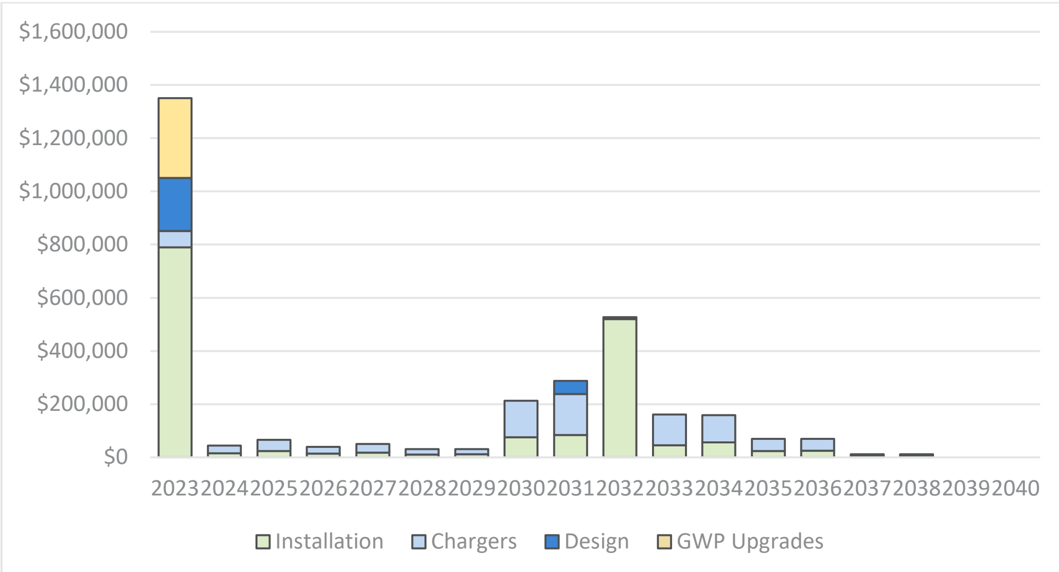

Figure 87. Annual Infrastructure cost for the City Hall Complex, 2040 Transition Scenario

GWP Utility Operations Center

Figure 88 shows the estimated annual infrastructure costs for the GWP Utility Operations Center. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2031.

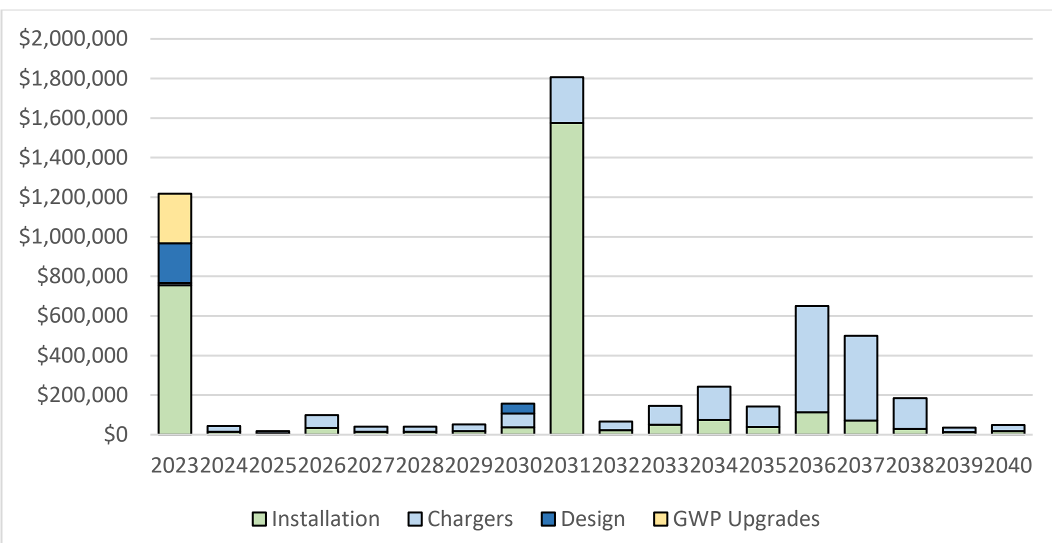

Figure 88. Annual Infrastructure cost for the GWP Utility Operations Center, 2040 Transition Scenario

Integrated Waste Yard

Figure 89 shows the estimated annual infrastructure costs for the Integrated Waste Yard. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2029. Half the cost of the Acacia Station upgrade is included in 2026 and 2027, resulting in significantly higher costs during those years.

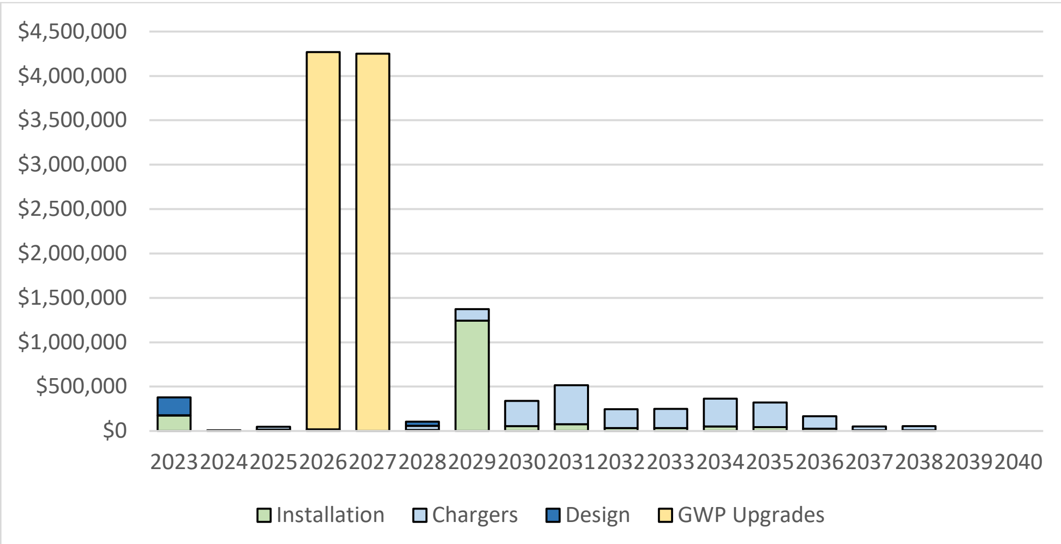

Figure 89. Annual Infrastructure cost for the Integrated Waste Yard, 2040 Transition Scenario

Fire Station 21

Figure 90 shows the estimated annual infrastructure costs for the Fire Station 21. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2030.

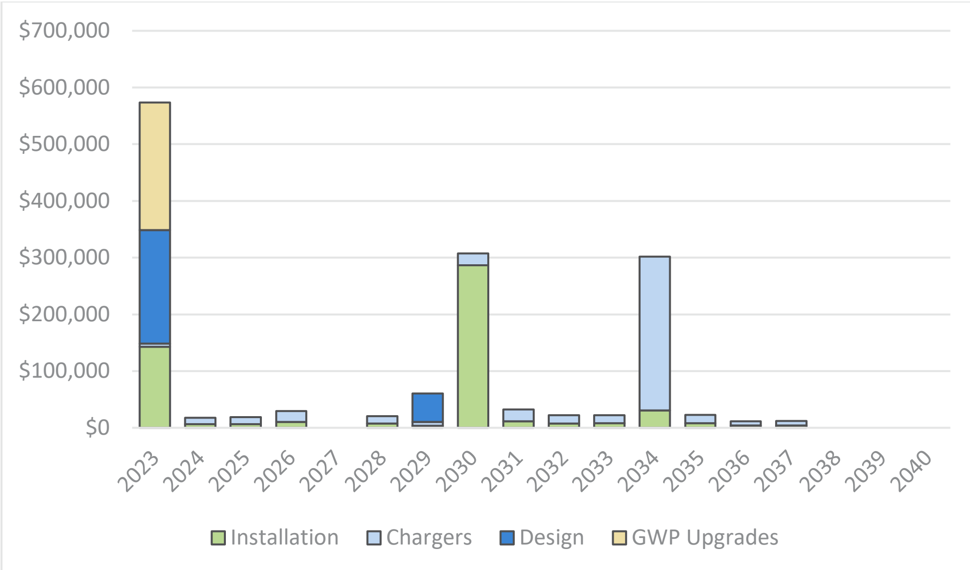

Figure 90. Annual Infrastructure cost for Fire Station 21, 2040 Transition Scenario

Police Parking Lot

Figure 91 shows the estimated annual infrastructure costs for the Police Parking Lot. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2030.

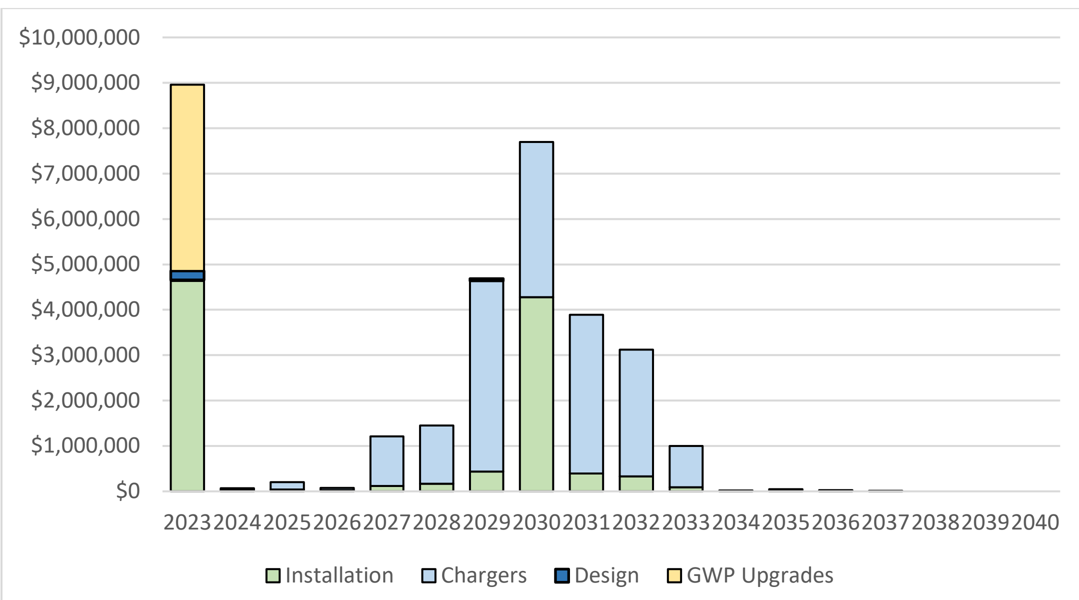

Figure 91. Annual Infrastructure cost for the Police Parking Lot, 2040 Transition Scenario

100% EV Fleet by 2035

Table 46 provides the summary of costs at each facility for the 2035 Scenario, including the Acacia Station upgrade. As with the 2040 Scenario, the cost for the Acacia Station upgrade is split between the two facilities that it supplies, the Public Works Yard and Integrated Waste Yard. The highest cost site is the Police Parking Lot, where chargers installed for the pursuit vehicles are DC 150 kW to meet the challenge of fast charging. Total charging infrastructure costs are estimated to be more than $66.8 million at a 1:1 ratio. This estimate represents a maximum cost scenario. Using a 2:1 ratio of chargers would lower the cost of installation and chargers significantly, saving an estimated $22.4 million.

Table 46. Summary of Charger and Installation Costs at Priority Sites, 2035

Facility	GWP Upgrades	Design	Charging Equipment	Installation	Total Costs by Facility
Public Works Yard	8,500,000	250,000	1,547,179	1,946,867	12,244,046
City Hall Complex	300,000	250,000	808,183	1,654,028	3,012,211
GWP Utility Operations Center	250,000	250,000	935,592	1,941,297	3,376,889
Integrated Waste Yard	8,500,000	250,000	2,064,200	1,703,968	12,518,168
Fire Station 21	225,000	250,000	423,723	501,590	1,400,313
Police Parking Lot	4,100,000	250,000	17,418,093	10,702,235	32,470,328
Other Locations			1,297,683	480,821	1,778,504
TOTAL	**21,875,000**	**1,500,000**	**24,494,653**	**18,930,806**	**66,800,459**

Total Costs, 2035 Scenario

Figure 92 provides the annual cost over time throughout the 2035 transition scenario, including the Acacia Station upgrade. As with the 2040 Scenario, CTE assumed the Acacia Station upgrade would occur over two years beginning in 2026. The first year of the scenario has the highest cost because all selected facilities incur a full design and installation of trenching, conduits, and stubbing out of approximately half the planned chargers. The second design build out for the individual facilities is spread over the years from 2028 through 2031. The remainder of this section outlines the cost by facility.

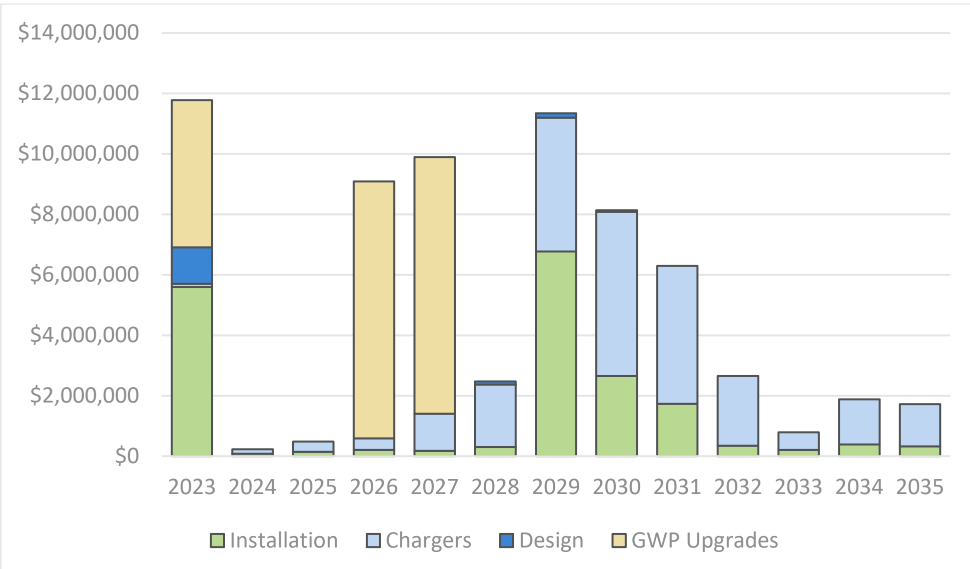

Figure 92. Total Infrastructure Costs for the 2035 Transition Scenario

Public Works Yard

Figure 93 shows the estimated annual infrastructure costs for the Public Works Yard. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2031. The individual chargers are spread out over the period to coincide with the delivery of the EVs.

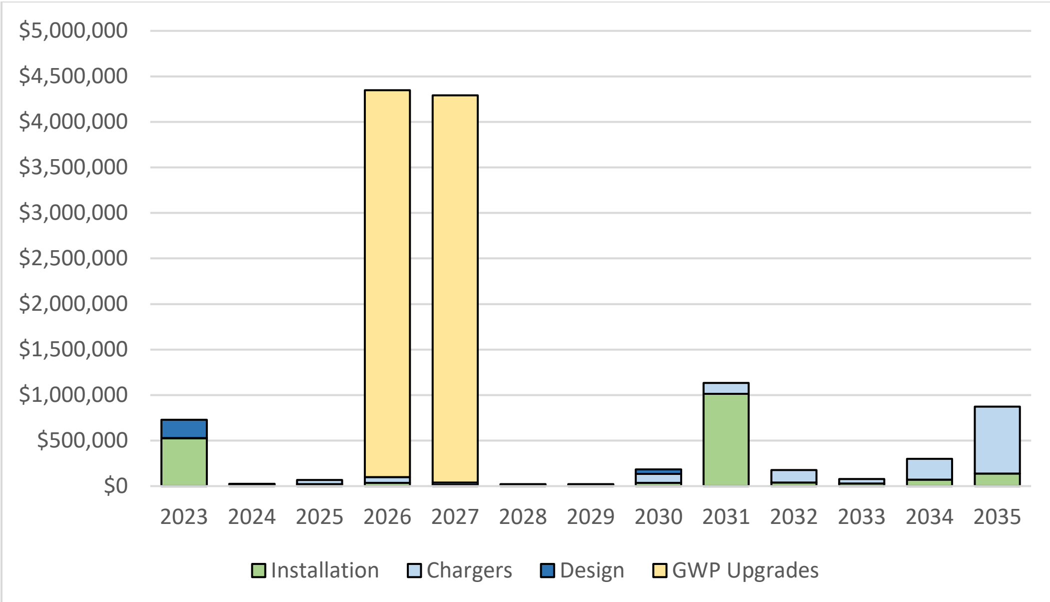

Figure 93. Annual Infrastructure cost for the Public Works Yard, 2035 Transition Scenario

City Hall Complex

Figure 94 shows the estimated annual infrastructure costs for the City Hall Complex. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2030.

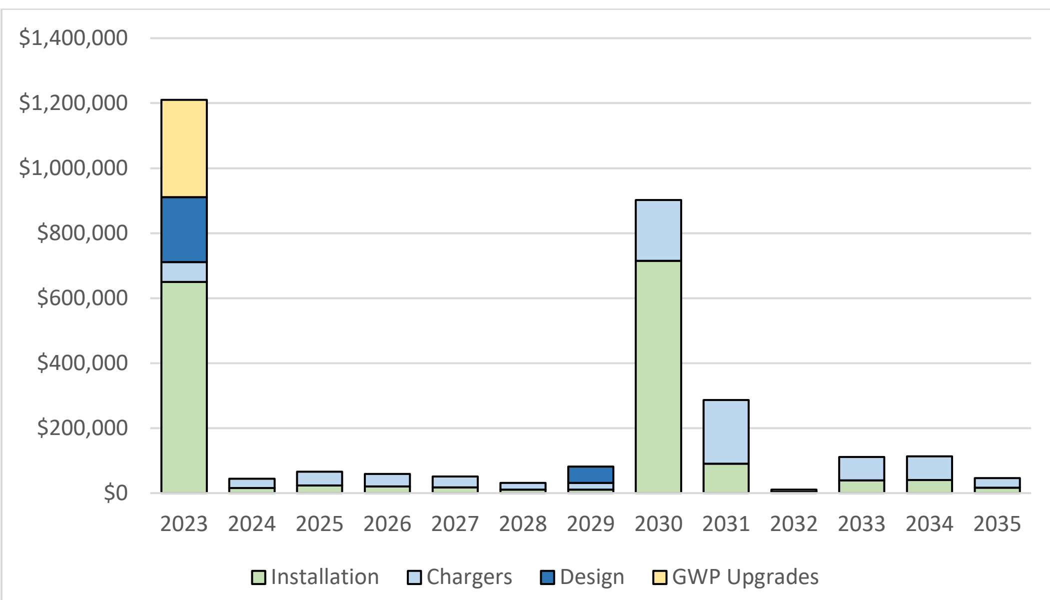

Figure 94. Annual Infrastructure cost for the City Hall Complex, 2035 Transition Scenario

GWP Utility Operations Center

Figure 95 shows the estimated annual infrastructure costs for the GWP Utility Operation Center. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2030.

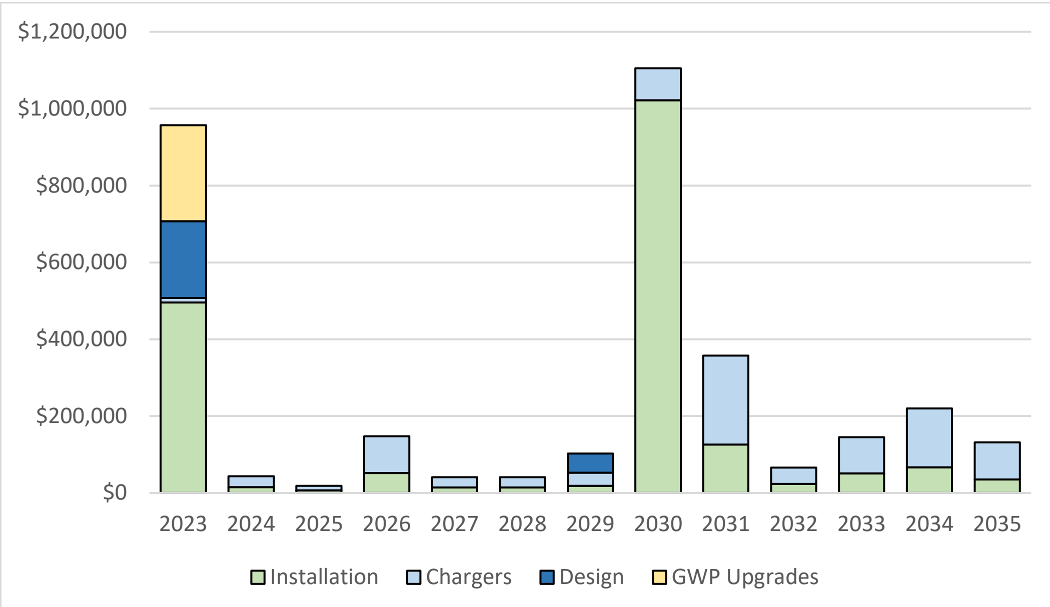

Figure 95. Annual Infrastructure cost for the GWP Utility Operations Canter, 2035 Transition Scenario

Integrated Waste Yard

Figure 96 shows the estimated annual infrastructure costs for the Integrated Waste Yard. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2029.

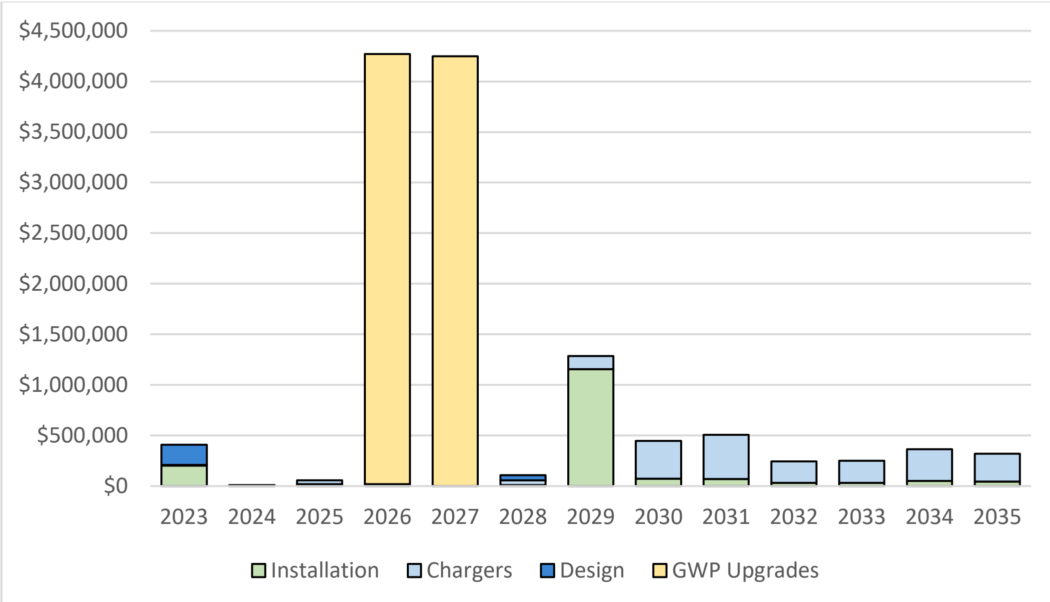

Figure 96. Annual Infrastructure cost for the Integrated Waste Yard, 2035 Transition Scenario

Fire Station 21

Figure 97 shows the estimated annual infrastructure costs for the Fire Station 21. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2030.

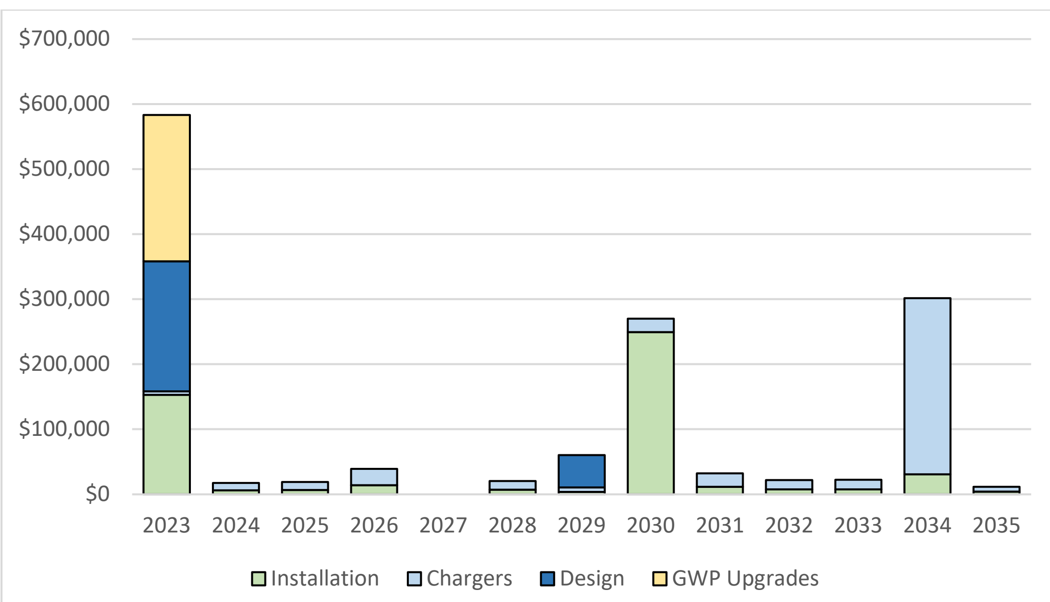

Figure 97. Annual Infrastructure cost for Fire Station 21, 2035 Transition Scenario

Police Parking Lot

Figure 98 shows the estimated annual infrastructure costs for the Police Parking Lot. Design Phase 1 happens during the first year and Phase 2 is scheduled for 2029.

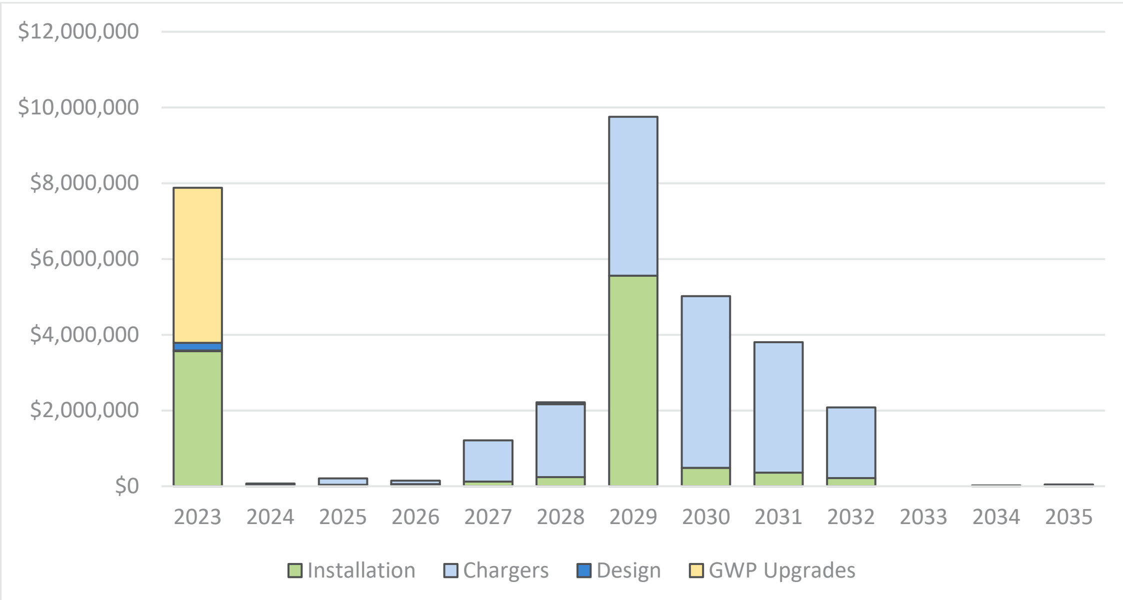

Figure 98. Annual Infrastructure cost for the Police Parking Lot, 2035 Transition Scenario

Fuel Assessment

The Fuel Assessment estimates fuel consumption and costs for electricity. This assessment calculates fuel costs using estimated annual energy requirements per vehicle and demand based on the number of chargers at each location for each year of the transition which are used as the basis for estimating cost under Glendale Water and Power's PC-1-B Time-of-Use Service Rate. CTE completed this analysis for the two zero-emission fleet transition scenarios: the 2035 target and 2040 target. The analysis produced estimates of the fuel costs for each projected fleet composition through the transition period. Operation and maintenance costs for charging infrastructure are also included. Fuel cost estimates are based on the assumptions shown in **Table 47.**

Table 47 - Fuel Cost Assumptions

Glendale Water and Power PC-1-B Time-of-Use Service Rate	Cost
Customer Charge - per meter per day	$5.8200
Energy Charges - per kWh	
<u>July through October (High Season)</u>	
Base Period *	$0.0714
Peak Period **	$0.2008
KVAR - Per kVar per day	$0.0040
Demand - Per kW (maximum kW reading for last 12 months) per day	$0.8200
<u>November through June (Low Season)</u>	
Base Period *	$0.0714
Peak Period ***	$0.1163
KVAR - Per kVar per day	$0.0040
Demand - Per kW (maximum kW reading for last 12 months) per day	$0.5800

* Base Period: All other times, including all weekend hours and all Holidays
** High Season Peak Period: 2:00 p.m. - 7:59 p.m., Monday - Friday (excluding Holidays)
*** Low Season Peak Period: 12:00 p.m. - 8:59 p.m., Monday - Friday (excluding Holidays)

The primary source of energy for an EV is often the local electrical grid. Glendale Power and Water is the electricity provider, or utility, for the city. Glendale Power and Water charges customers for energy consumption, measured in kWh, using a time-of-use (TOU) rate. Under a TOU rate, the cost per kWh of electricity varies by time of day with overnight rates being the lowest in the daily cycle.

Demand charges are the costs incurred by an agency's peak power demand. Peak demand is defined as the maximum amount of energy that a customer pulls from the grid for any 15-minute window within a month. Demand charges are then applied on a per-kW basis to that maximum demand. Demand charges are applied to the maximum estimated demand at each location. Demand is driven by the power and number of chargers since a higher power charger will pull more power from the grid and more chargers operating simultaneously will also pull more power than a single charger. For example, a 150kW charger will create more demand than a 50kW charger and three 50kW chargers operating simultaneously would create more demand than a single 50kW charger.

As Glendale adds more vehicles and chargers, the energy consumption and the peak power demand both increase. Electricity rates also vary throughout the year and throughout the day, making costs highly variable if charging is not managed. Charge management strategies aim to minimize charging costs by taking advantage of this variability. Charge management strategies include charging vehicles during times of day at which rates are lower and avoiding demand charges by spreading out the number of vehicles charging at once to minimize increases in peak power demand. For this reason, CTE assumes that Glendale will charge vehicles only overnight to avoid higher charges during the day. The one exception to this is the Police vehicle charging, which is expected to occur evenly throughout all hours of the day due to the vehicle demands. CTE's analysis also assumes that no more than 50% of Glendale's fleet will ever be charging at a given time to help reduce demand costs. The effect of increasing or decreasing the number of vehicles allowed to charge simultaneously can be seen in **Figure 99**(2040 Scenario) and **Figure 100** (2035 Scenario).

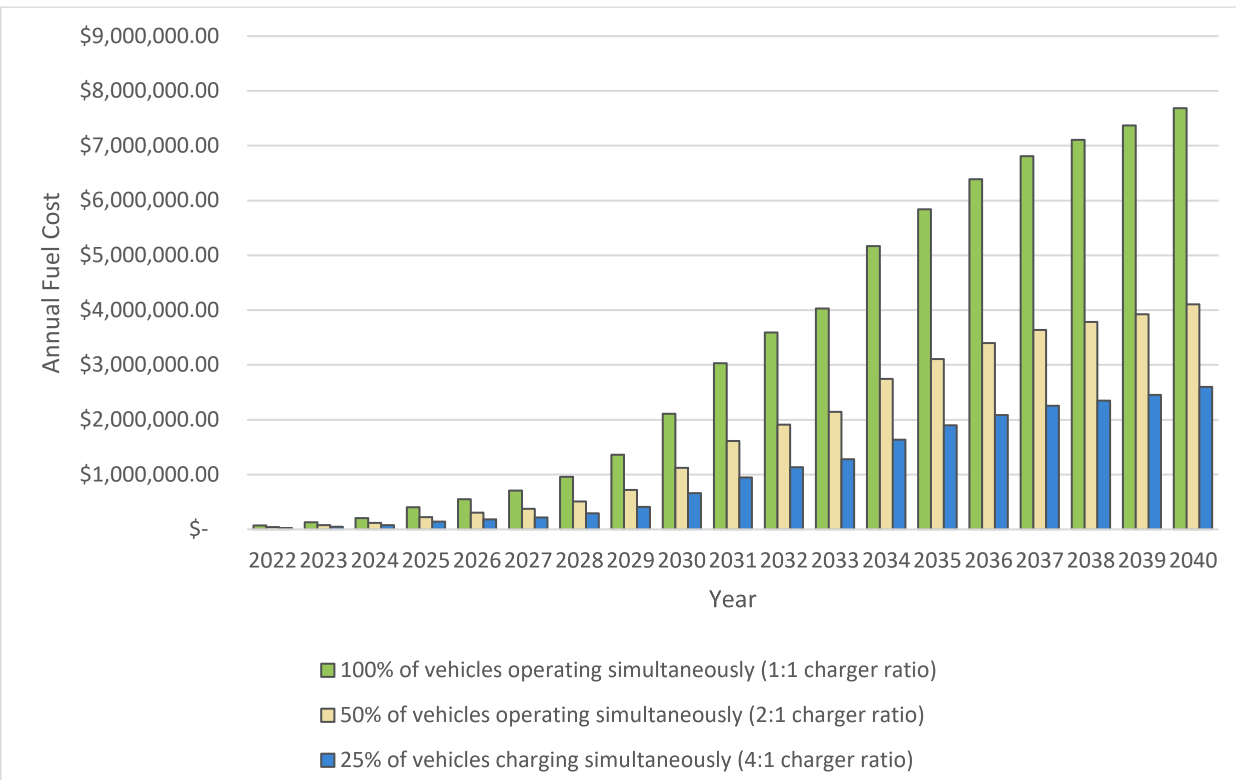

Figure 99. Vehicle to Charger Ratio Cost Impact, 2040 Transition Scenario

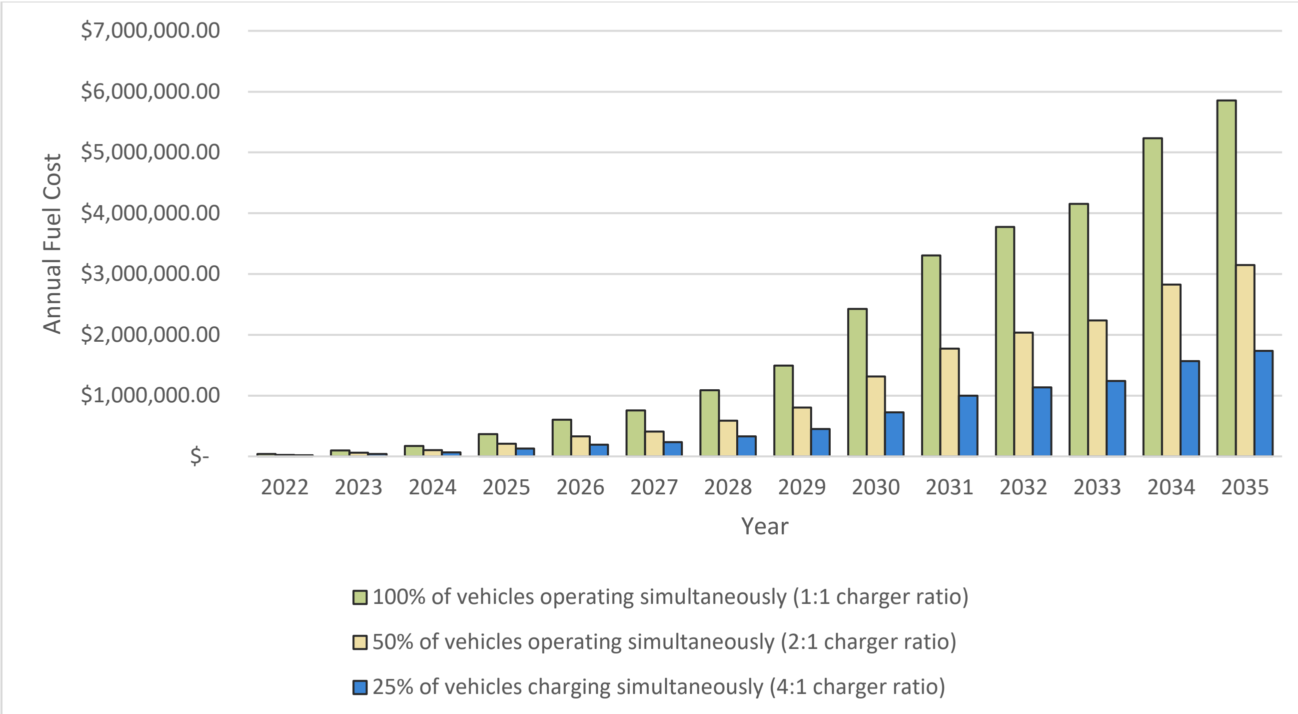

Figure 100. Vehicle to Charger Ratio Cost Impact, 2035 Transition Scenario

Total Fuel Cost

Figure 101 shows the total annual expense to charge the municipal EV fleet over time across all charging locations. By these estimates, annual expenses will increase from the present annual cost of around $20 thousand to $2.7 million per year in 2040. **Figure 102** shows the total annual expense to charge the fleet for the 2035 Scenario. By these estimates, annual expenses will increase from the present annual cost of around $26 thousand to $2.6 million per year in 2035.

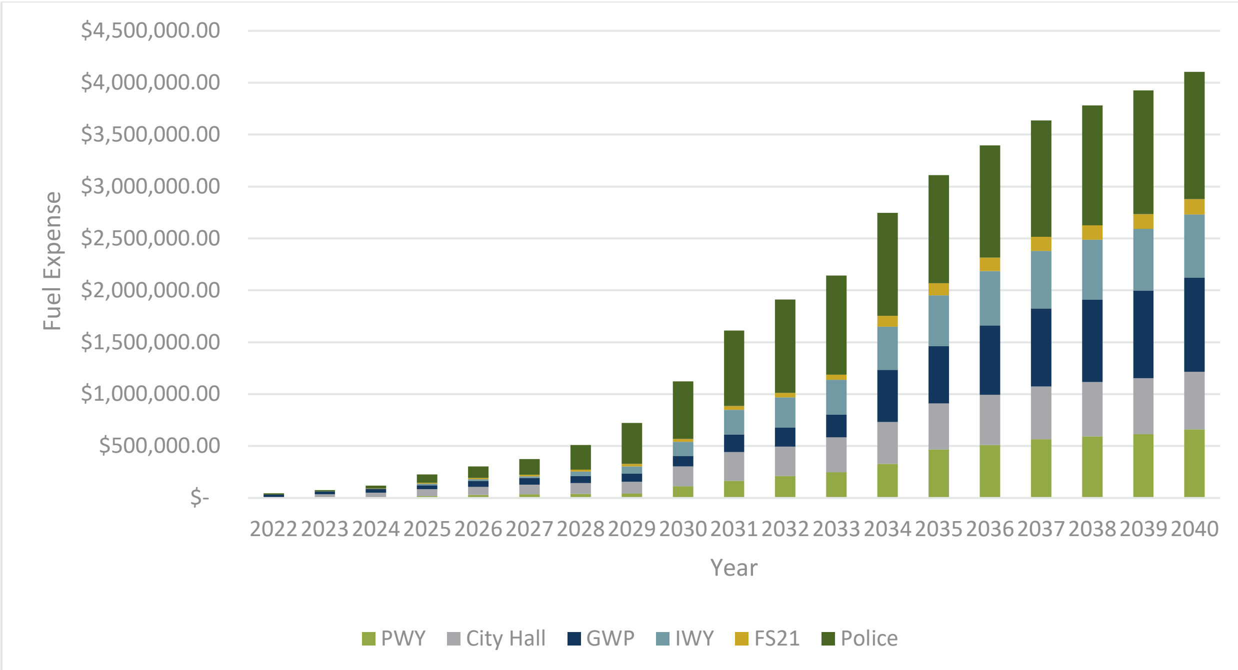

Figure 101. Glendale Annual Fuel Costs, 2040 Scenario

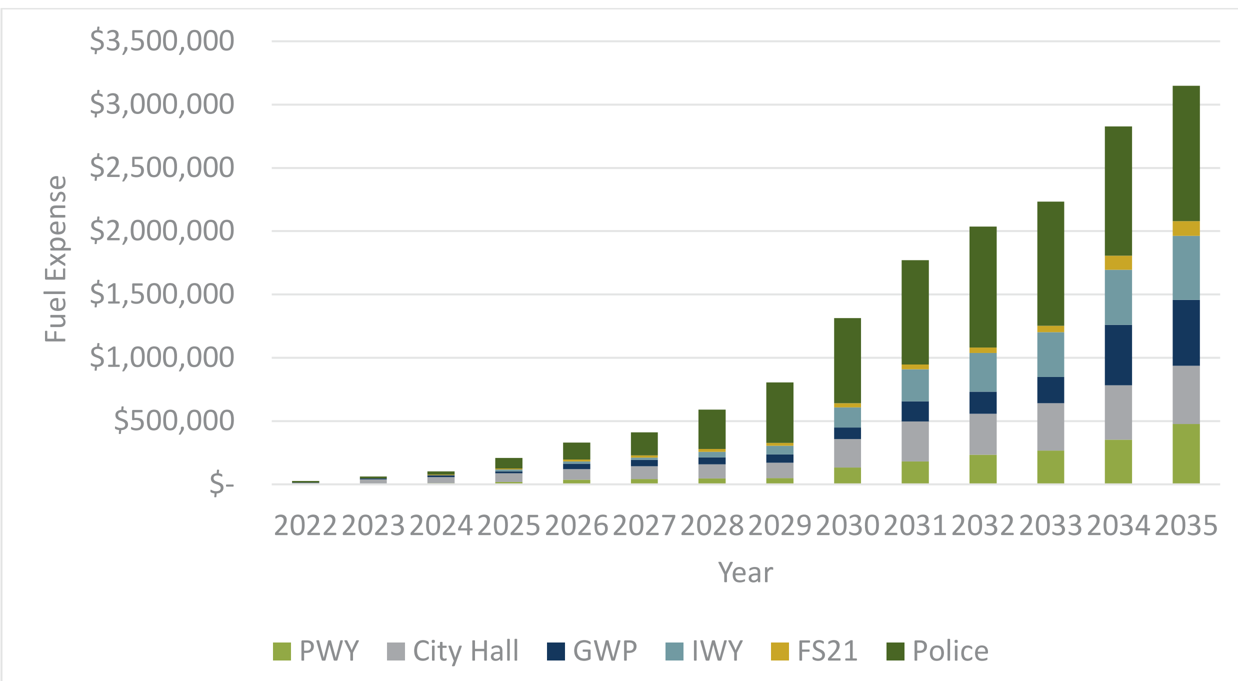

Figure 102. Glendale Annual Fuel Costs, 2035 Scenario

EVs are generally at least four times as efficient as ICEs. However, while generally favorable, the cost of electricity can sometimes be higher than fossil fuels. Utility rates vary significantly across the county based on generation mix and local demand. With proper planning, fleets can take advantage of low utility rates by charging overnight during off-peak hours. We've estimated the impact of each scenario using electricity as a fuel instead of fossil fuel, as shown below in **Figure 103, Figure 104, Figure 105,** and **Figure 106.**

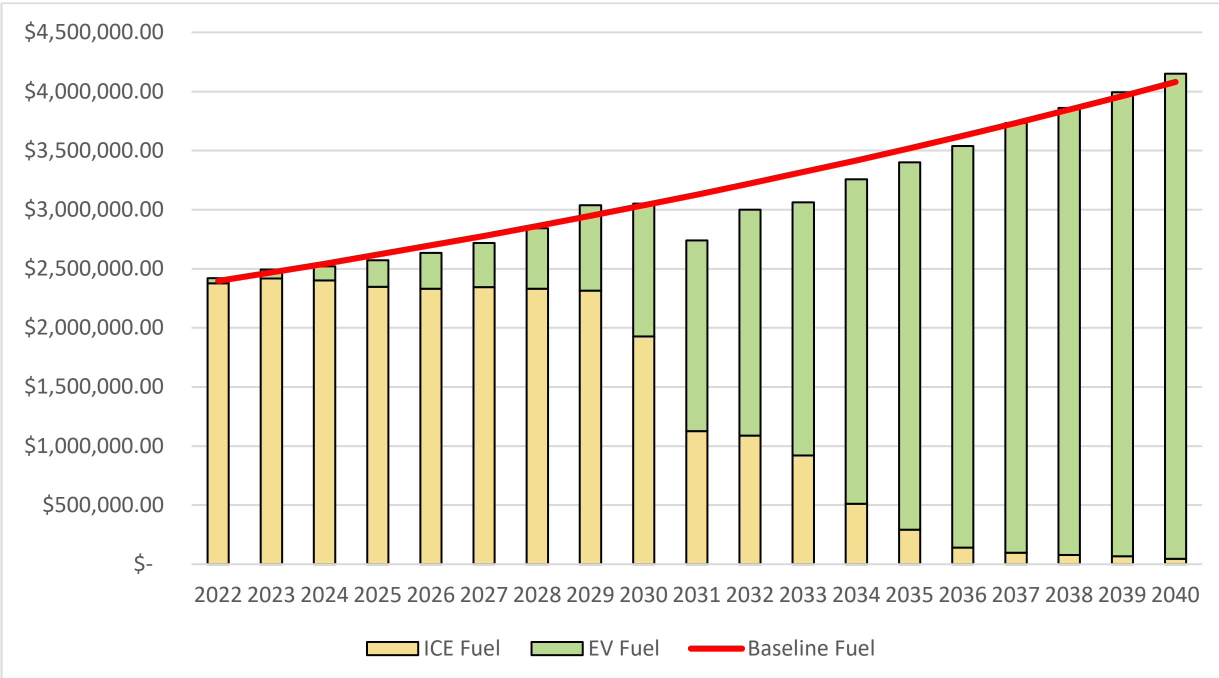

Figure 103. Annual Fuel Cost vs. Baseline, 2040 Scenario

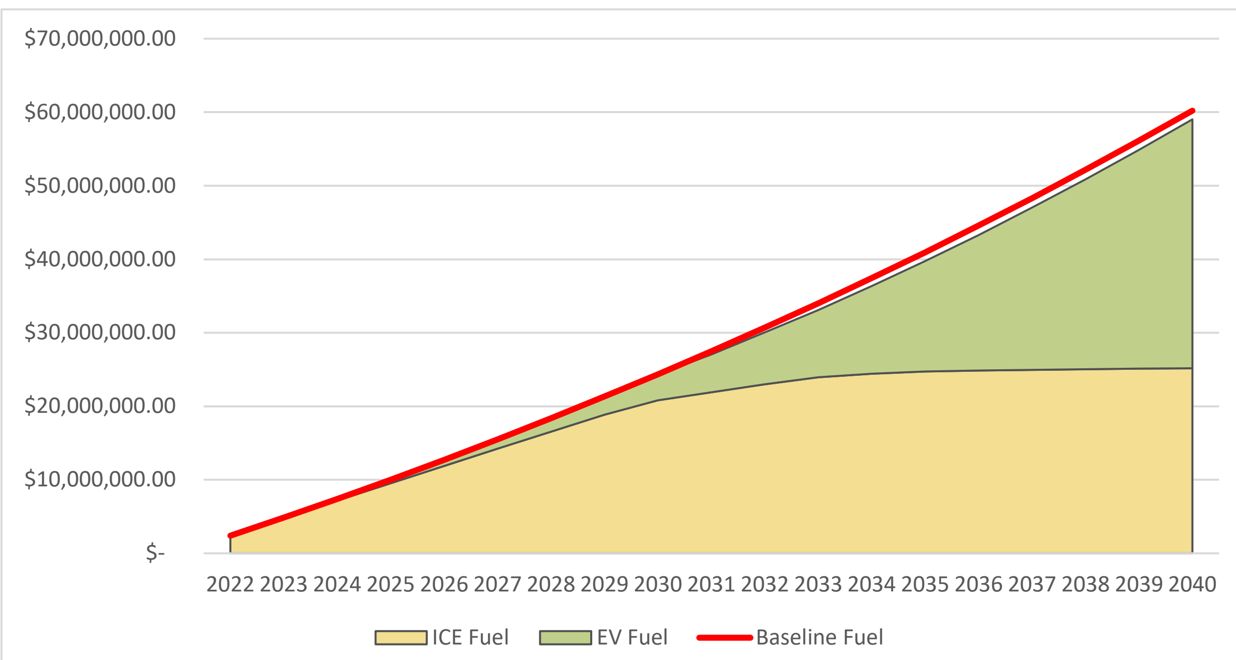

Figure 104. Cumulative Fuel Cost vs. Baseline, 2040 Scenario

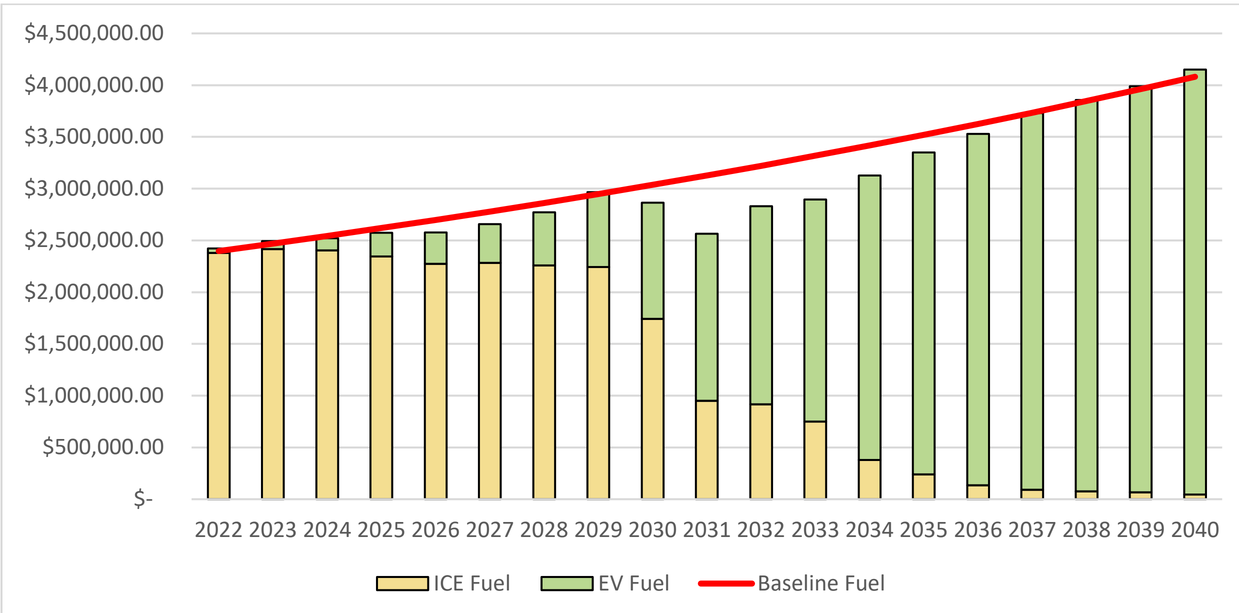

Figure 105. Annual Fuel Cost vs. Baseline, 2035 Scenario

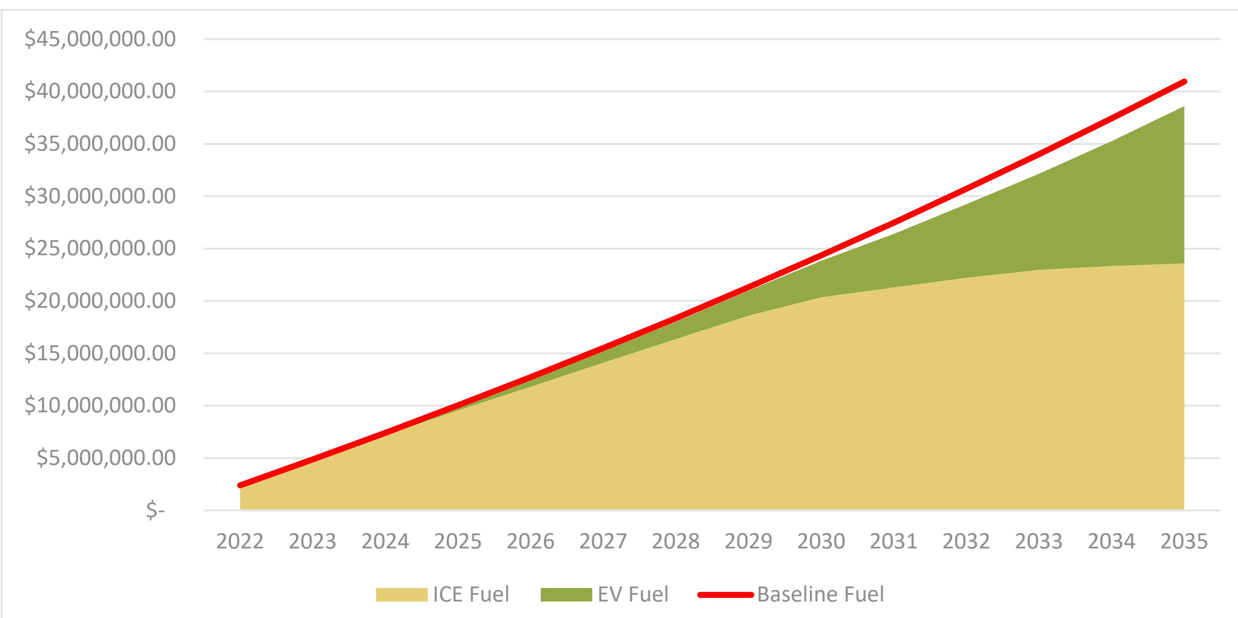

Figure 106. Cumulative Fuel Cost vs. Baseline, 2035 Scenario

Charging Analysis

To accurately estimate energy consumption, peak power demand, and resultant costs, CTE conducted simulations of charging at each location for each year of the transition. Electrical energy consumption and peak power demand were estimated based on current annual energy requirements by vehicle and projections of EV purchases. CTE then used Glendale Power and Water's tariff schedules to calculate the annual cost of charging. This annual cost is evaluated for each year of the study (2022–2040) to obtain a total charging cost of vehicles for the transition period. This estimate of total charging cost is used as the total fuel cost for the growing number of battery-electric vehicles in the municipal fleet over time.

The results of CTE's analysis are presented as a series of graphs, the first of which is the Facility Consumption graph, which demonstrates how the annual energy consumption increases over time as more vehicles are electrified. This energy consumption represents the amount of energy consumed by the vehicles as fuel.

Next, the Facility Demand graph for each location illustrates the demand at each location increasing over time as more chargers are added to support the increasing number of EVs. As previously mentioned, demand is dependent on the quantity and power of chargers at the location. For this reason, the demand is broken out by charger power to illustrate the proportion of the demand that can be attributed to each charger type. Under Glendale Water and Power's PC-1-B Time-of-Use Service Rate, demand is a large component of the costs associated with the rate and managing demand is very important for managing electricity costs. These graphs present the demand under a 2:1 charger ratio, meaning that two vehicles are assumed to use the same charger or that half of the vehicles ever charge at one time. In this way, the demand is cut in half to help manage costs. The facilities assessment assumes a 1:1 charger ratio, so the assumption is that charge management will be used to manage demand by limiting the number of chargers that can operate simultaneously.

Finally, the third graph presents the combined costs of the energy consumed and demand, as well as the meter costs and charger maintenance, which is estimated at $2,800 per charger per year. The costs are broken out by the costs associated with demand from the various charger types and the costs incurred through consumption.

2040 Transition Scenario

In the 2040 scenario, EVs are purchased and deployed according to the schedules outlined in the fleet assessment with the goal of transitioning the municipal fleet to zero-emission vehicles by 2040 as the required vehicle types become commercially available. The estimated energy consumption, demand and cost associated with each location are summarized in the figures below. This information is broken out into three separate graphs for each location.

Public Works Yard

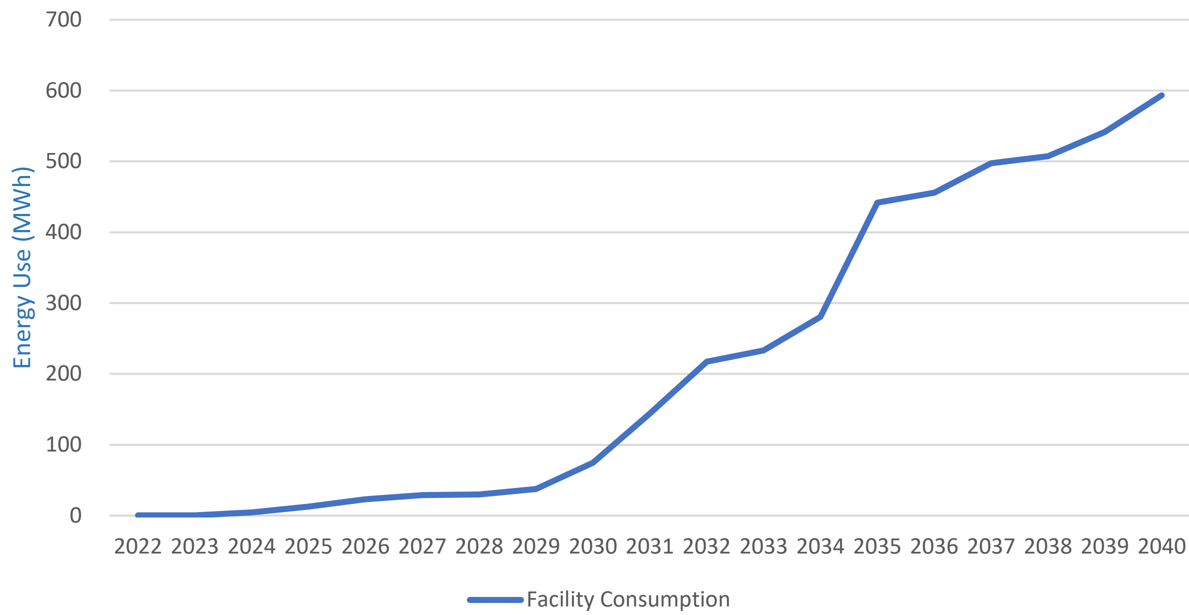

Figure 107. Public Works Yard Annual Electricity Consumption, 2040 Transition Scenario

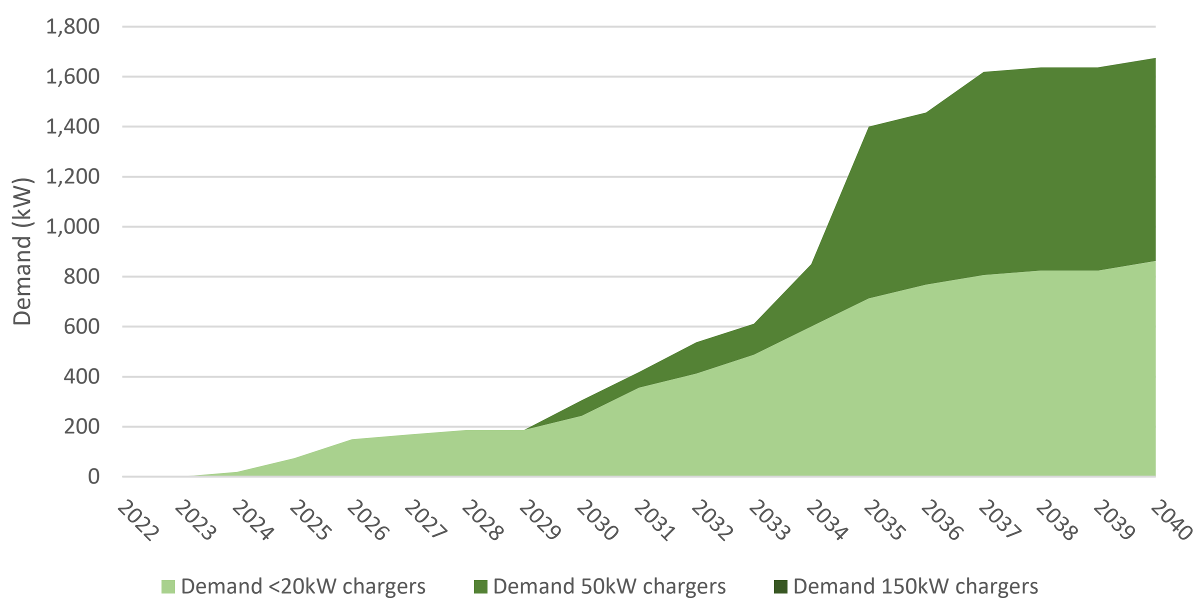

Figure 108. Public Works Yard Annual Electricity Demand, 2040 Transition Scenario

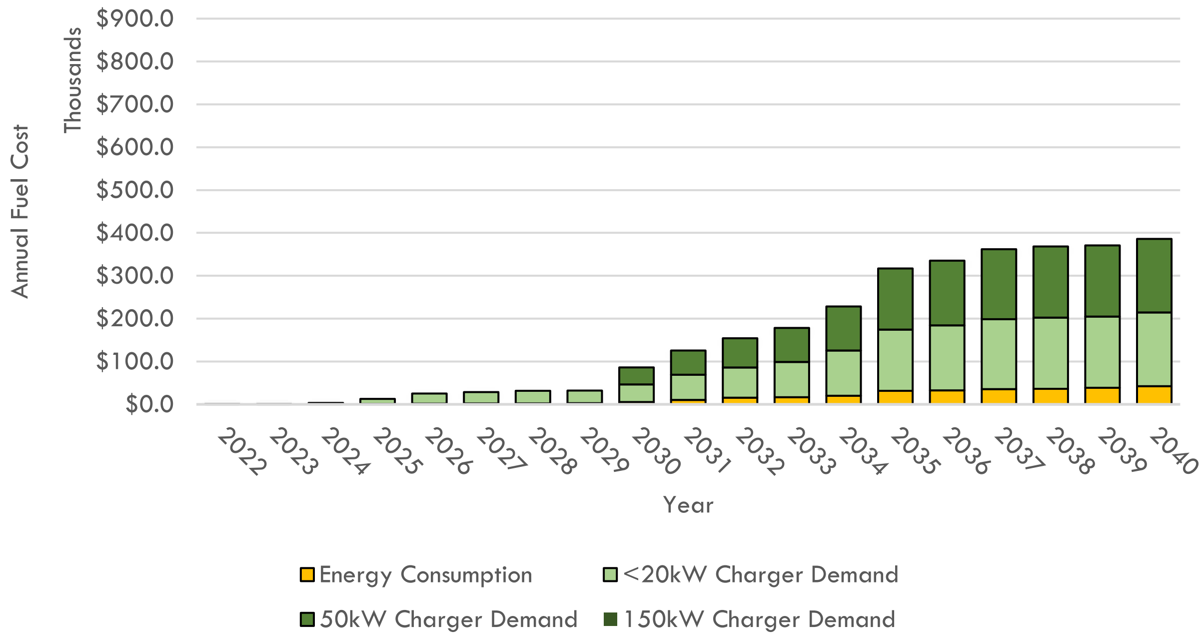

Figure 109. Public Works Yard Annual Electricity Cost, 2040 Transition Scenario

City Hall

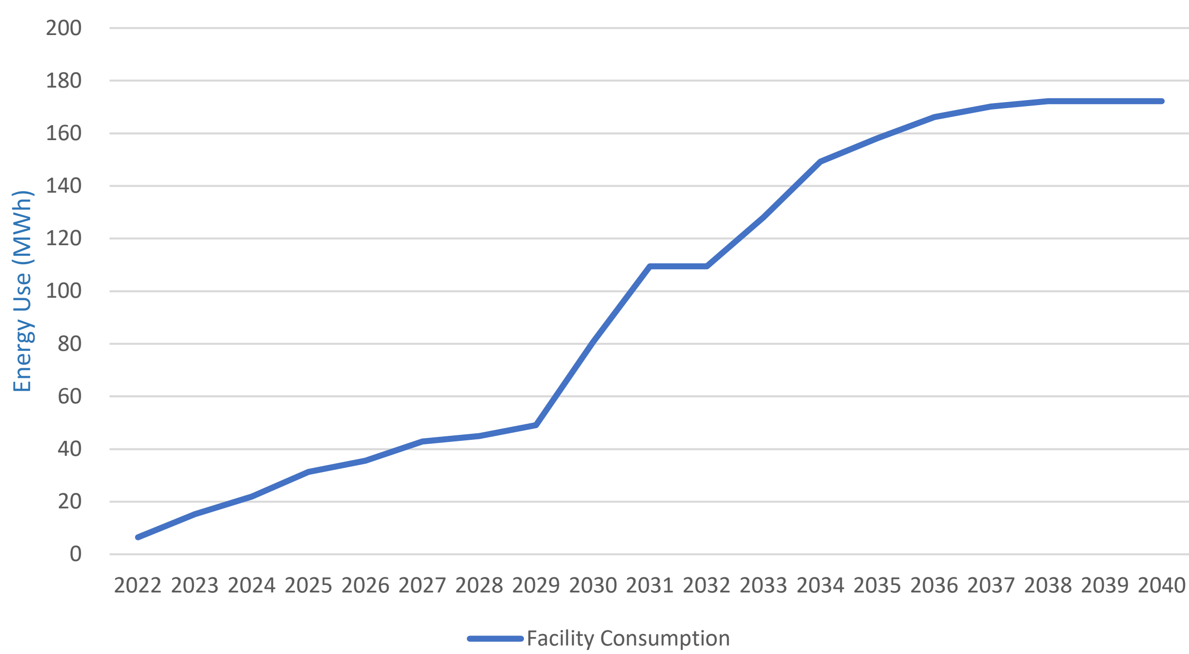

Figure 110. City Hall Annual Electricity Consumption, 2040 Transition Scenario

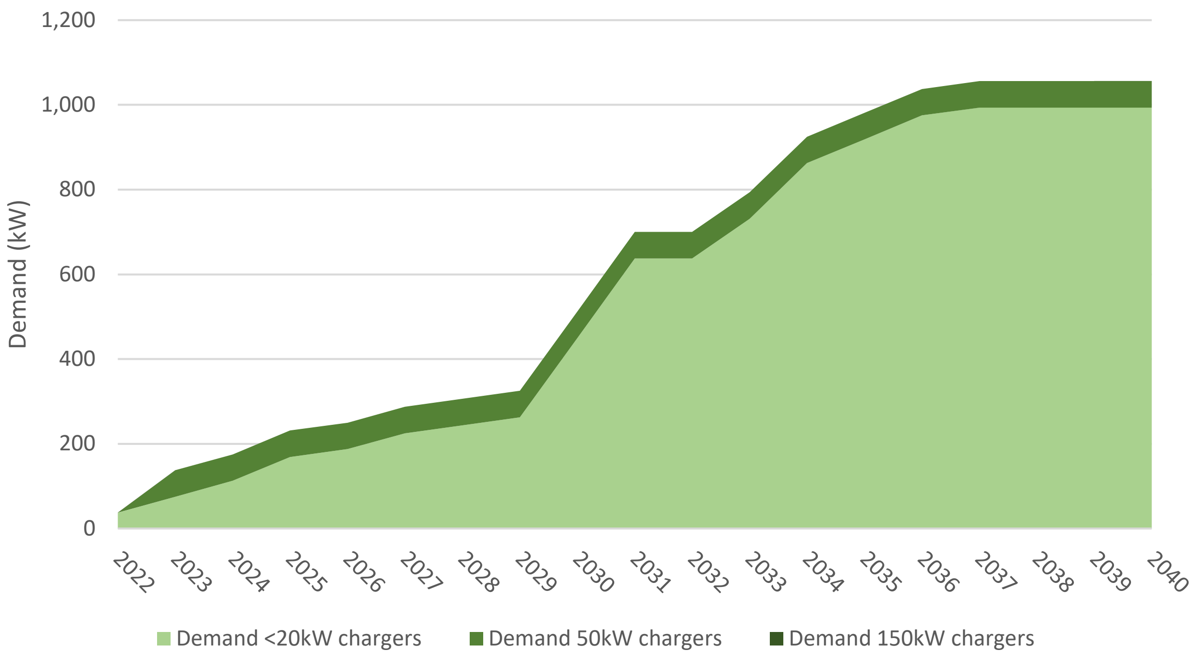

Figure 111. City Hall Annual Electricity Demand, 2040 Transition Scenario

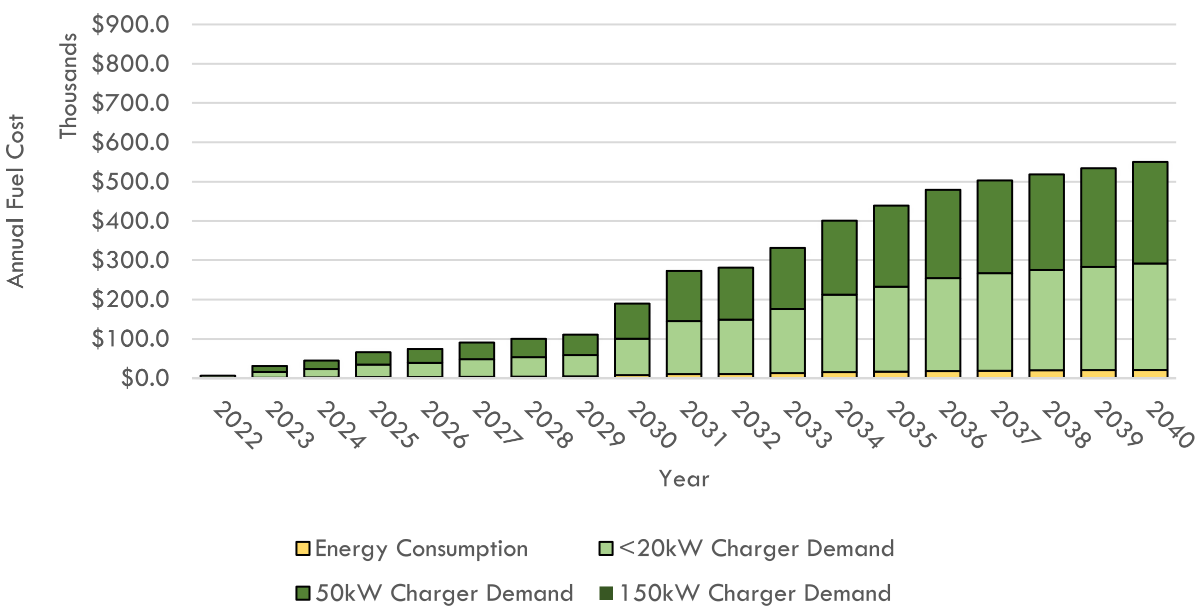

Figure 112. City Hall Annual Electricity Cost, 2040 Transition Scenario

GWP Ops Center

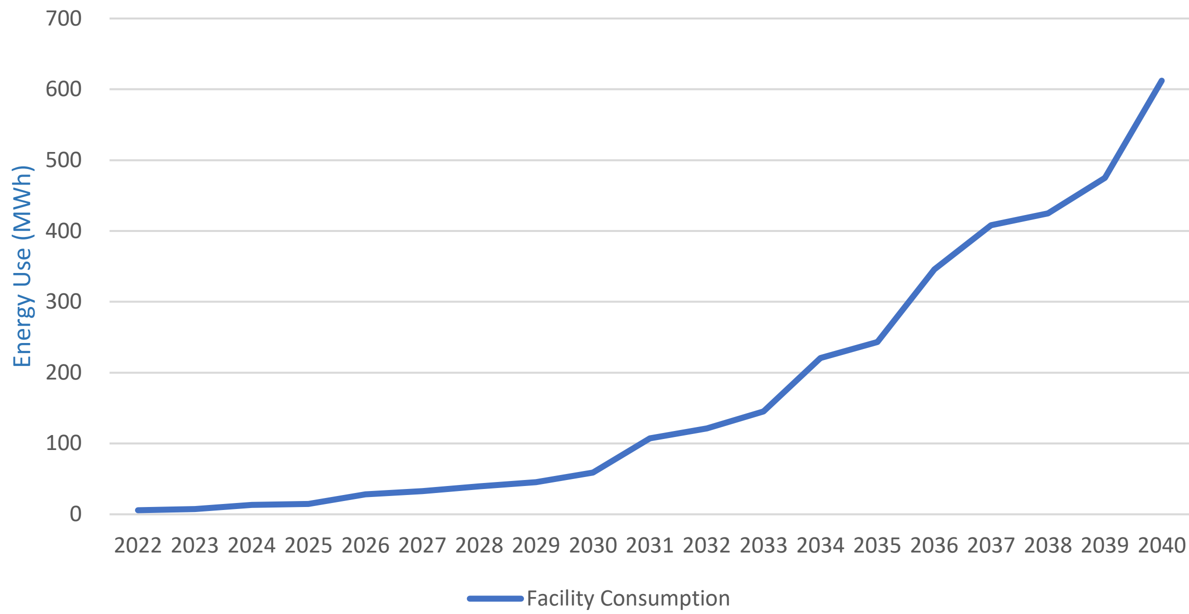

Figure 113. GWP Ops Center Annual Electricity Consumption, 2040 Transition Scenario

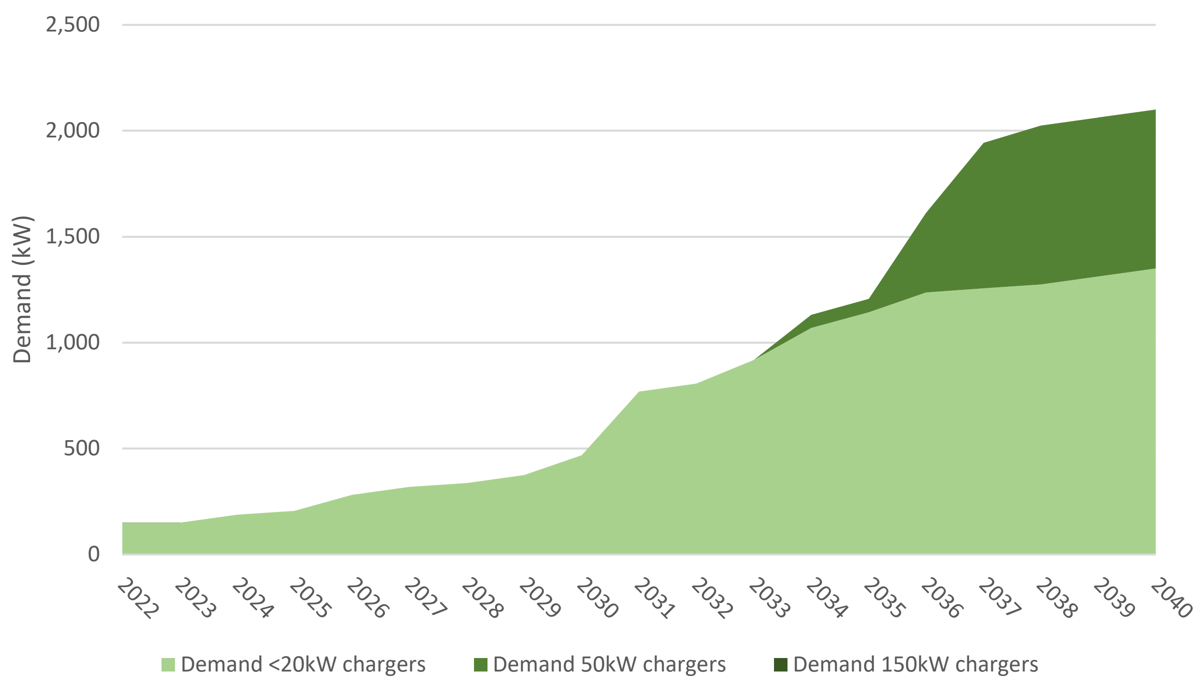

Figure 114. GWP Ops Center Annual Electricity Demand, 2040 Transition Scenario

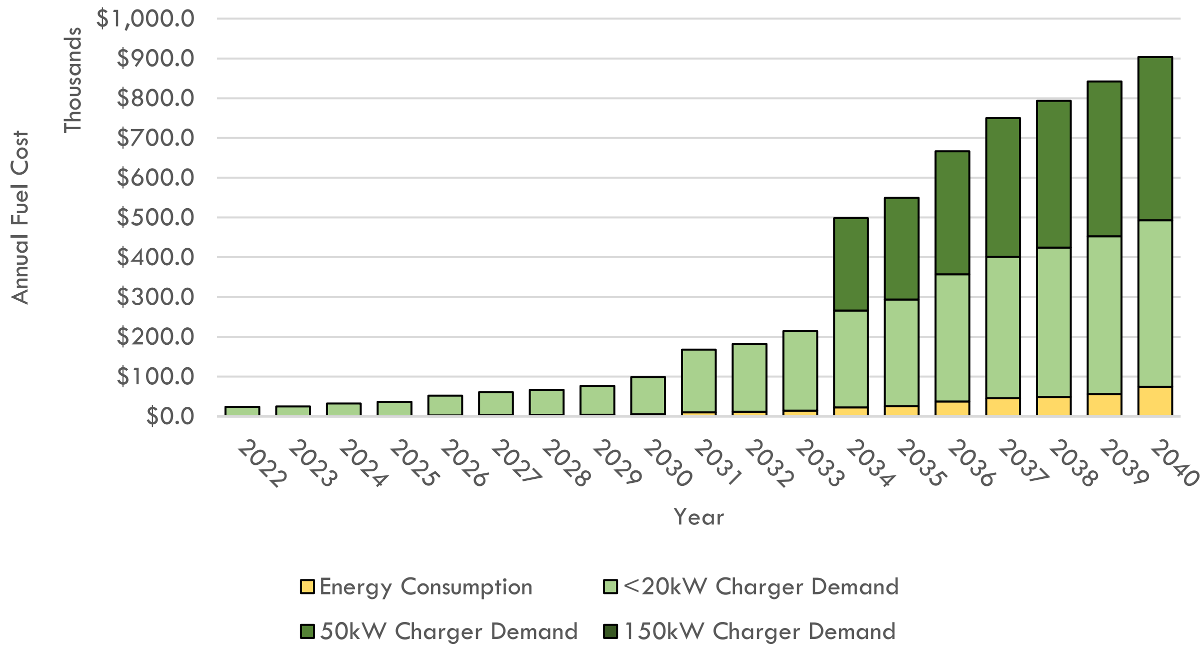

Figure 115. GWP Ops Center Annual Electricity Cost, 2040 Transition Scenario

Integrated Waste Yard

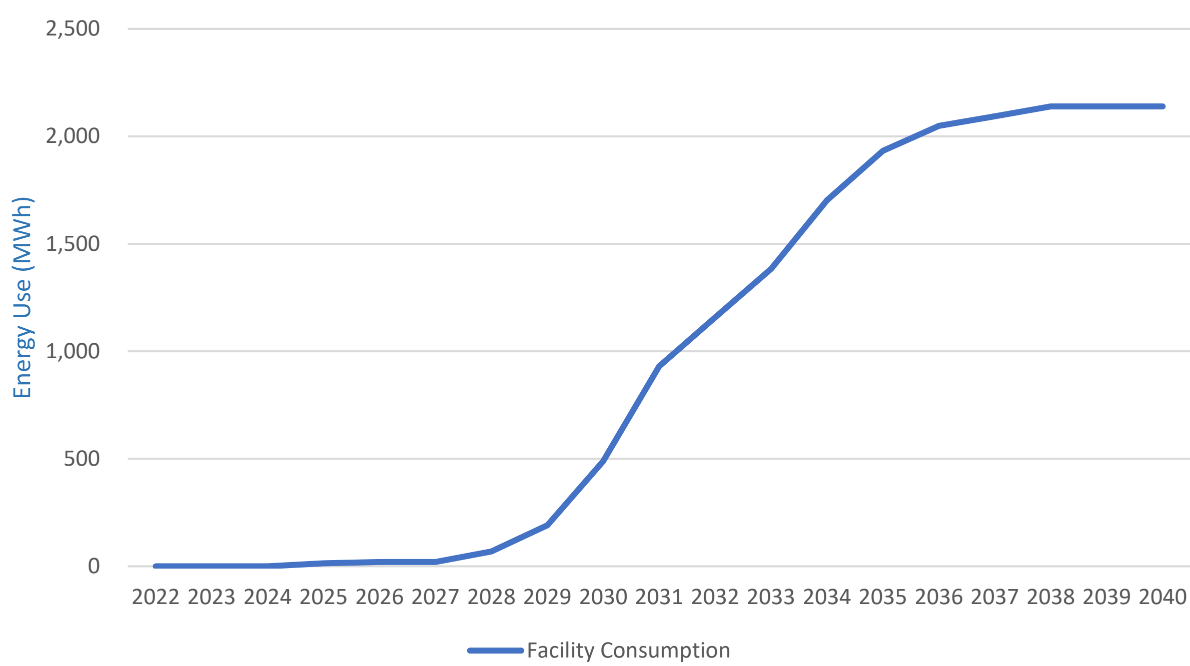

Figure 116. Integrated Waste Yard Annual Electricity Consumption, 2040 Transition Scenario

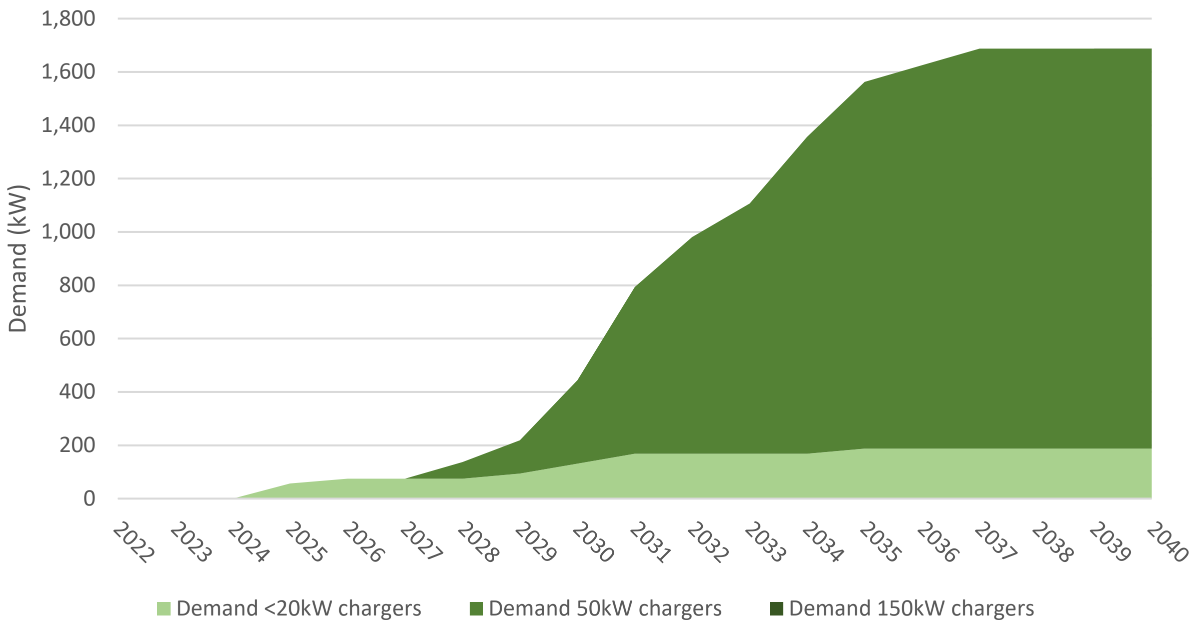

Figure 117. Integrated Waste Yard Annual Electricity Demand, 2040 Transition Scenario

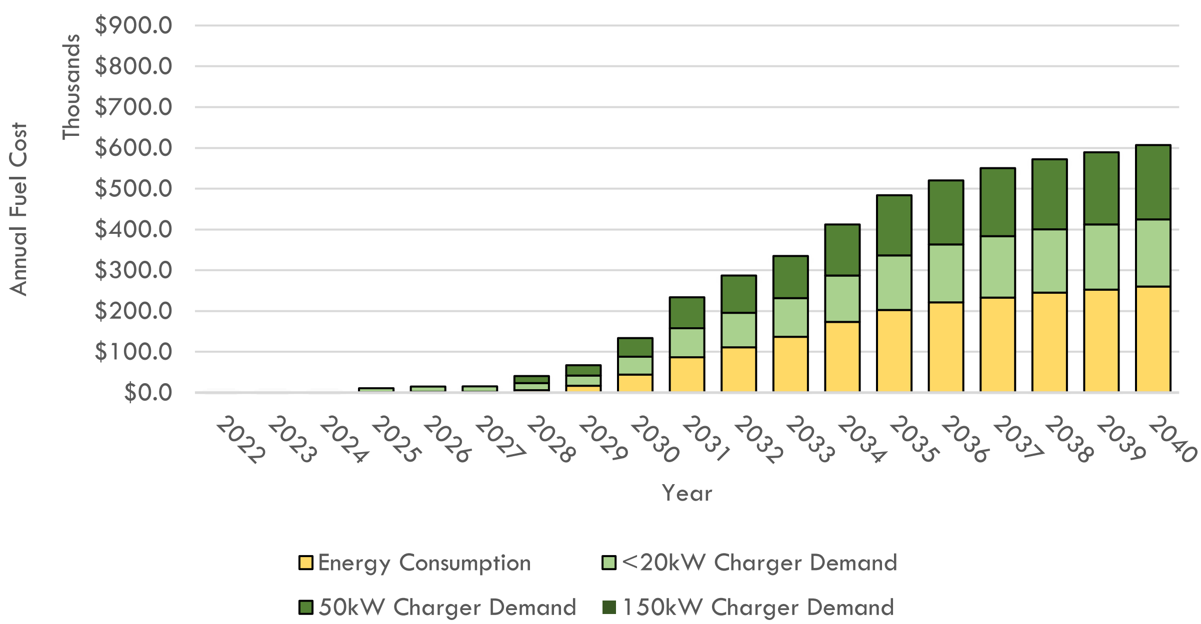

Figure 118. Integrated Waste Yard Annual Electricity Cost, 2040 Transition Scenario

Fire Station 21

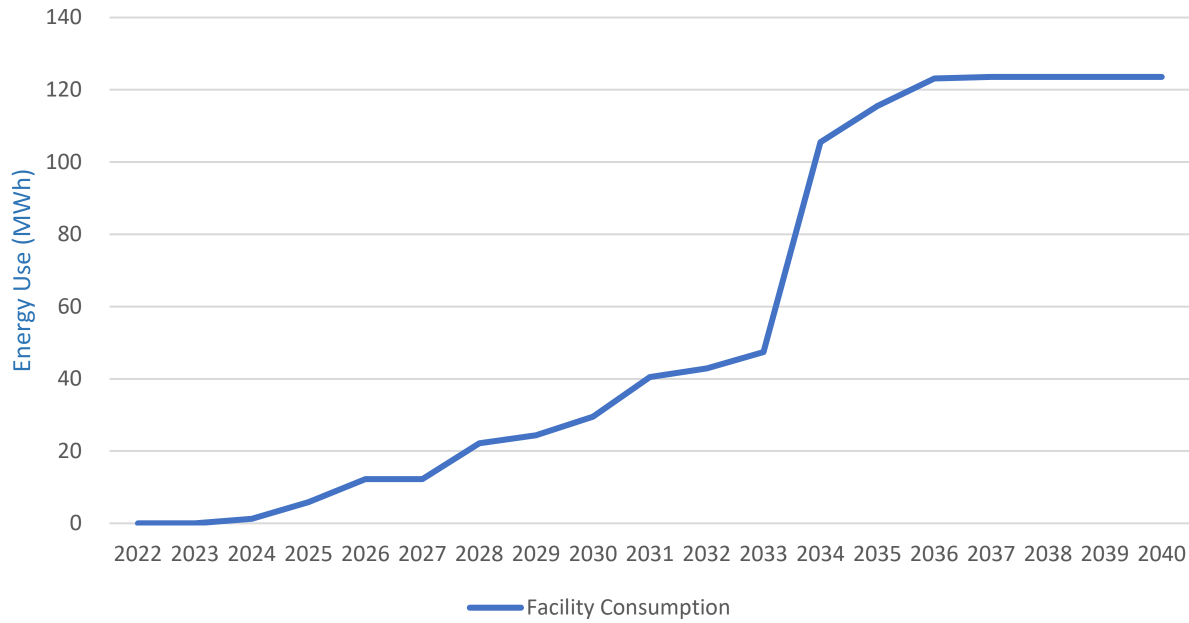

Figure 119. Fire Station 21 Annual Electricity Consumption, 2040 Transition Scenario

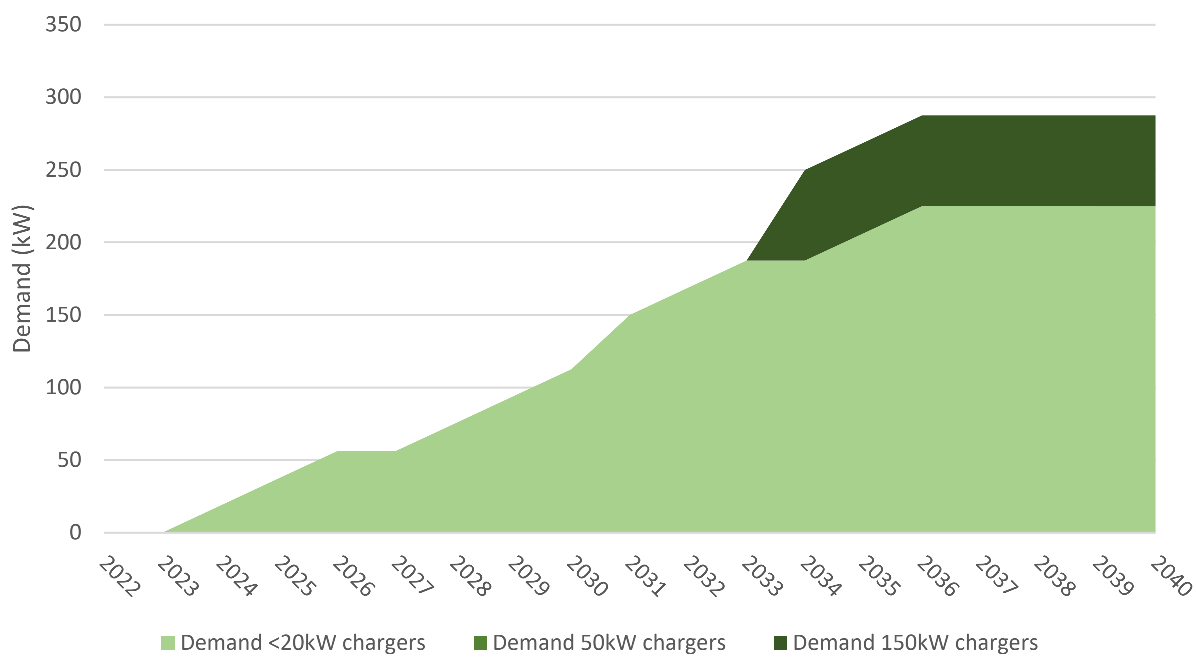

Figure 120. Fire Station 21 Annual Electricity Demand, 2040 Transition Scenario

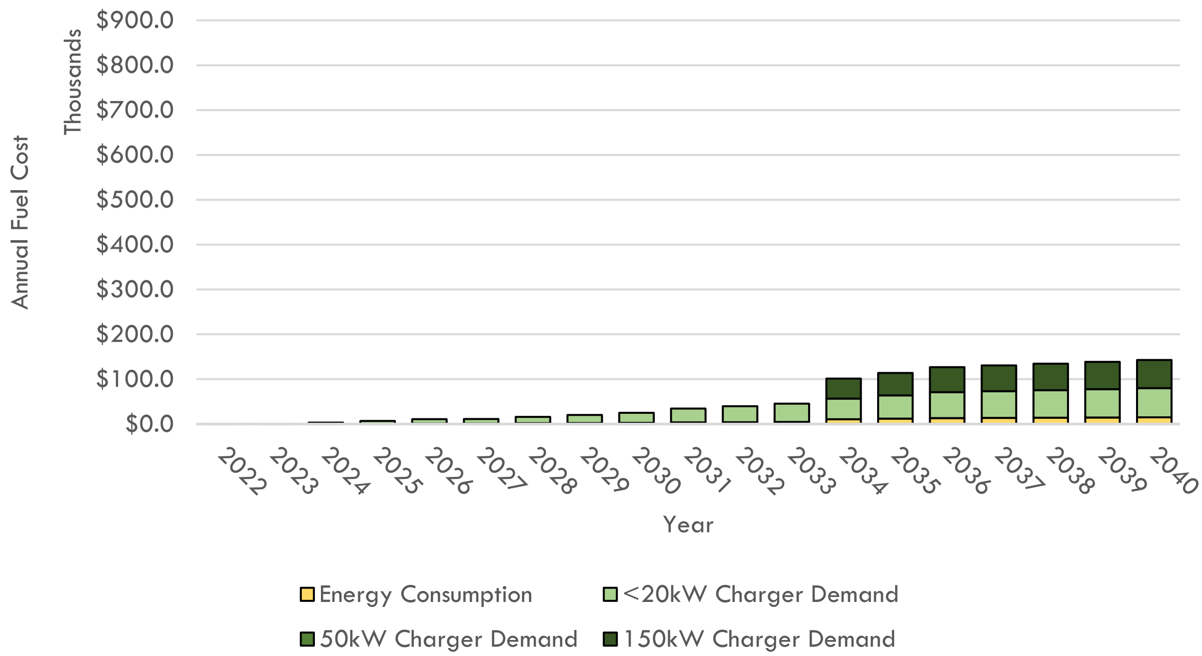

Figure 121. Fire Station 21 Annual Electricity Cost, 2040 Transition Scenario

Police Parking Lot

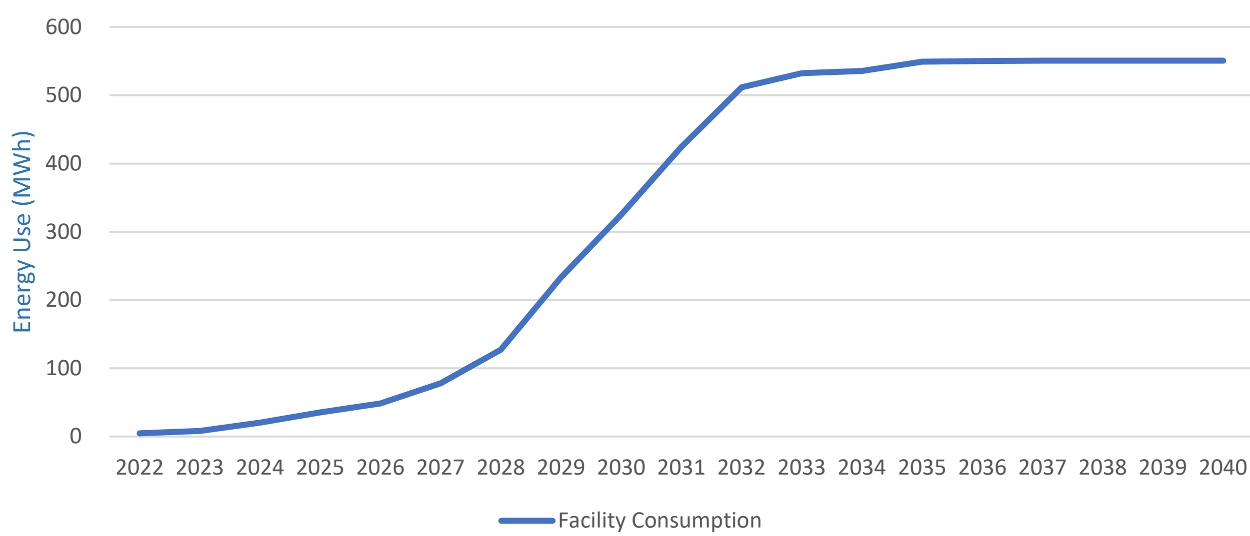

Figure 122. Police Parking Lot Annual Electricity Consumption, 2040 Transition Scenario

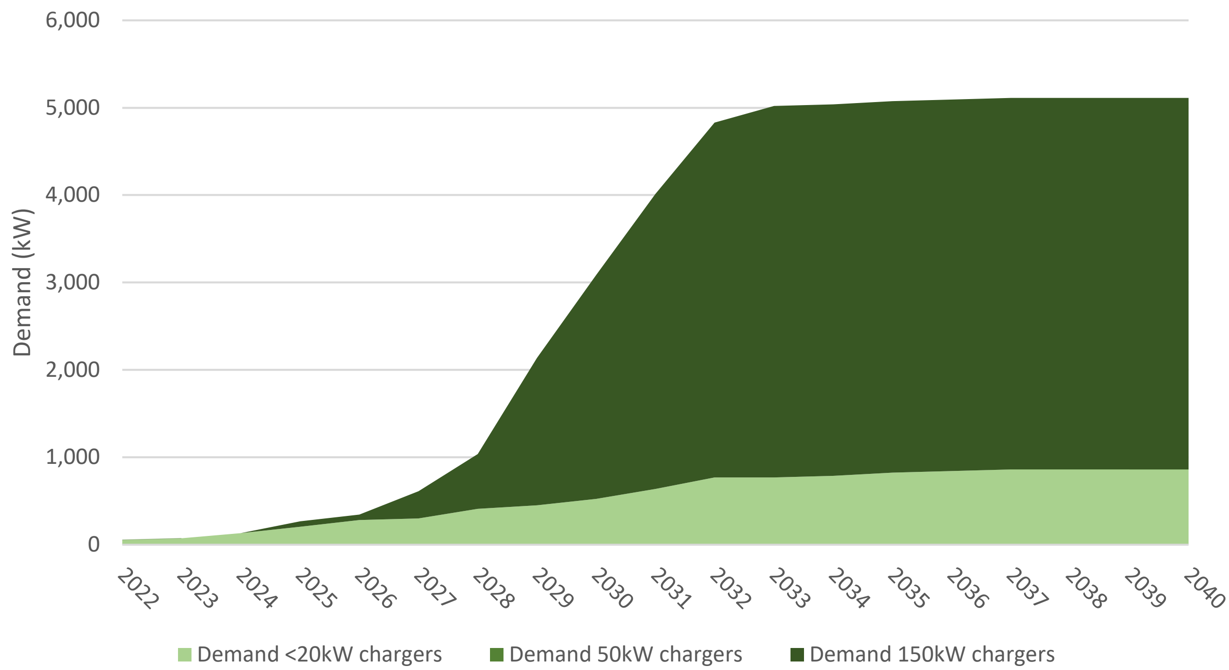

Figure 123. Police Parking Lot Annual Electricity Demand, 2040 Transition Scenario

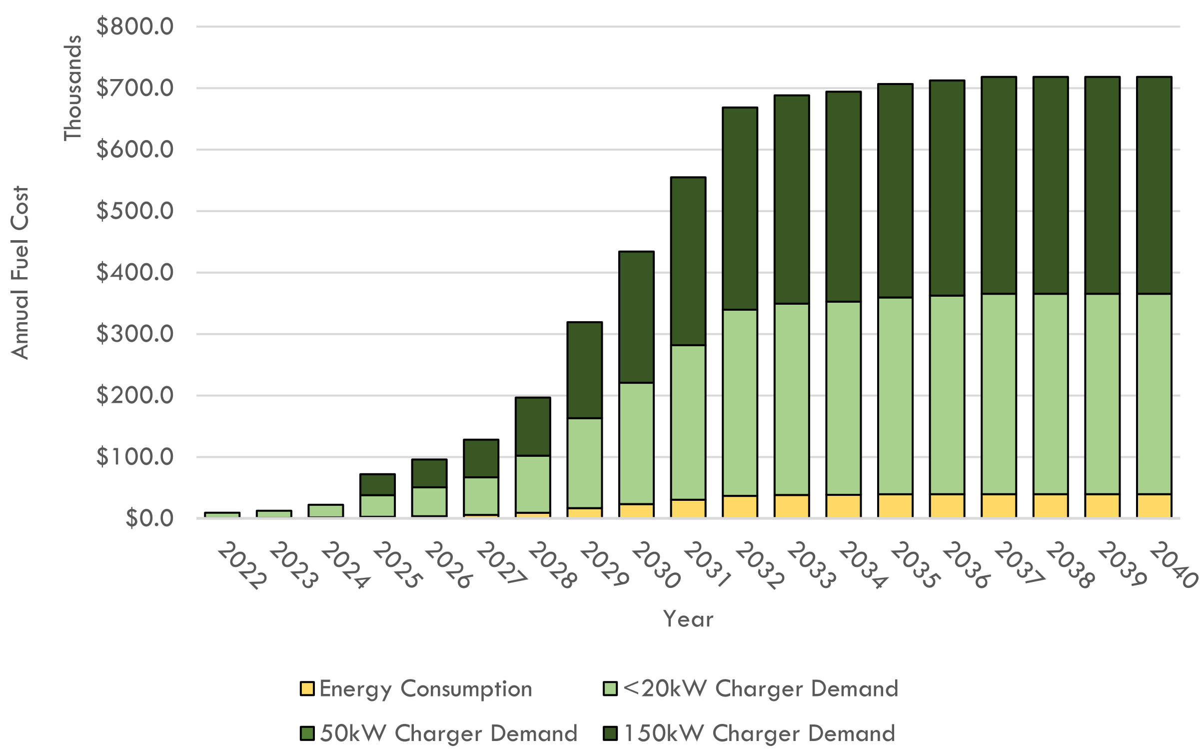

Figure 124. Police Parking Lot Annual Electricity Cost, 2040 Transition Scenario

2035 Fuel Assessment

In the 2035 scenario, EVs are purchased and deployed according to the schedules outlined in the fleet assessment with the goal of transitioning the municipal fleet to zero-emission vehicles by 2035 as the required vehicle types become commercially available. The estimated energy consumption, demand and cost associated with each location are summarized in the figures below. This information is broken out into three separate graphs for each location.

Public Works Yard

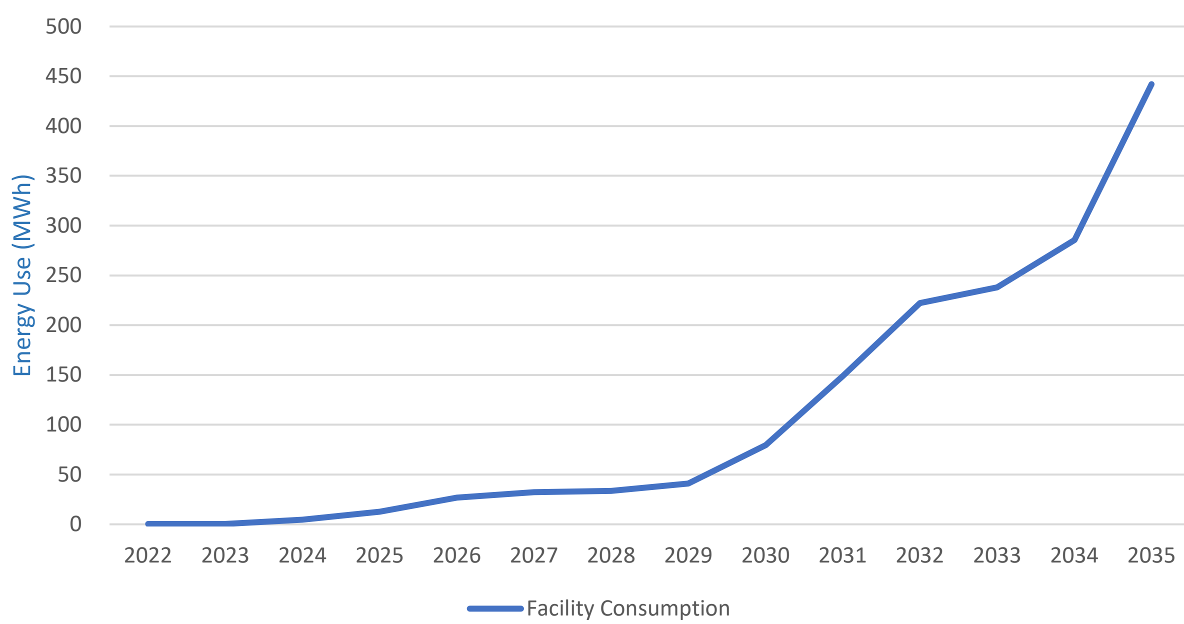

Figure 125. Public Works Yard Annual Electricity Consumption, 2035 Transition Scenario

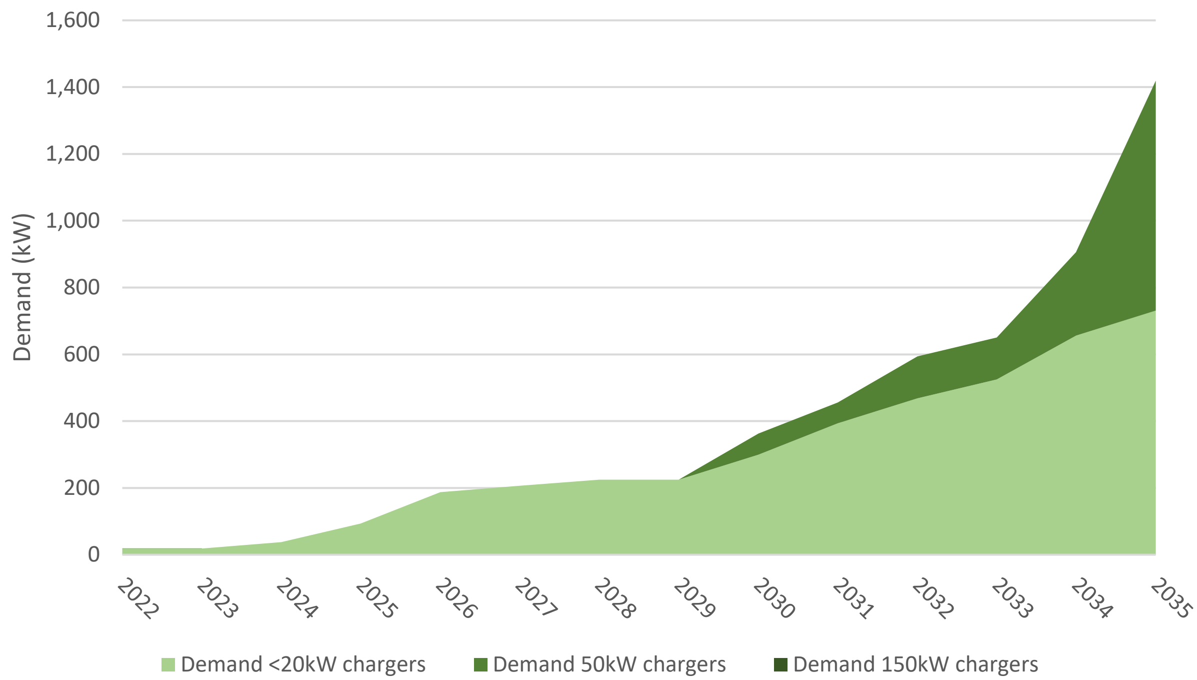

Figure 126. Public Works Yard Annual Electricity Demand, 2035 Transition Scenario

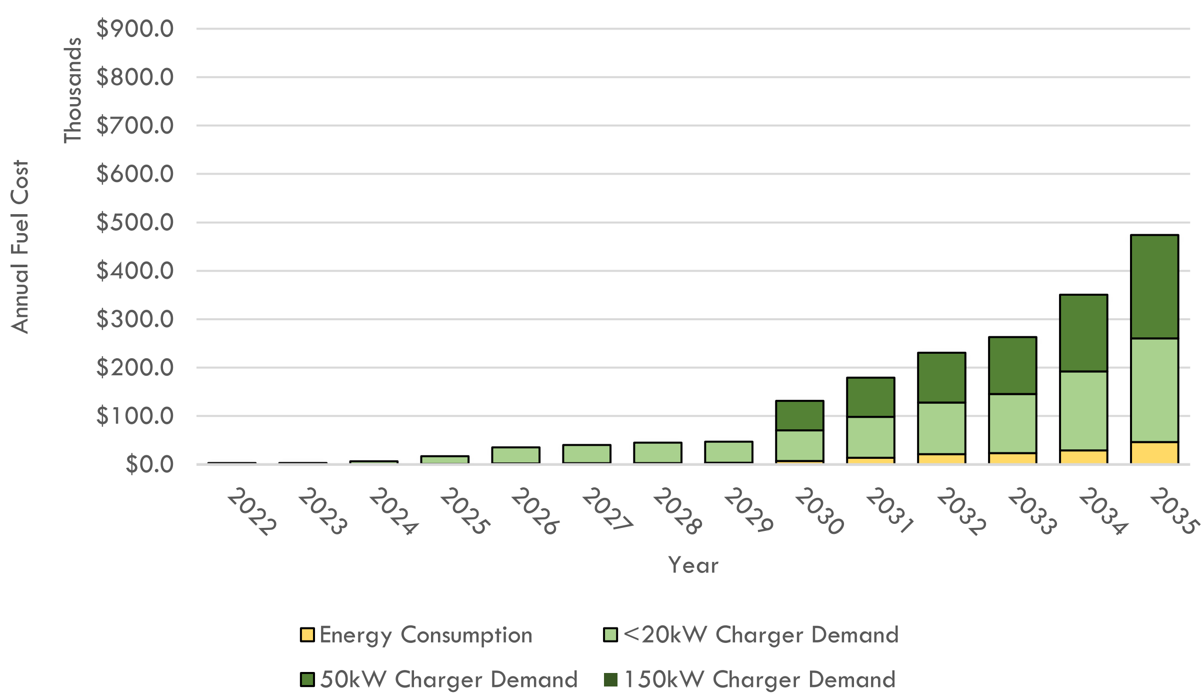

Figure 127. Public Works Yard Annual Electricity Cost, 2035 Transition Scenario

City Hall

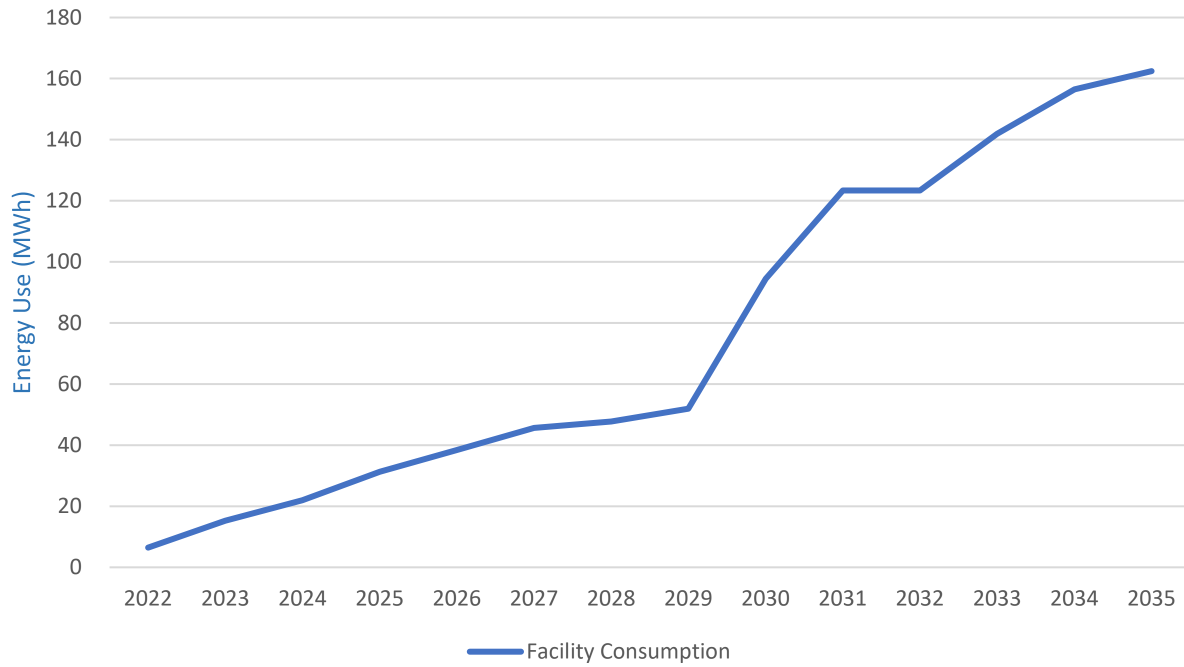

Figure 128. City Hall Annual Electricity Consumption, 2035 Transition Scenario

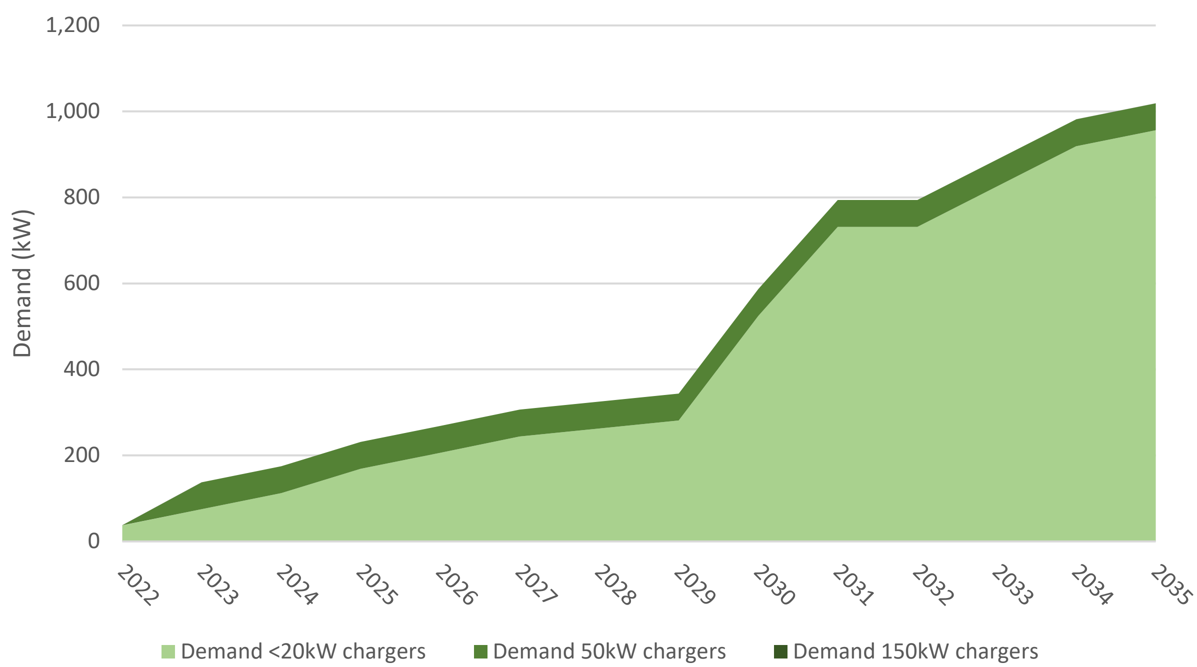

Figure 129. City Hall Annual Electricity Demand, 2035 Transition Scenario

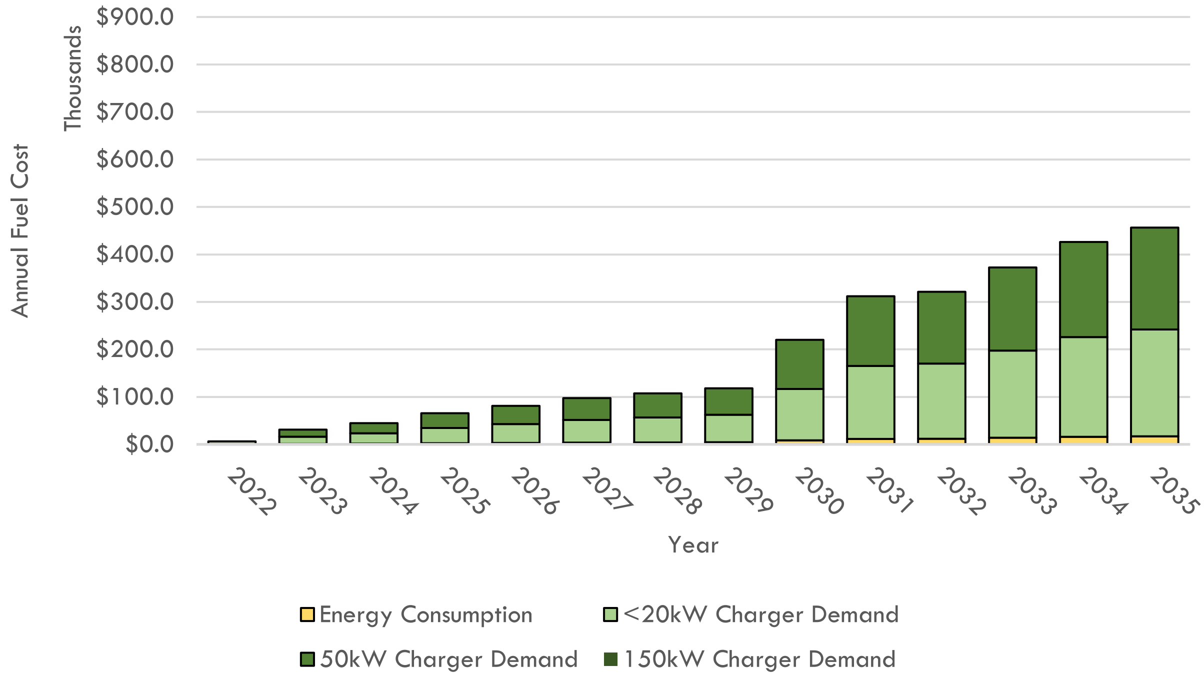

Figure 130. City Hall Annual Electricity Cost, 2035 Transition Scenario

GWP Ops Center

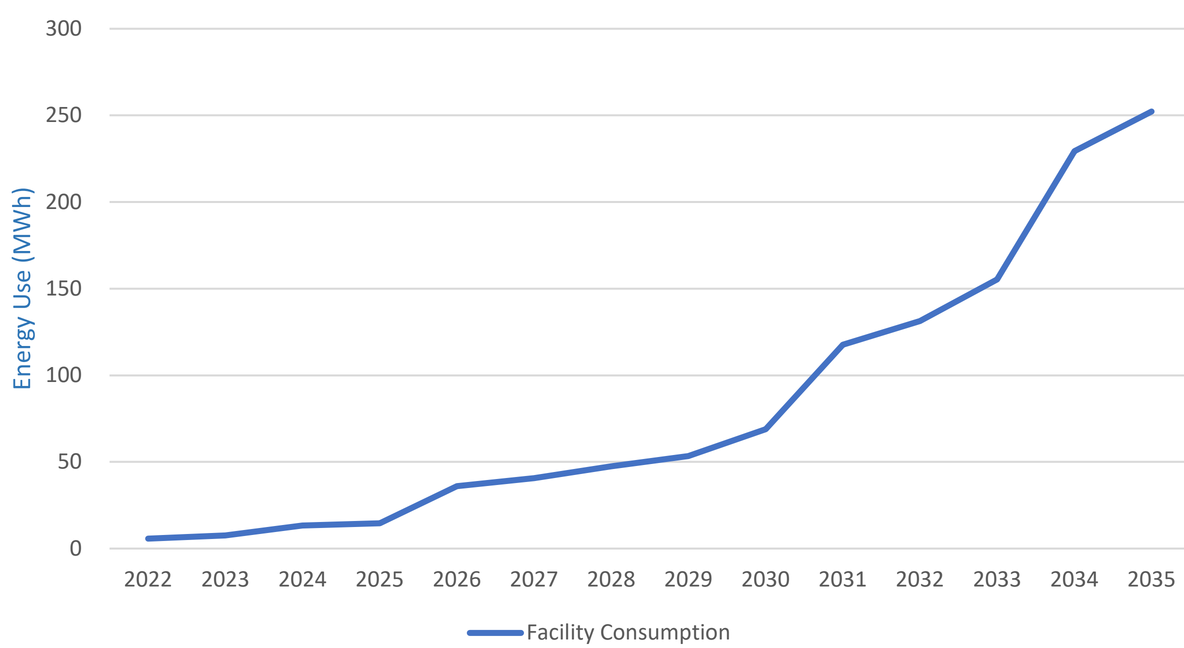

Figure 131. GWP Ops Center Annual Electricity Consumption, 2035 Transition Scenario

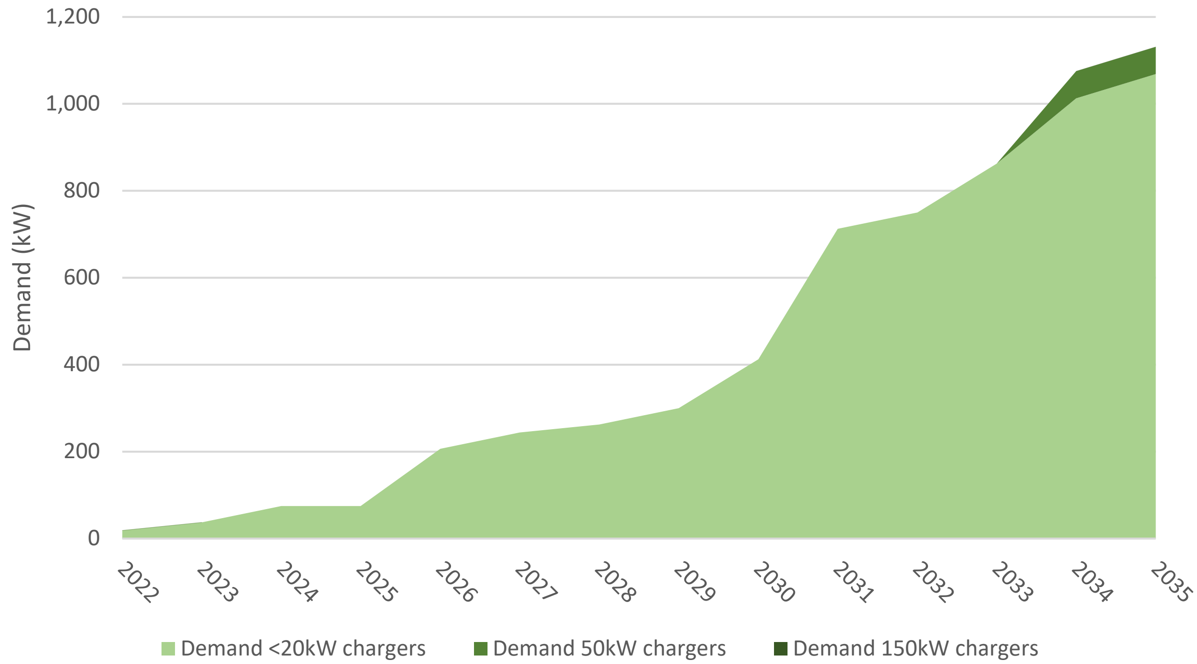

Figure 132. GWP Ops Center Annual Electricity Demand, 2035 Transition Scenario

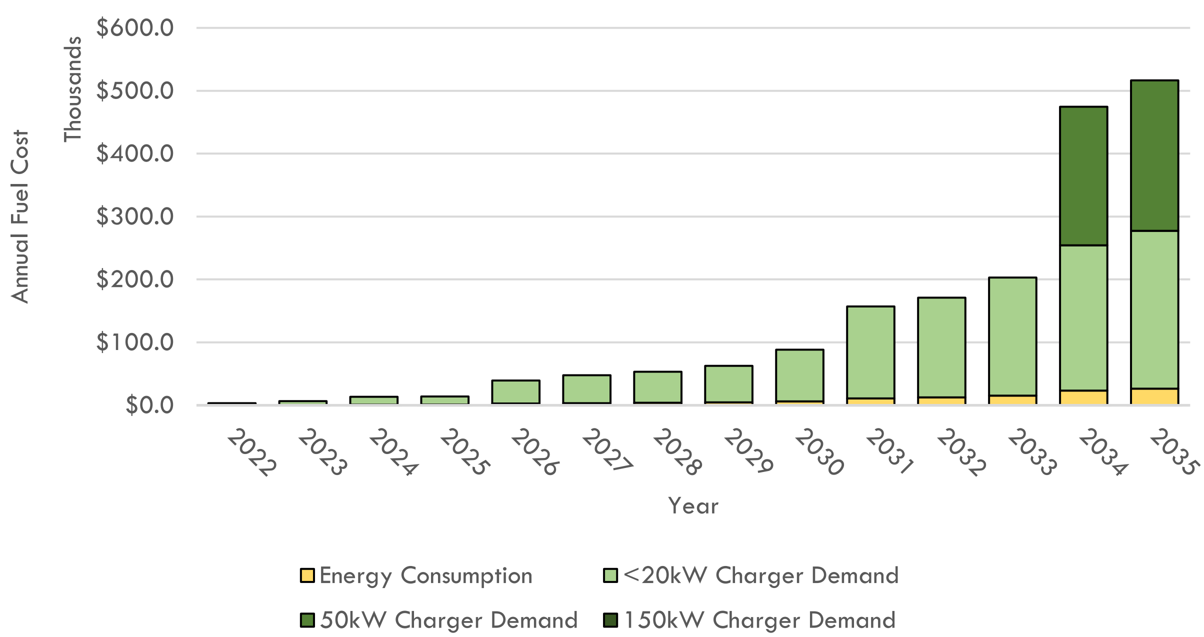

Figure 133. GWP Ops Center Annual Electricity Cost, 2035 Transition Scenario

Integrated Waste Yard

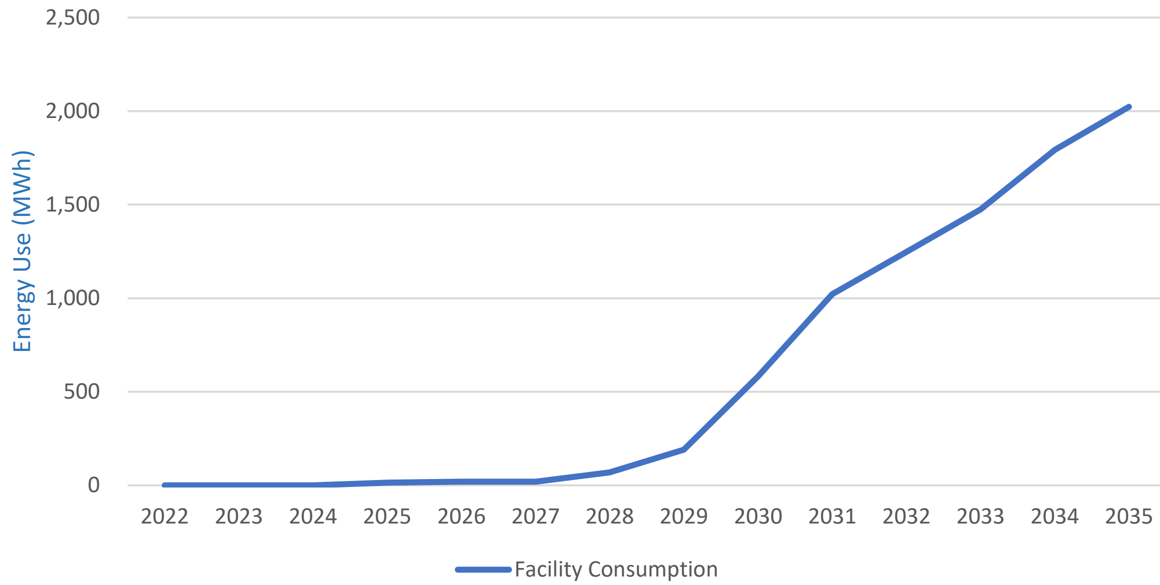

Figure 134. Integrated Waste Yard Annual Electricity Consumption, 2035 Transition Scenario

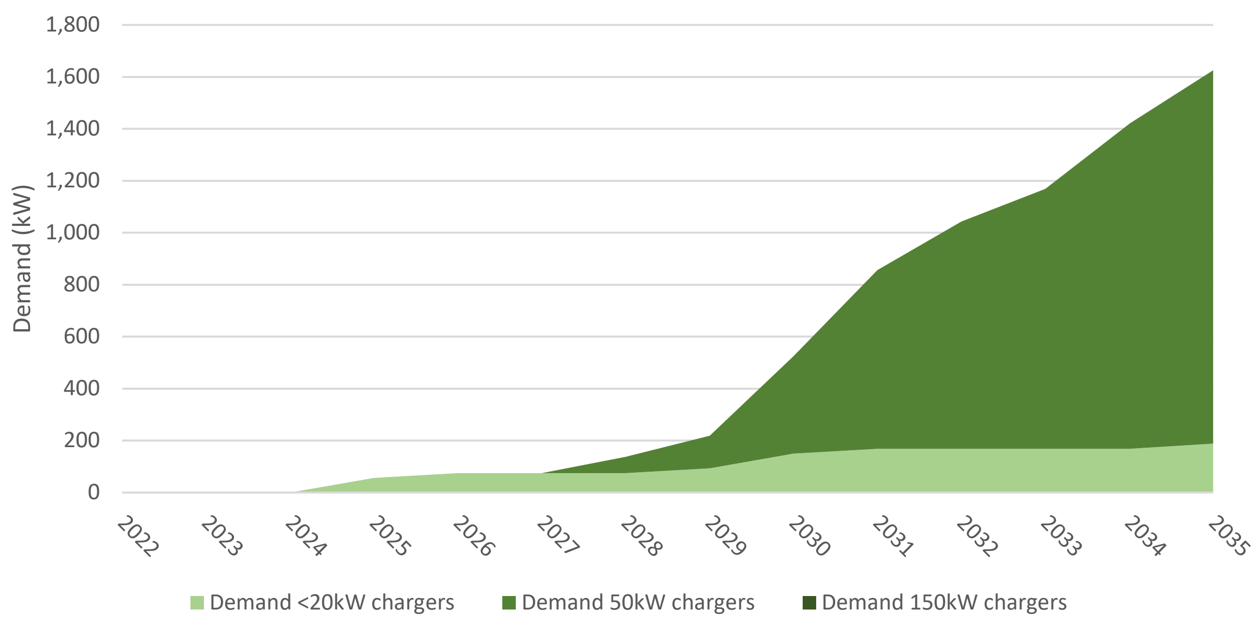

Figure 135. Integrated Waste Yard Annual Electricity Demand, 2035 Transition Scenario

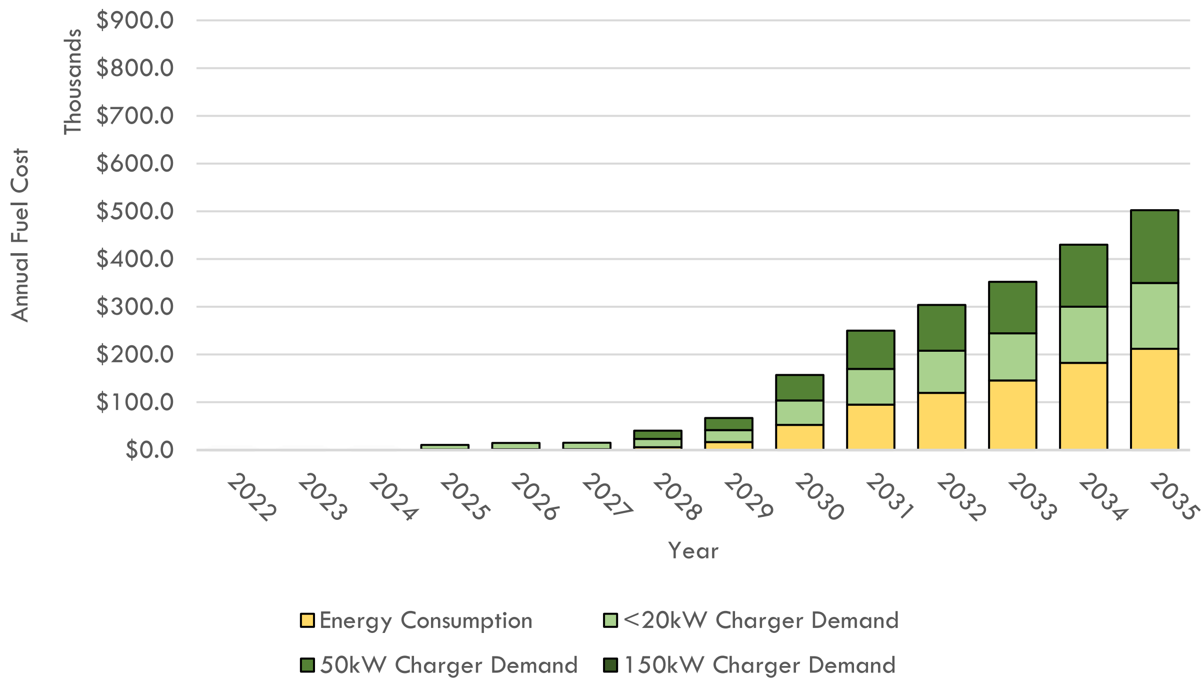

Figure 136. Integrated Waste Yard Annual Electricity Cost, 2035 Transition Scenario

Fire Station 21

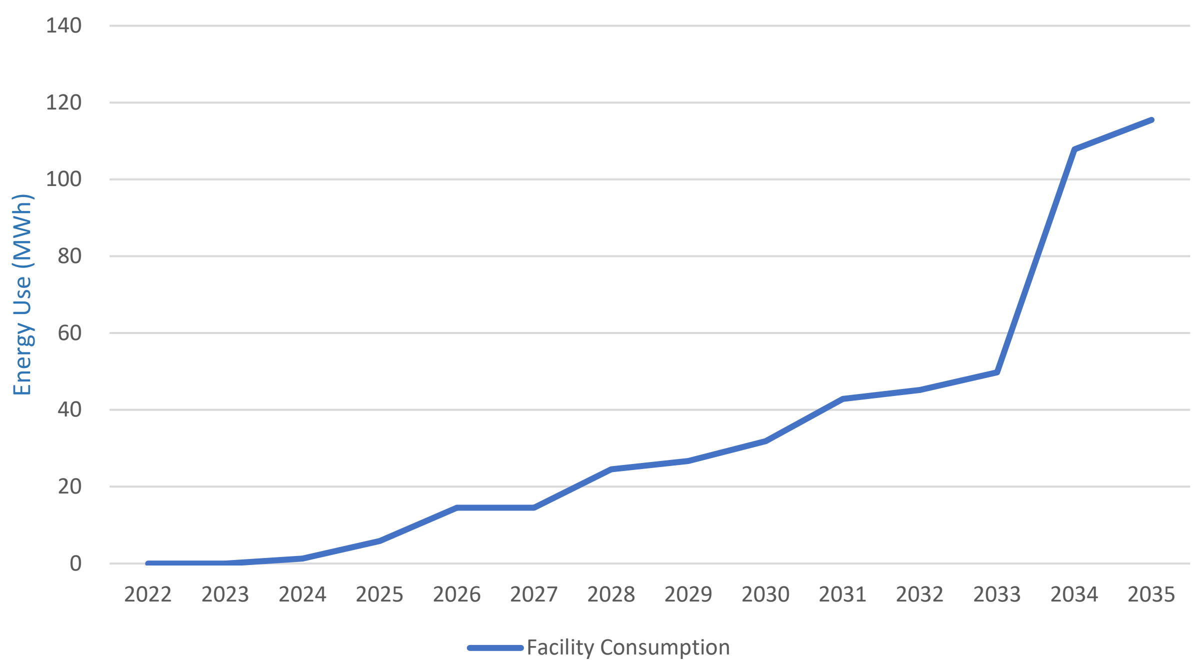

Figure 137. Fire Station 21 Annual Electricity Consumption, 2035 Transition Scenario

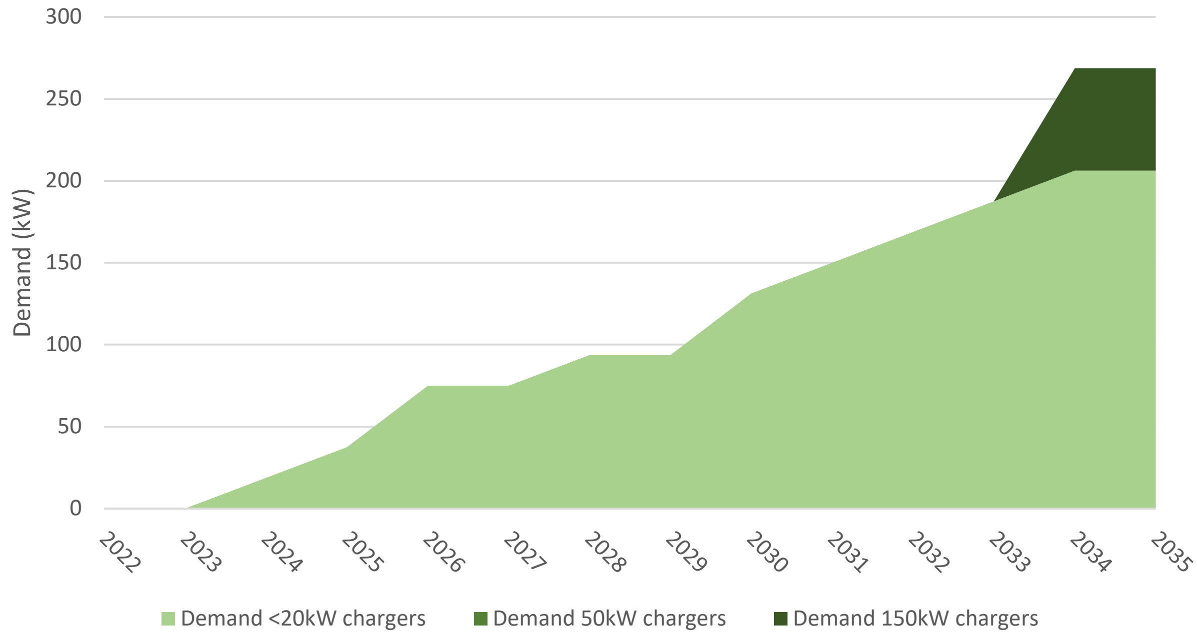

Figure 138. Fire Station 21 Annual Electricity Demand, 2035 Transition Scenario

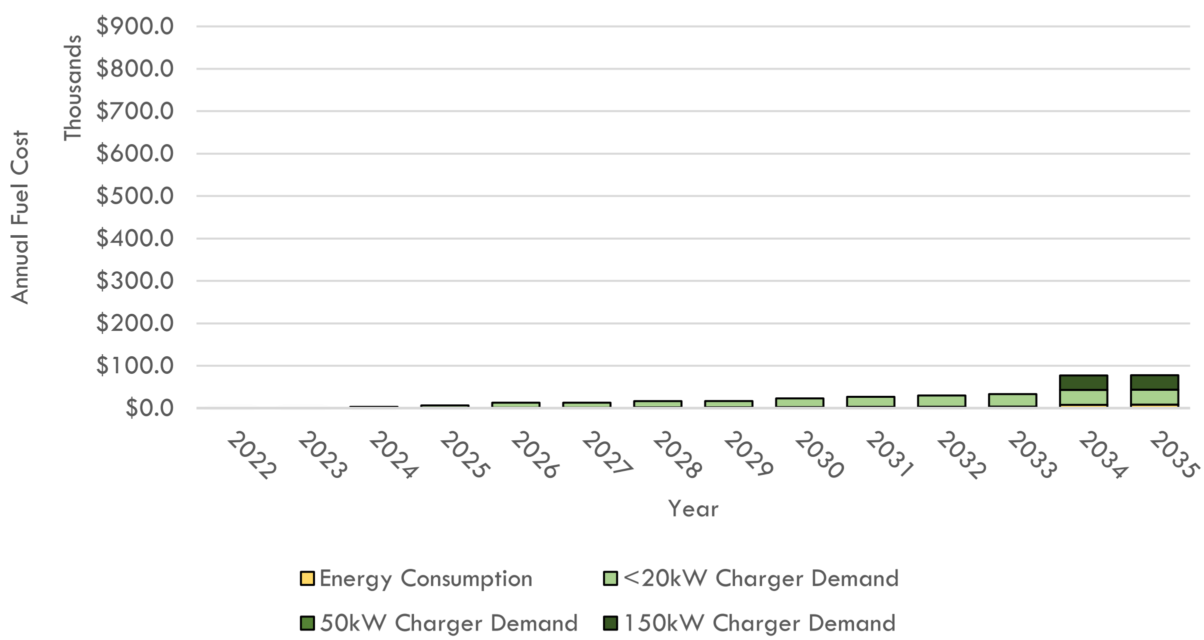

Figure 139. Fire Station 21 Annual Electricity Cost, 2035 Transition Scenario

Police Parking Lot

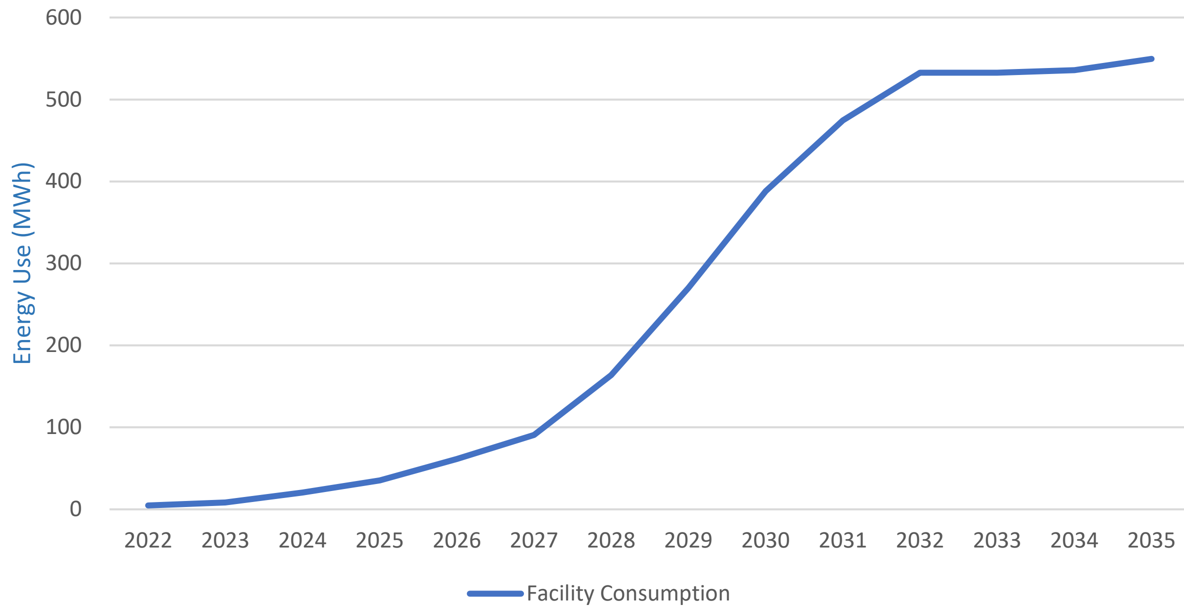

Figure 140. Police Parking Lot Annual Electricity Consumption, 2035 Transition Scenario

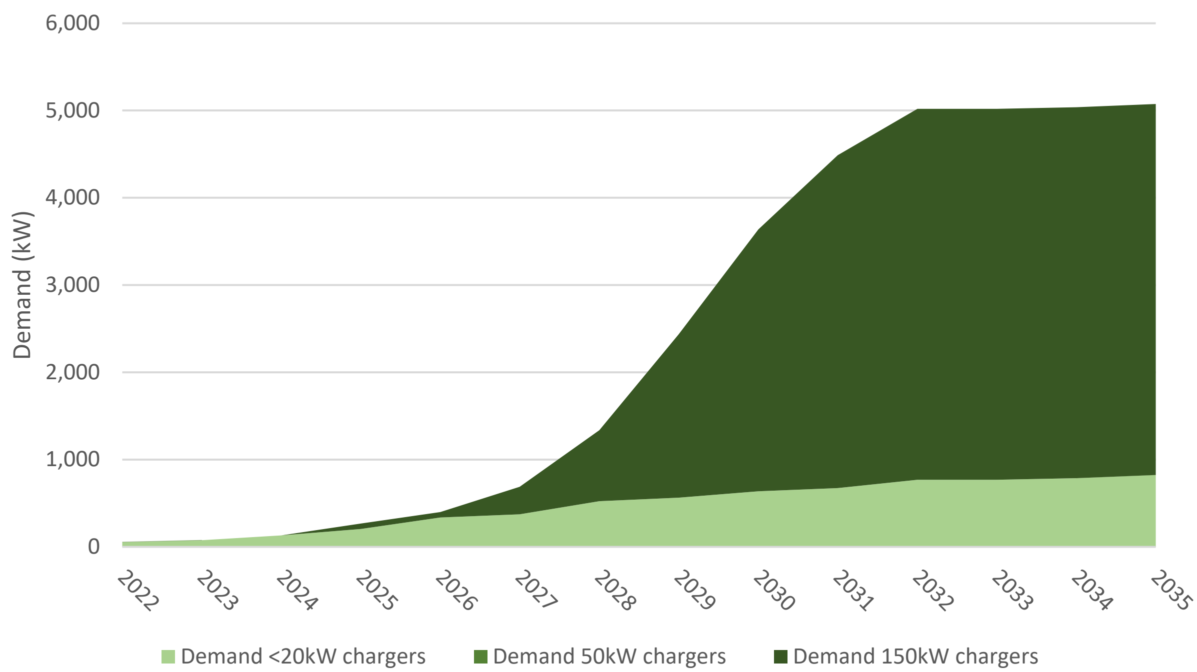

Figure 141. Police Parking Lot Annual Electricity Demand, 2035 Transition Scenario

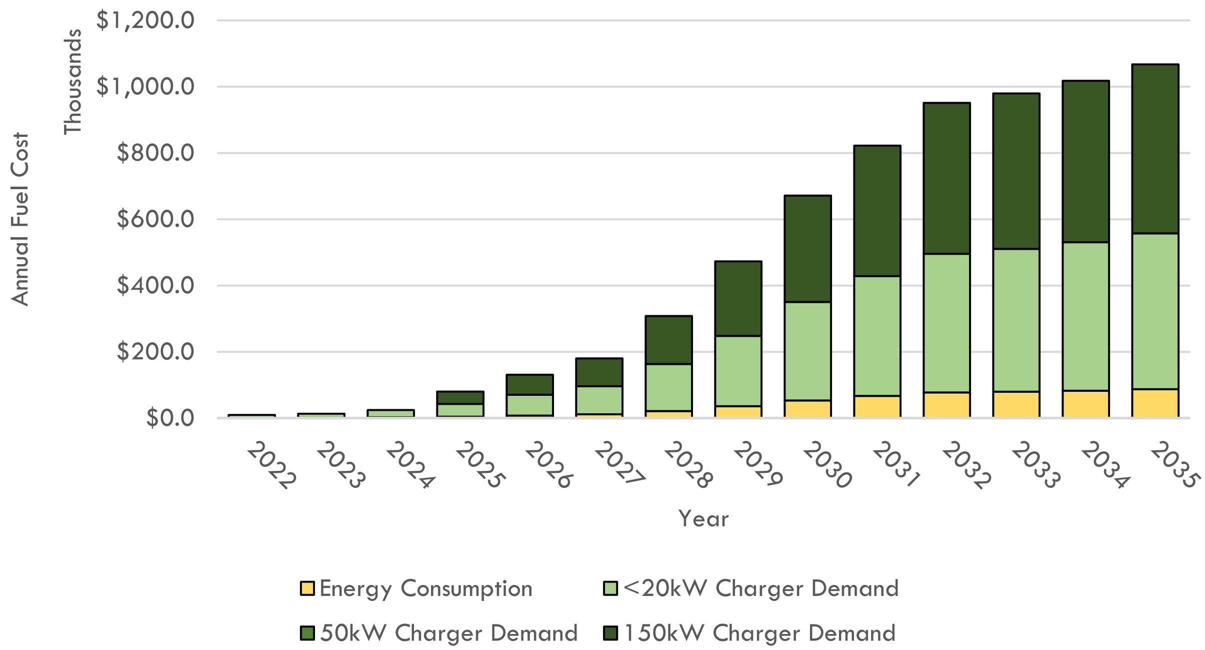

Figure 142. Police Parking Lot Annual Electricity Cost, 2035 Transition Scenario

Benefits Assessment

Maintenance Cost Potential Savings

Manufacturers and industry sources report that EVs should realize maintenance savings over that of their conventional baseline counterparts. In the early stages of deployment, CTE has not documented this savings, but expects savings in the long term once the industry matures. EVs have an advantage over ICE with respect to maintenance due to fewer moving parts, no fluids to replace, and less frequent brake changes due to regenerative braking. Although there is very little data, we estimate that fleets can save approximately 30% on maintenance over the life of the vehicle. Switching from conventionally fueled vehicles to EVs has other benefits that are less easy to quantify. Over time, the City should expect savings from the reduced need for engine oil and costs associated with used oil storage and disposal.

The estimated annual maintenance cost compared to baseline vehicles for the 2040 and 2035 Scenarios is provided below in **Figure 143** and **Figure 144** respectively. Cumulative costs for each scenario are provided in **Figure 145**. and **Figure 146.** Cumulative maintenance costs in the 2040 EV scenario are estimated at $213.8 million, a cumulative savings of $37.4 million over the Baseline scenario. Cumulative maintenance costs in the 2035 EV scenario are estimated at $212.7 million, a cumulative savings of $38.5 million over the Baseline scenario.

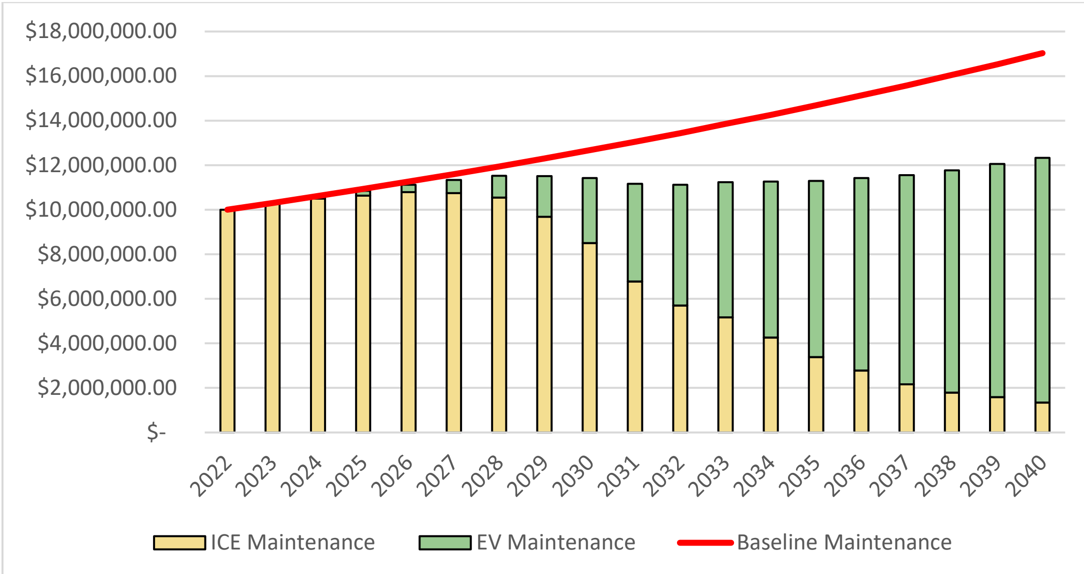

Figure 143. Estimated Annual EV Maintenance Costs Compared to Baseline, 2040

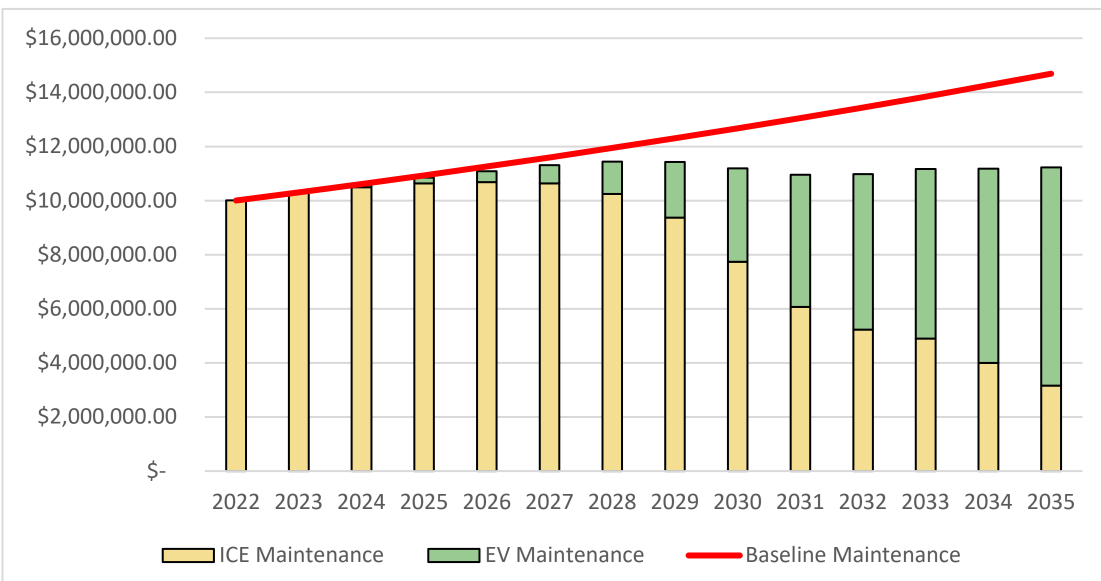

Figure 144. Estimated Annual EV Maintenance Costs Compared to Baseline, 2035

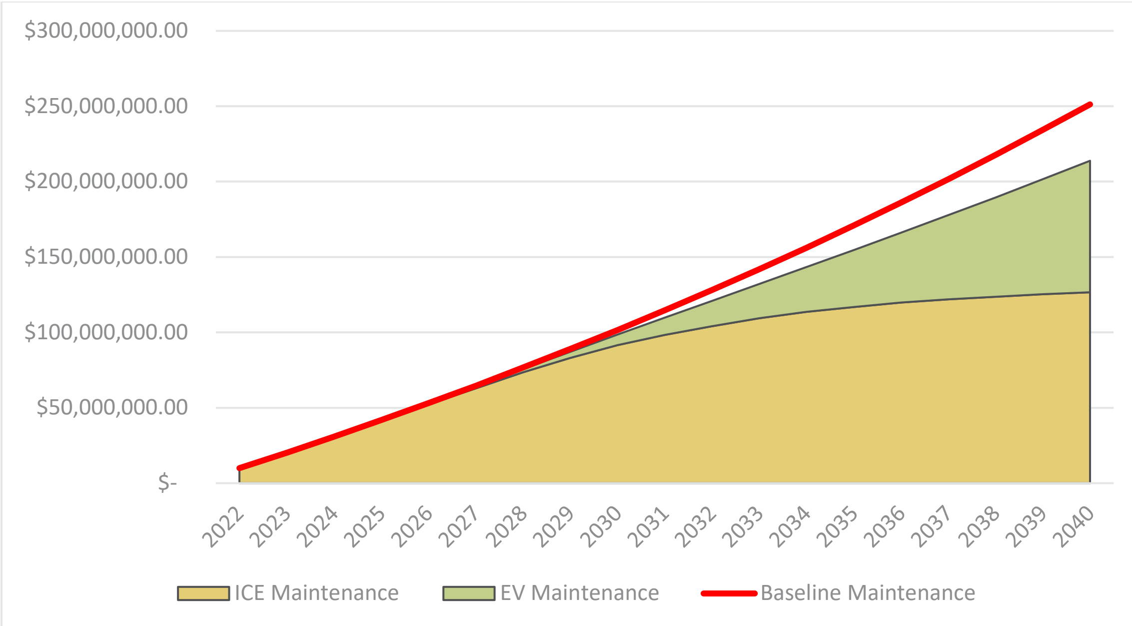

Figure 145. Cumulative EV Maintenance Costs Compared to Baseline, 2040

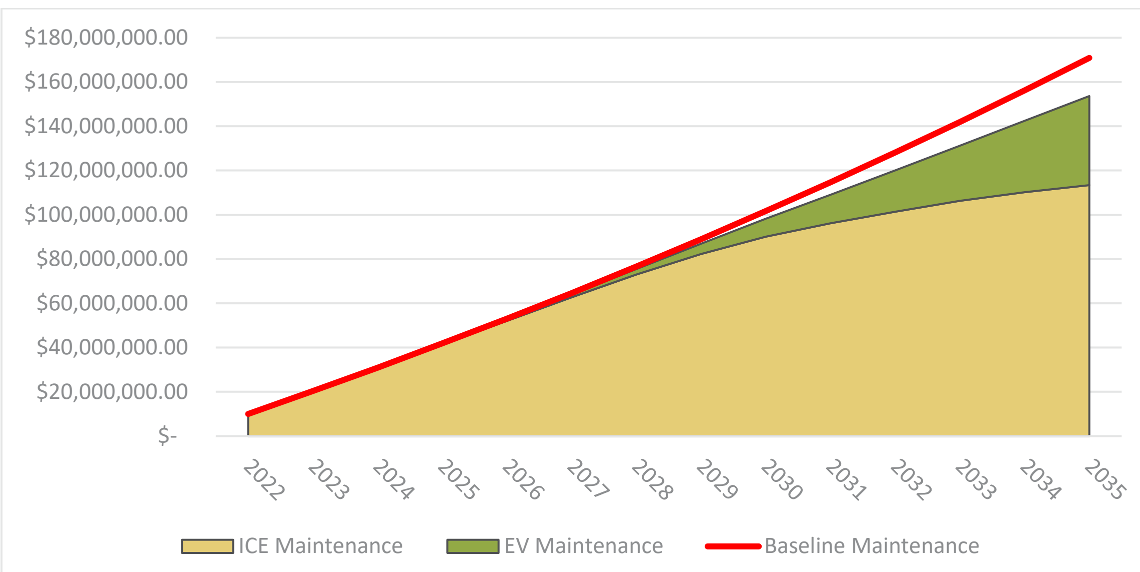

Figure 146. Cumulative EV Maintenance Costs Compared to Baseline, 2035

Emissions Reductions

Reduction of criteria pollutants and GHG emissions are one of the benefits of operating EVs. EVs produce zero tail-pipe emissions, however well-to-wheel emissions depend on how the electricity is produced. CTE uses the AFLEET[2] tool to estimate emissions based on the current use of the City's baseline vehicles. the **A**lternative **F**uel **L**ife-Cycle **E**nvironmental and **E**conomic **T**ransportation (AFLEET) Tool was developed by the Department of Energy's Argonne National Laboratory to aid stakeholders in estimating petroleum use, greenhouse gas (GHG) emissions, air pollutant emissions, and cost of ownership of light-duty and heavy-duty vehicles. The tool calculates well-to-wheel emissions for both EV and conventional fueled vehicles.

CTE analyzed the baseline fleet data to determine the estimated miles per year for each type of vehicle. New EVs will be purchased to replace current conventional fueled vehicles, therefore the service, and resulting mileage would be roughly the same. CTE reviewed the vehicle class assigned by the City and matched those with the classes used in the AFLEET tool. **Table 49** shows the matchup for the City's fleet along with the recommended fuel economy by class.

Table 48. Fuel economy assumptions used for emission savings calculations

Glendale Vehicle Class	AFLEET Vehicle Class	FE Recommended kWh/100 miles
Compact	Passenger Car	44
Midsize	Passenger Car	36
Truck	Passenger Truck	49
SUV	Passenger Car	31
Vans	Passenger Car	49
Motorcycles	Passenger Car	20
Other	Light Commercial Truck	50

To estimate emissions for charging the EVs, CTE used the Western Electricity Coordinating Council Grid Mix (**Table 50)**. More than 42% of the power generated by this mix comes

[2] AFLEET web site: https://afleet.es.anl.gov/home/

from renewable sources such as solar and wind. Natural gas makes up 31% of the power, with coal rounding out the mix at 17%.

Table 49. Western electricity coordinating council grid mix

Energy Source	Percent
Residual Oil	0.1%
Natural Gas	31.2%
Coal	17.4%
Nuclear Power	8.4%
Biomass	0.5%
Other (Wind, Solar, Hydro, etc.)	42.4%

Outputs from the AFLEET tool include emissions of greenhouse gases and particulate matter. The emissions over time for the 2040 Scenario are seen in **Figure 147, Figure 148,** and **Figure 149.** The emission over time for the 2035 Scenario are shown in **Figure 150, Figure 151, and Figure 152.**

2040 Scenario

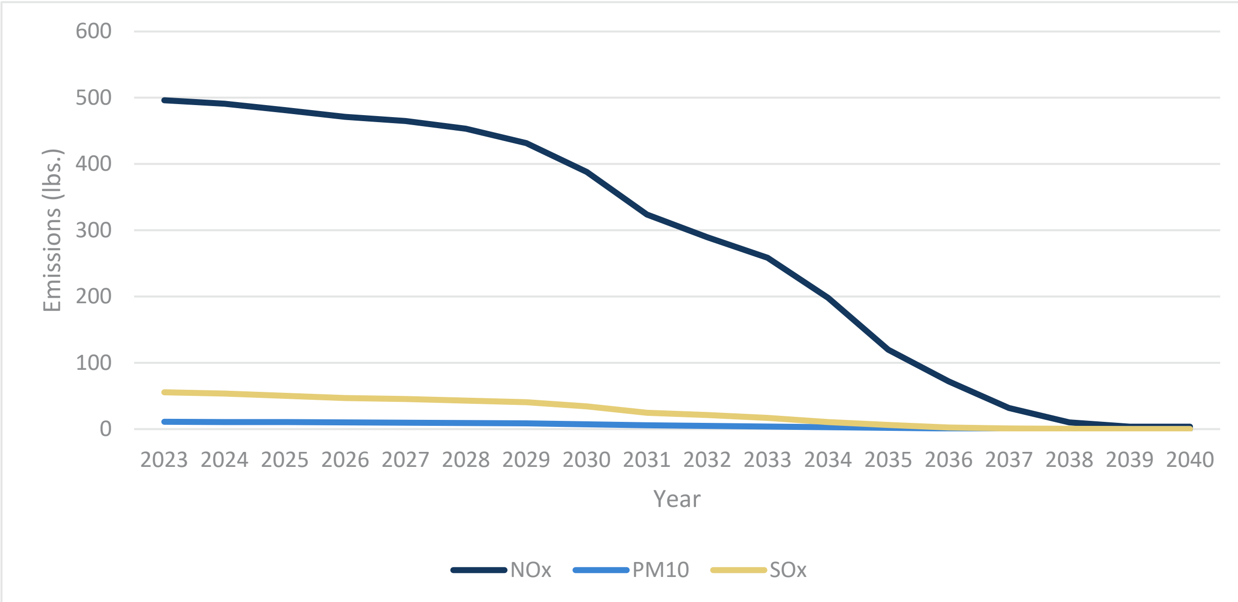

Figure 147. Estimated Emission Reduction of NOx, SOx, PM 10, 2040 Scenario

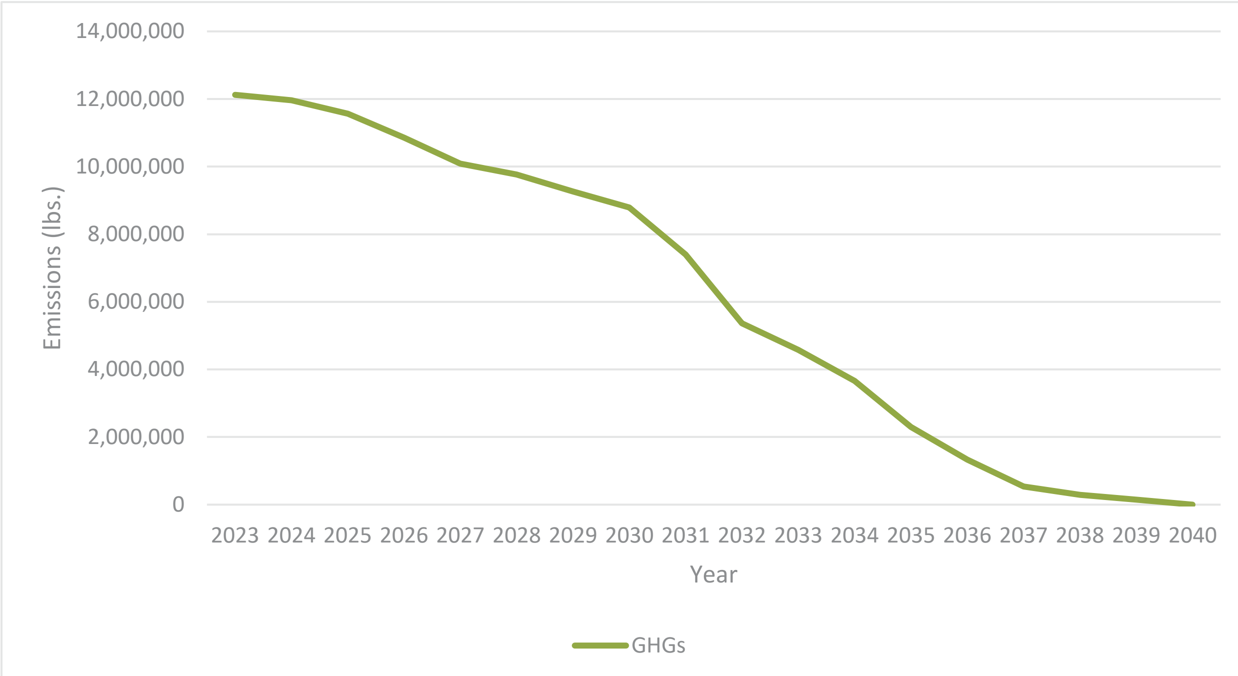

Figure 148. Greenhouse Gas Emissions Over Time, 2040 Scenario

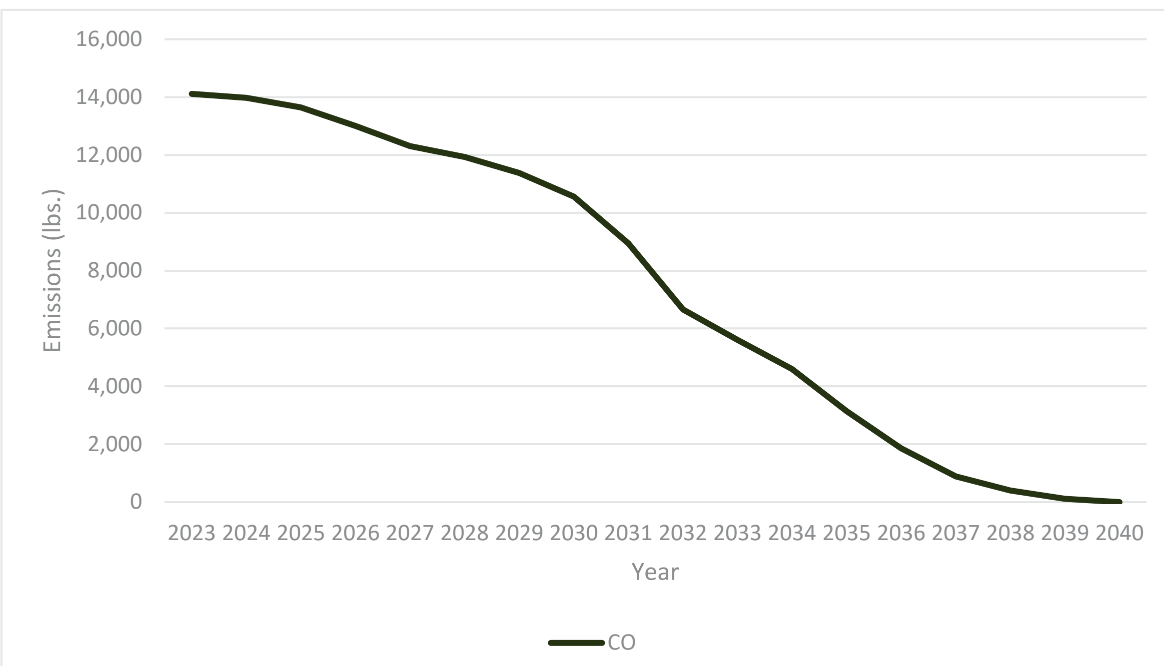

Figure 149. CO Emissions Over Time, 2040 Scenario

2035 Scenario

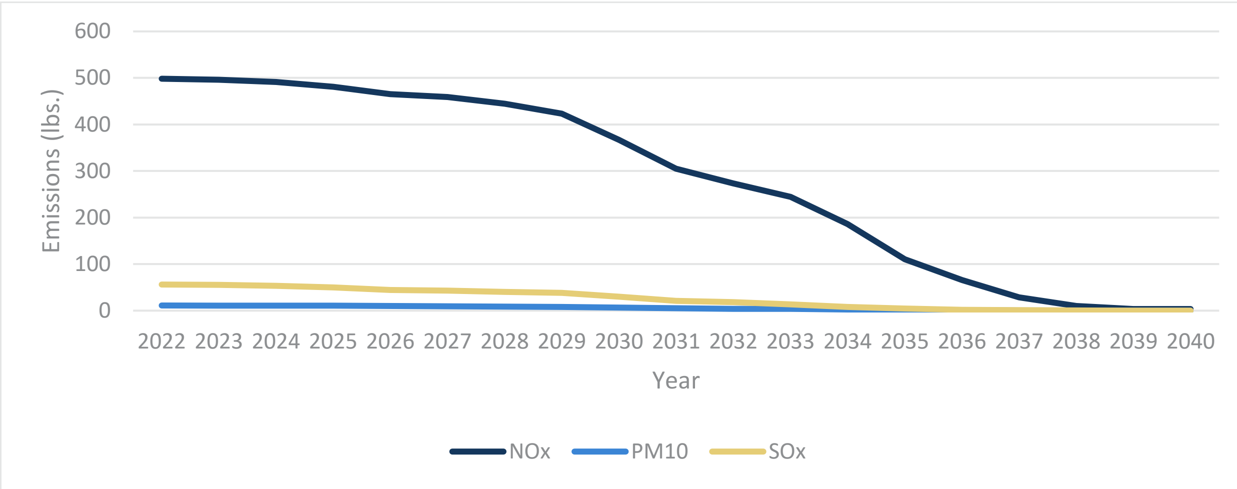

Figure 150. Estimated Emission Reduction of NOx, SOx, PM 10, 2035 Scenario

Figure 151. Greenhouse Gas Emissions Over Time, 2035 Scenario

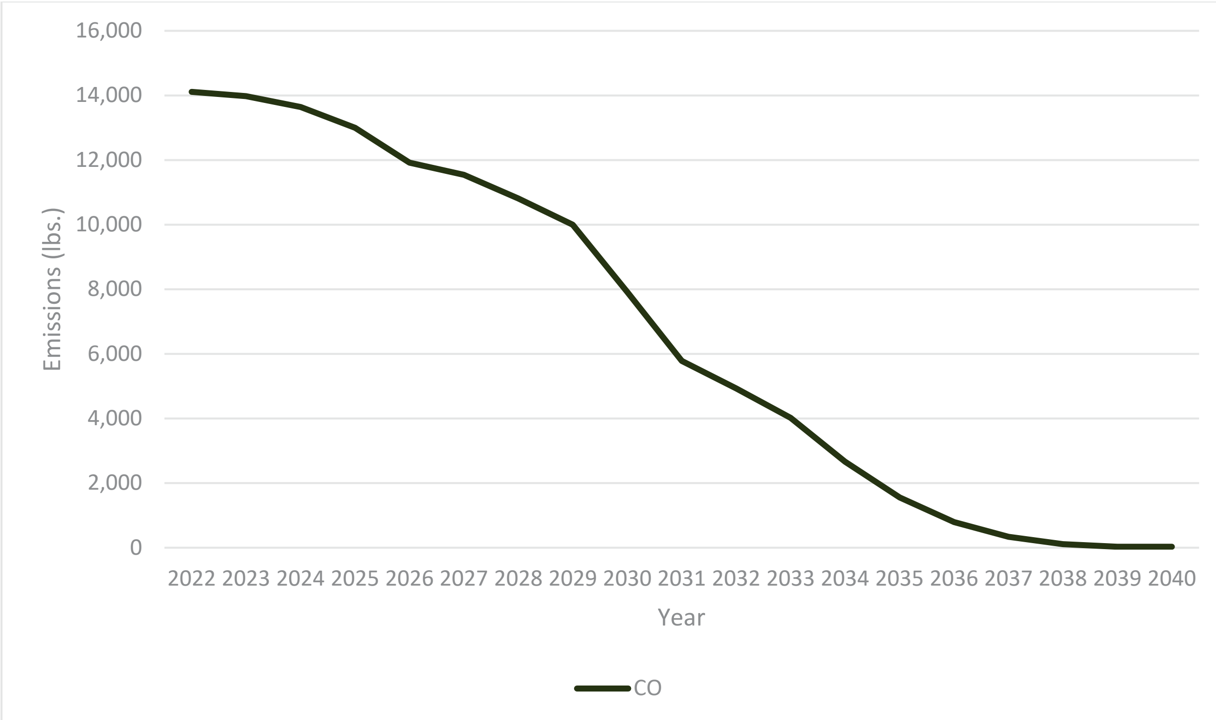

Figure 152. CO Emissions Over Time, 2035 Scenario

Cost Assessment

Transition Costs

As a result of the City's asset replacement schedule, duty cycle feasibility, vehicle type suitability, and the City's transition goals, **Table 50** outlines the annual number of EVs purchased that represent first-time replacement of ICE with EVs for a given vehicle for each scenario. Tracking the first-time cost of replacing conventional vehicles with EVs is important to understand the cost to transition.

Table 50. First Time EV Procurements for each Scenario

Year	2035 EV Procurements	2040 EV Procurements
2023	8	8
2024	20	20
2025	35	35
2026	56	36
2027	24	24
2028	44	34
2029	54	54
2030	126	98
2031	125	133
2032	50	62
2033	49	56
2034	81	86
2035	62	71
2036	38	51
2037	24	25
2038	10	12
2039	6	6
2040	9	10

Figure 153 shows the first-time EV procurement quantities each year for the two scenarios, and **Figure 154** shows the annual cost associated with the first-time EV procurements each year by scenario.

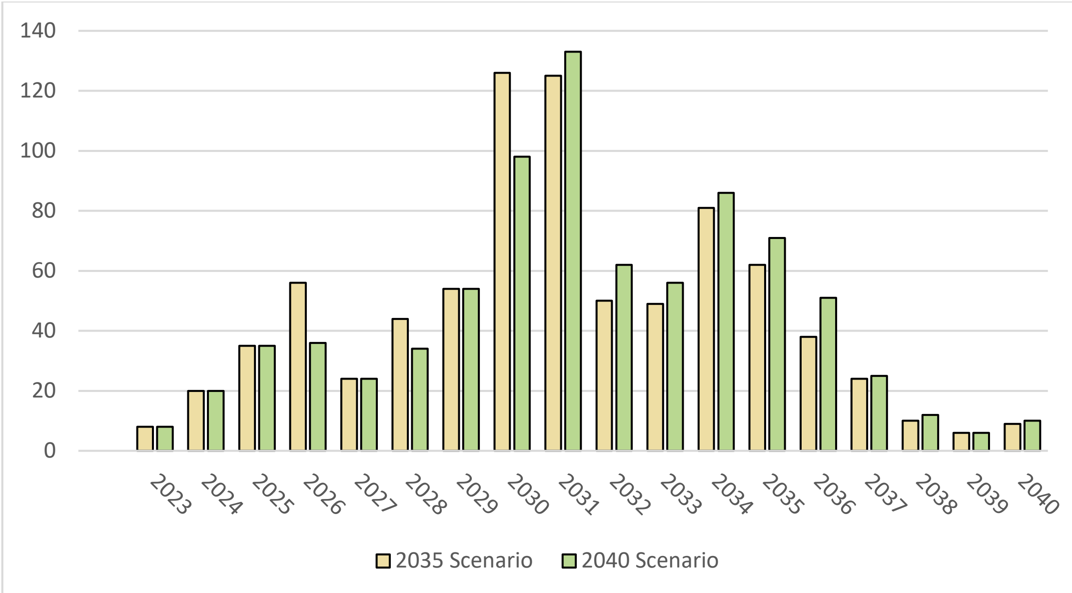

Figure 153. First Time EV Procurement Quantities

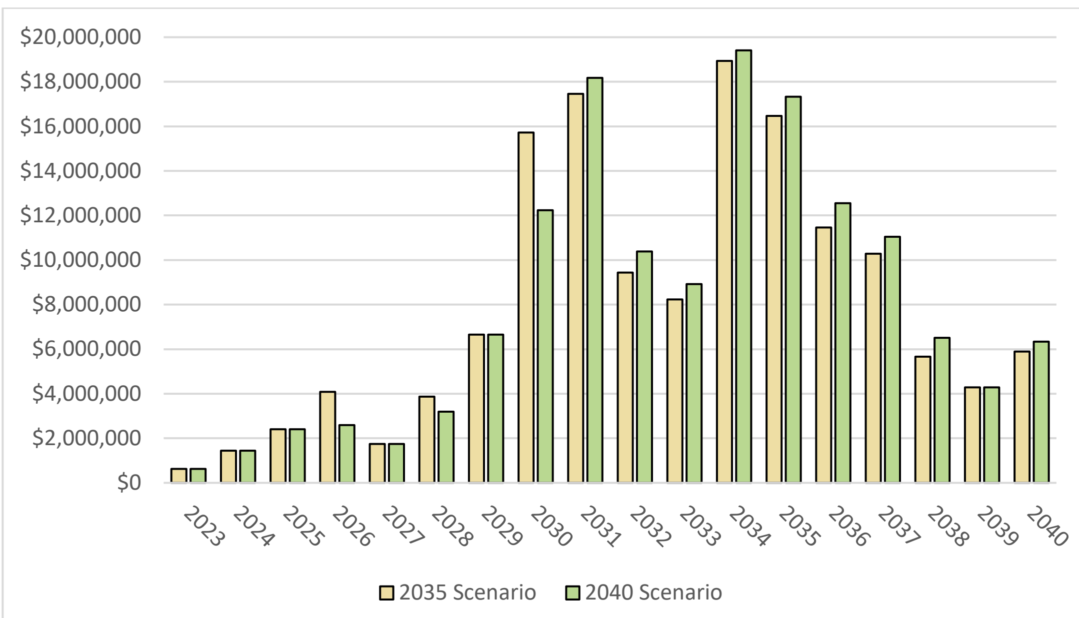

Figure 154. First Time Procurement EV Amounts

Total Transition Cost is the total incremental cost of first-time EV replacements plus total EV infrastructure costs. It represents the incremental capital funding required to transition to an all-electric fleet. **Figure 155** provides the total cumulative transition cost for the 2040 scenario which is estimated at $124.3 million.

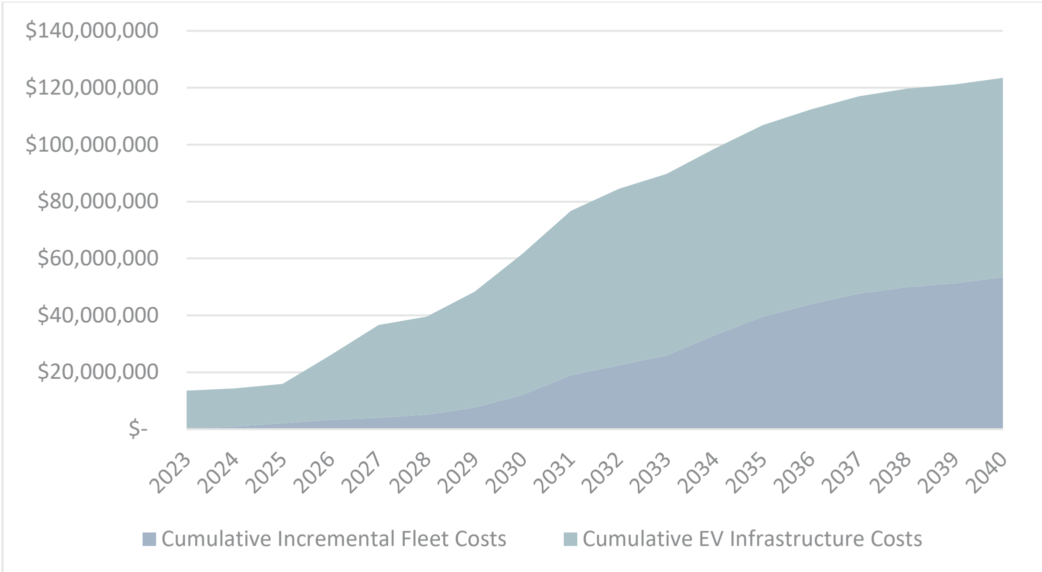

Figure 155. Cumulative Transition Costs, 2040 Scenario

Figure 156 provides the total cumulative transition cost for the 2035 scenario which is estimated at $107.1 million. Because this scenario does not complete the transition to 100% EVs, additional costs will be incurred for installing the remainder of the charging infrastructure.

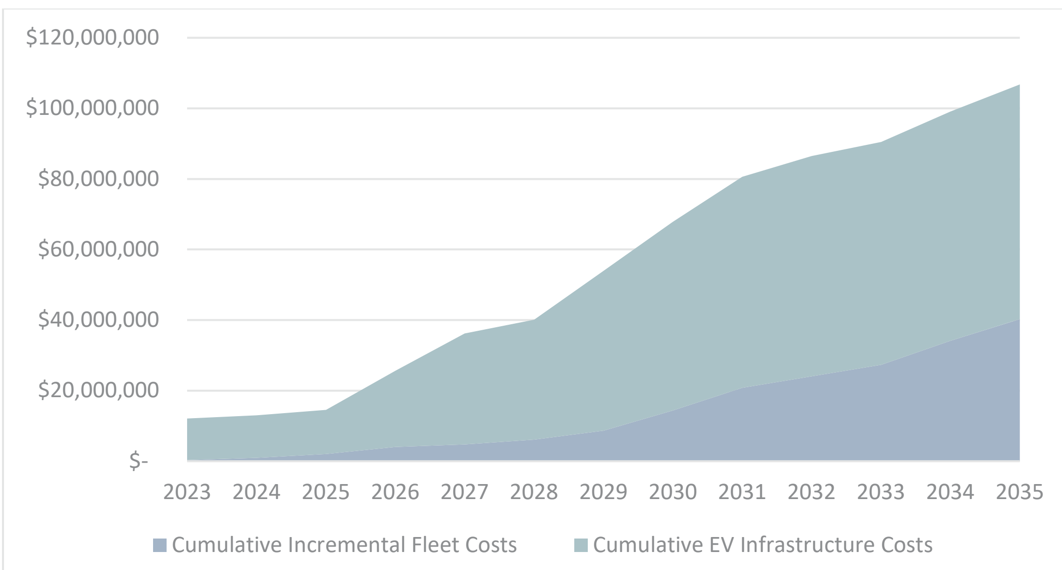

Figure 156. Cumulative Transition Costs, 2035 Scenario

Total Cost of Ownership

The City's TCO for EV Transition considers the total capital investment for the replacement vehicles over the transition period, including both ICEs and EVs, the upgrade of utility service to each facility, the design and construction of charging infrastructure, and the purchase and installation of chargers. The TCO also includes the total fuel and maintenance operating costs over the transition period. Fuel costs include all fuel types over the transition period including electricity, diesel, gasoline, and CNG. Maintenance cost includes maintenance of both ICE and EVs. The goal of the TCO analysis is to assess the impact that EV transition will have on both operating and capital costs for the entire fleet. While fuel and maintenance costs are likely to be lower, it usually does not offset the incremental capital costs. Taking into count the previous analyses of cost, **Figure 157** and **Figure 158** provide the total cost of ownership for the 2035 and 2040 Transition Scenarios. As the number of EVs in the fleet increase, the costs per year increase.

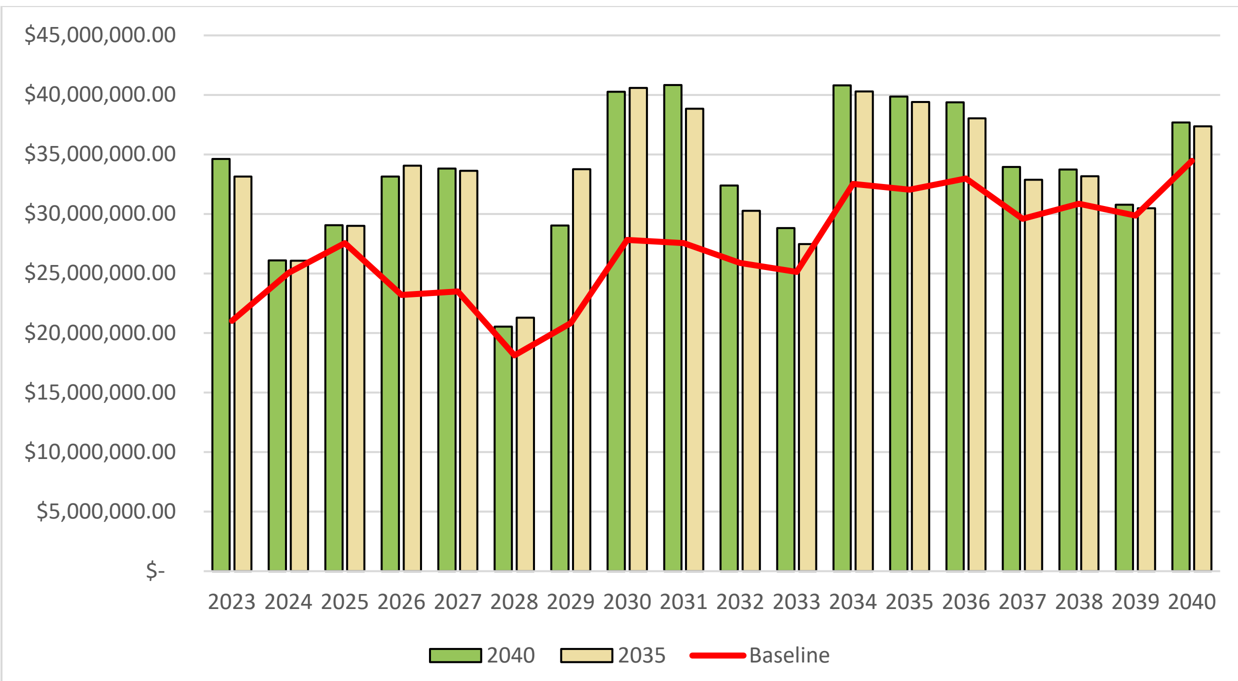

Figure 157. Annual Total Cost of Ownership by Scenario

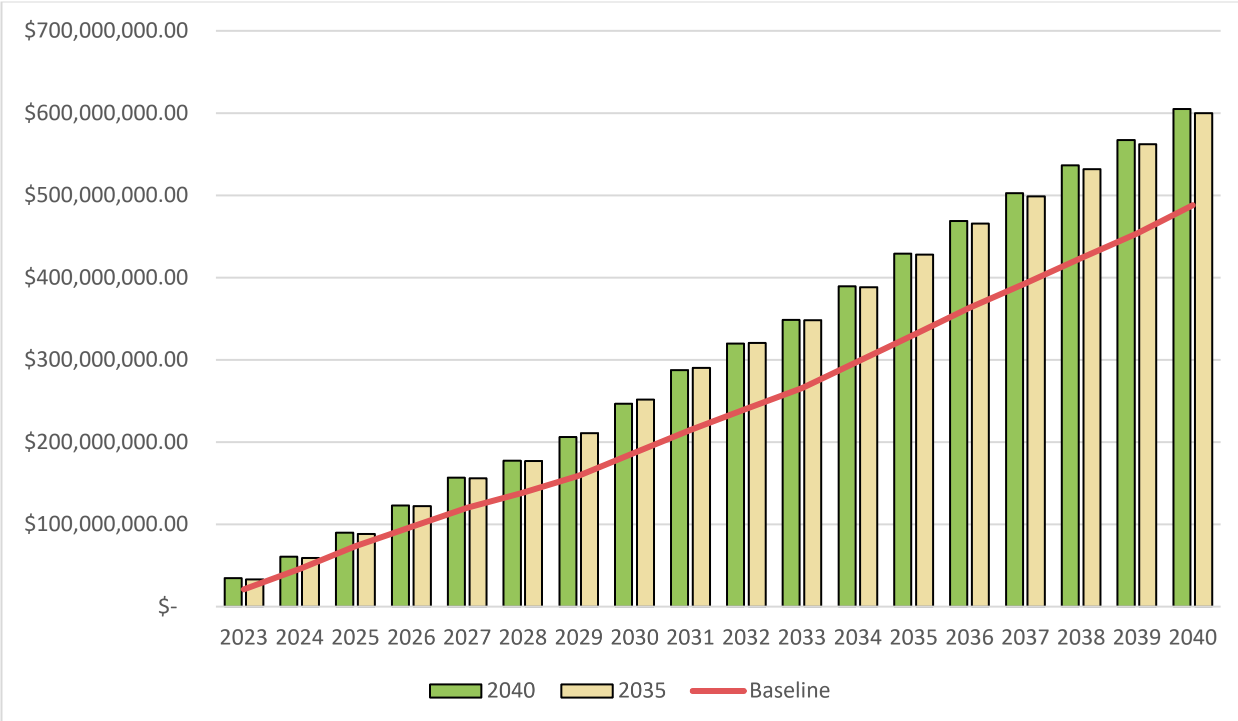

Figure 158. Cumulative Total Cost of Ownership by Scenario

Funding Strategies

Below are potential zero-emission vehicle and infrastructure funding opportunities available to the city of Glendale, CA. Use the links provided to find more information about the funding programs as well as information on how to apply.

HVIP: HVIP provides point-of-sale vouchers to buyers to allow zero emission vehicles to be more affordable. Voucher requests are currently open. While funding specifically allocated to drayage trucks and school buses have been fully subscribed, they can still be accepted and funded using the Standard HVIP funds. Eligible vehicles include: shuttle buses, vans, step vans, utility vehicles, box trucks, flatbed trucks, tractors, and more. Before applying, applicants will need to look through the vehicle catalog to view the electric vehicles that are approved for the program. Once a vehicle is chosen, the applicant will contact the approved dealer(s) to set up a purchase. Dealers will apply for the program on the purchaser's behalf.[3]

https://californiahvip.org/funding/#:~:text=HVIP%20will%20reserve%20%2425%20million,to%20fleets%20of%20any%20size, https://californiahvip.org/purchasers/

VW Environmental Mitigation Trust Funding: The VW Environmental Trusts provides over $400 million in funds to California for the state to mitigate excess nitrogen oxide emissions within the atmosphere that are caused by VW's illegal use of emissions testing defeat devices in some of the VW diesel vehicles. This funding is allocated mostly on "scrap and replace" projects for heavy duty vehicles such as school buses, shuttle buses, forklifts, and more. Funding from this project requires the existing vehicles/engines, except for ocean-going vessel shore power and light-duty zero-emission vehicle infrastructure, to be scrapped and replaced with zero emission vehicles.[4] https://ww2.arb.ca.gov/our-work/programs/volkswagen-environmental-mitigation-trust-california/how-apply-vw-environmental

LCFS ZEV Infrastructure Crediting: A zero-emission vehicle infrastructure crediting provision was added to the 2018 LCFS amendments in order to support zero-emission vehicle deployments. This new provision allows users to generate LCFS credit for all fuel dispensed along with infrastructure credits, which is calculated by subtracting the amount of dispensed fuel from the capacity of the station or charger. This provision applies to hydrogen refueling infrastructure and direct current fast charging infrastructure.[5]

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[3] "Funding Updates - Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project: California HVIP." Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project | California HVIP, August 23, 2022. https://californiahvip.org/funding/#:~:text=HVIP%20will%20reserve%20%2425%20million,to%20fleets%20of%20any%20size., "Purchasers - Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project: California HVIP." Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project | California HVIP, August 19, 2022. https://californiahvip.org/purchasers/.

[4] "How to Apply for VW Environmental Mitigation Trust Funding." How to Apply for VW Environmental Mitigation Trust Funding. Accessed August 23, 2022. https://ww2.arb.ca.gov/our-work/programs/volkswagen-environmental-mitigation-trust-california/how-apply-vw-environmental.

[5] "California Air Resources Board." LCFS ZEV Infrastructure Crediting | California Air Resources Board. Accessed August 23, 2022. https://ww2.arb.ca.gov/resources/documents/lcfs-zev-infrastructure-crediting.

https://ww2.arb.ca.gov/resources/documents/lcfs-zev-infrastructure-crediting, https://www.srectrade.com/markets/lcfs/california

Electric Vehicle (EV) Rebate Program: Through the Clean Fuel Reward Program, CARB offers point-of-sale rebates of up to $750 for the purchase or lease of a battery electric or plug-in hybrid vehicle. To be eligible for this rebate, the electric vehicle will need to have a battery capacity of at least 5 kWh and be purchased from participating retailers. Also, the buyer/leaser must reside in California and have the electric vehicle registered in California.[6] https://www.cleanfuelreward.com/

National Electric Vehicle Infrastructure Formula Program: This program provides funding to states to strategically deploy electric vehicle charging infrastructure and to establish an interconnected network to facilitate data collection, access, and reliability. There is $5 billion available in funding.[7] https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs

Discretionary Grant Program for Charging and Fueling Infrastructure ($2.5 billion): This competitive grant program provides funding to strategically deploy publicly accessible electric vehicle charging infrastructure and other alternative fueling infrastructure along designated alternative fuel corridors. At least 50 percent of this funding must be used for a community grant program where priority is given to projects that expand access to EV charging and alternative fueling infrastructure within rural areas, low- and moderate-income neighborhoods, and communities with a low ratio of private parking spaces.[8] https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs

The EPA's DERA Program funds grants and rebates: This program protects human health and improve air quality by reducing harmful emissions from diesel engines. The program can be used to replace heavy-duty diesel vehicles and

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[6] "Make Your Best Deal. Then Save up to $750 More." California Clean Fuel Reward | EV Rebates and Incentives. Accessed August 23, 2022. https://www.cleanfuelreward.com/.

[7] "Federal Funding Programs." U.S. Department of Transportation. Accessed August 23, 2022. https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs.

[8] "Federal Funding Programs." U.S. Department of Transportation. Accessed August 23, 2022. https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs.

equipment with electric vehicles and chargers. DERA has multiple grant programs for different types of applicants and projects including National Grants, Tribal and Insular Area Grants, State Grants, and School Bus Rebates.[9] https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs

Clean Vehicle Rebate Project (CVRP): The Clean Vehicle Rebate Project for Fleets offers rebates to public agencies, including local or state government entities in California for the purchase or lease of new, eligible zero-emission and plug-in hybrid light-duty vehicles. This program is sponsored by the California Air Resources Board (CARB) and administered by the Center for Sustainable Energy. At the time of lease or purchase, the vehicles must be new and operated and registered in the state of California for at least 30 months. Leased vehicles must be on a 30-month minimum agreement. Additionally, vehicles must be on the CVRP list of eligible vehicles. Facilities in disadvantaged communities in CA are eligible for increased rebates.[10] https://cleanvehiclerebate.org/en/fleet/public-agencies

Southern California Incentive Project (SCIP): The Southern Incentive Project (SCIP) offers rebates to entities in Los Angeles, Orange, Riverside, and San Bernardino counties for the purchase and installation of eligible public electric vehicle chargers. There is currently $29 million available in funds. Rebates include up to $70,000 per DC fast charger (DCFC) and up to $40,000 per DC fast charger. Some disadvantaged communities are eligible for rebates up to $80,000 per DC fast charger installation or 80% of total project cost, depending on the prices. Eligible applicants include public or government entities.[11] https://calevip.org/incentive-project/southern-california

[9] "Federal Funding Programs." U.S. Department of Transportation. Accessed August 23, 2022. https://www.transportation.gov/rural/ev/toolkit/ev-infrastructure-funding-and-financing/federal-funding-programs.

[10] "Public Fleets." Clean Vehicle Rebate Project. Accessed August 23, 2022. https://cleanvehiclerebate.org/en/fleet/public-agencies.

[11] "Southern California Incentive Project (SCIP)." CALeVIP. Accessed August 23, 2022. https://calevip.org/incentive-project/southern-california.

Appendix A: City of Glendale Vehicle Market Analysis

Fleet Summary

The City of Glendale's ("Glendale") fleet is comprised of 868 passenger-vehicles with an additional 155 trailers, parade vehicles, and equipment. The non-bus fleet is critical in the operations of the city's services and revenue producing fleets.

This section describes the vehicles used in the Glendale fleet, including physical characteristics and operating profiles of the vehicles relevant to assessing suitable electric alternatives. Analyzing the following variables is important for understanding whether a zero-emission alternative is available to replace Glendale's existing fleet:

- Passenger capacity
- ADA compliance
- Typical distance and time traveled per pullout
- Typical energy use per pullout

CTE analyzed the operational and deployment characteristics to assess the feasibility of zero-emission vehicles to meet requirements of Glendale's fleet and to develop a timeline for the transition.

Vehicle Types

Glendale's vehicles have been categorized into light-duty, medium-duty, heavy-duty, pursuit, and non-road vehicles. The specific vehicle and equipment types that make up each of these six categories are described below.

Light-Duty

Motorcycles. Motorcycles serve a variety of purposes including long-range travel, sport, and commuting. It is classified as a two or three wheeled motor vehicle. The City of Glendale operates 30 motorcycles in its fleet.

Sedans: Sedans are a broad group of vehicles built on standard car chassis, often with a sedan body. Sedans typically seat four to five passengers maximum. Because of their small size, passenger cars do not typically have space for wheelchairs or a wheelchair lift. The fleet consist of 108 sedans in total.

Pickup Trucks: Pickup trucks are motor vehicles with towing capacity that have an open cargo area in the rear. The chassis is typically constructed of channel or tubular rails and has the cab separated from the cargo section, which allows the chassis to flex under stress. Pickups are classified according to their payloads; the current categories in North

America include half-ton, three-quarter-ton, 1-ton, and 1-and-a-half-ton.[12] The Glendale fleet consists of 138 pickup trucks, making it the largest category that makes up the light duty vehicles.

Sport Utility Vehicles (SUVs): SUVs are often built on a light-duty truck chassis with a larger-volume body. These vehicles typically accommodate five to seven ambulatory passengers and can be equipped with a wheelchair lift. Glendale operates 39 SUVs in its fleet.

Vans: Vans are road vehicles used for transporting people and goods. There are 26 cargo mini-vans and 6 passenger mini-vans in the Glendale fleet to equal a total of 32 vans in the fleet.

Refuse Bin Trucks: Refuse trucks are light duty, utility vehicles that serve the sole purpose of removing waste. Glendale operates 8 refuse bin trucks in its fleet.

Medium-Duty

Medium-Duty Trucks: Medium-duty trucks are motor vehicles that refer to truck Classes 6-7, which have a gross vehicle weight rating (GVWR) range of 19,501- 33,000 lbs. Medium-duty trucks are used for lighter duty applications such as pickup and delivery trucks, small utility bodies, service bodies, small dump trucks, and lighter garbage truck applications due to a tight turning radius. Medium-duty trucks are ideal for almost any industry due to customizable features such as cab configurations, bodies, and chassis-mounted equipment.[13] Glendale has 96 medium-duty trucks including 67 pick-up trucks, 24 dump trucks, 3 mini-pumper fire trucks, and 2 other emergency vehicles.

Medium-Duty Vans/Buses: Medium-duty vans are on-road vehicles whose GVWR ranges from 10,001 lbs. to 26,000 lbs. Medium-duty vans can be used in passenger and cargo applications. Glendale has 41medium-duty vans.

Heavy-Duty

Heavy-Duty Trucks: Heavy-duty trucks are motor vehicles that refer to truck Class 8, which have a gross vehicle weight rating of 33,001+ lbs. Applications include 18-wheelers, sleeper cabs, dump trucks, and tractor trailers. [14] There are 122 heavy-duty trucks in the Glendale fleet including 5 dump trucks, 16 flatbed trucks, 10 manlift trucks,

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[12] https://www.kbb.com/what-is/pickup-truck/

[13] https://freightliner.com/blog-and-newsletters/what-is-a-medium-duty-truck/

[14] https://www.inlandtruck.com/blog/trucking-industry/heavy-duty-truck-classifications-explained/

[5]https://www.ford.com/police-vehicles/hybrid-utility/

7 crane trucks, 8 heavy trucks, 44 refuse trucks, 2 roll-off trucks, 25 emergency/firetrucks, and 5 street sweepers.

Pursuit Vehicles

Sedan – Pursuit: Sedan-pursuit vehicles are similar to general sedans, but are pursuit-rated (program designed by Ford) for police interceptor applications. The vehicle can sit 5 passengers. Pursuit vehicles may also include flashing lights. [15] There are 107 sedan-pursuit vehicles in the Glendale fleet.

SUV – Pursuit: SUV-pursuit vehicles are similar to general SUVs, but are pursuit-rated (program designed by Ford) for police interceptor applications. The vehicle can sit 5 passengers. Pursuit vehicles may also include flashing lights. [16] The Glendale fleet has 31 SUV-pursuit vehicles.

Non-Road Vehicles

Non-road vehicles are used for a variety of reasons including park maintenance, construction, public works projects, electric and water services, traffic safety, etc. Glendale's non-road fleet is comprised of 4 compressors, 102 trailers, 7 utility sweepers, 1 undefined police vehicle, 13 electric carts, 21 utility trucksters, 11 mowers, 8 bunker rakes, 23 loaders, 12 mobile construction equipment vehicles, 2 compact excavators, 12 forklifts, 3 parade antiques, and 32 miscellaneous engines.

Fleet Type Breakdown

Figure 1 shows a breakdown of Glendale's fleet by category. Light-duty vehicles make up the largest portion of the fleet (50%) followed by pursuit vehicles at 16%, heavy duty vehicles at 14%, non-road vehicles at 11%, and medium duty vehicles at 9%.

[15] https://www.ford.com/police-vehicles/hybrid-police-responder/

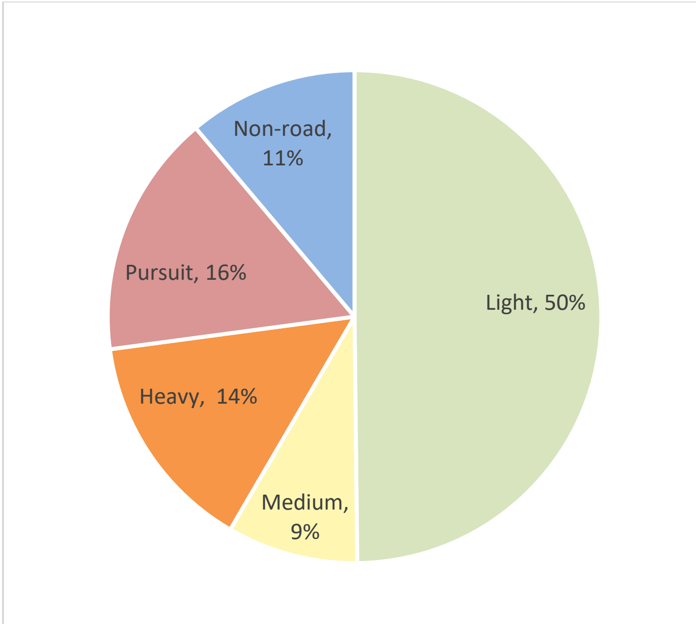

Figure A1. Glendale Fleet by Vehicle and Equipment Type

Figure 2 separates the light-duty fleet by subcategory, with the largest 9% (81) of which are sedans and 7% (60) compact pickups. The remaining subcategories (1 ton pickup, ½ ton pickup, ¾ ton pickup, cargo van, dump truck, flatbed, heavy truck, manlift truck, mini van, motorcycle, passenger minivan, refuse bin truck, SUV, and standard passenger vehicle) each make up 5% or less of Glendale's fleet.

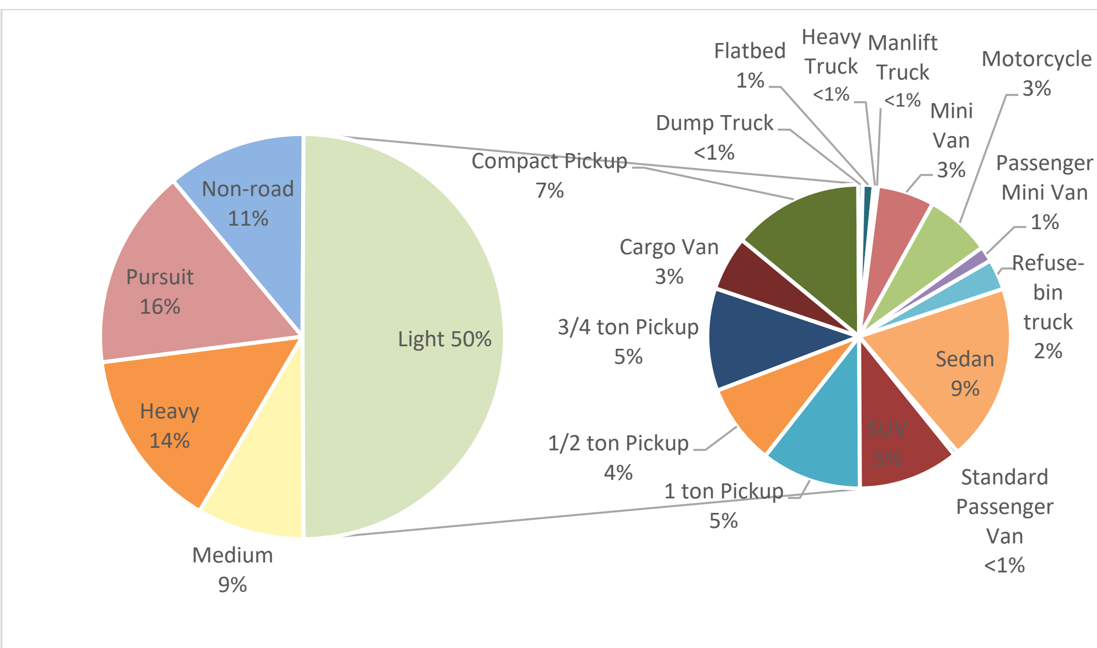

Figure A2. Glendale Fleet's Light-Duty Vehicle Makeup

Medium-duty vehicles make up 9% (74) of the City of Glendale fleet. These include 14 rescue vehicles, 12 walk-in vans, 12 heavy trucks, 12 dump trucks, 10 flatbeds, 8 manlift trucks, 5 specialty- medium duty vehicles, and one 1-ton pickup. Figure 3 shows this breakdown.

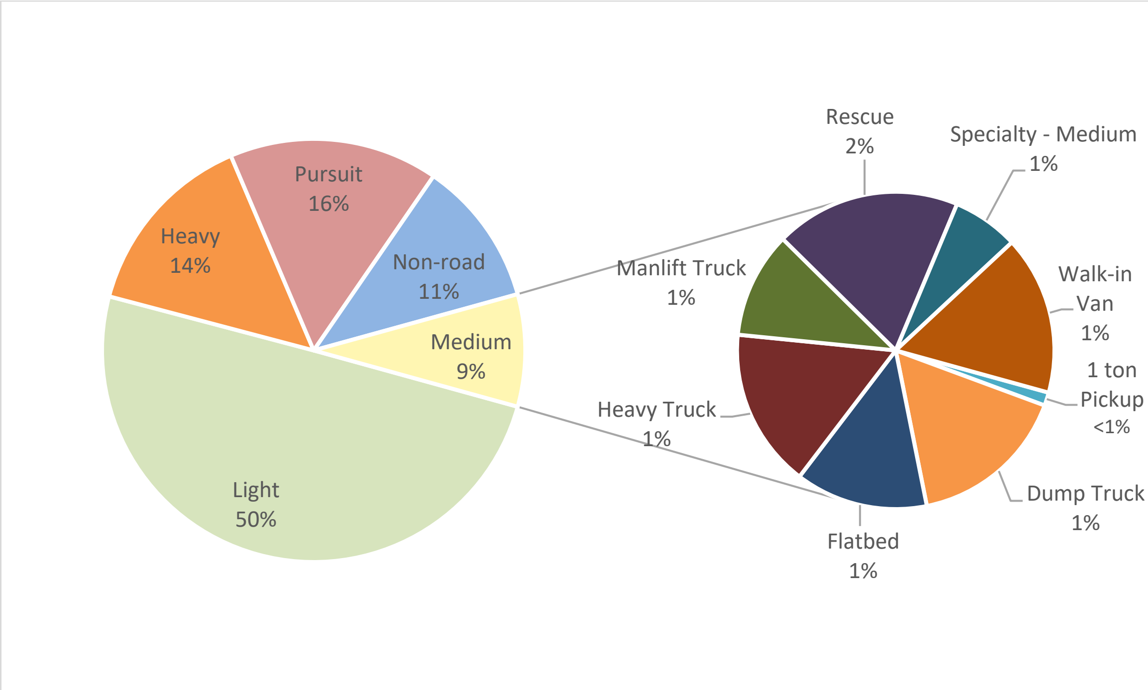

Figure A3. Glendale Fleet's Medium-Duty Vehicle Makeup

As seen in Figure 4, the Glendale fleet is 14% (125) heavy duty vehicles. These include 44 refuse trucks, 16 fire engines, 15 dump trucks, 14 heavy trucks, 10 manlift trucks, 7 crane trucks, 6 emergency specialty vehicles, 5 street sweepers, 4 ladder trucks, 2 roll-off trucks, 1 flatbed, and 1 walk-in van.

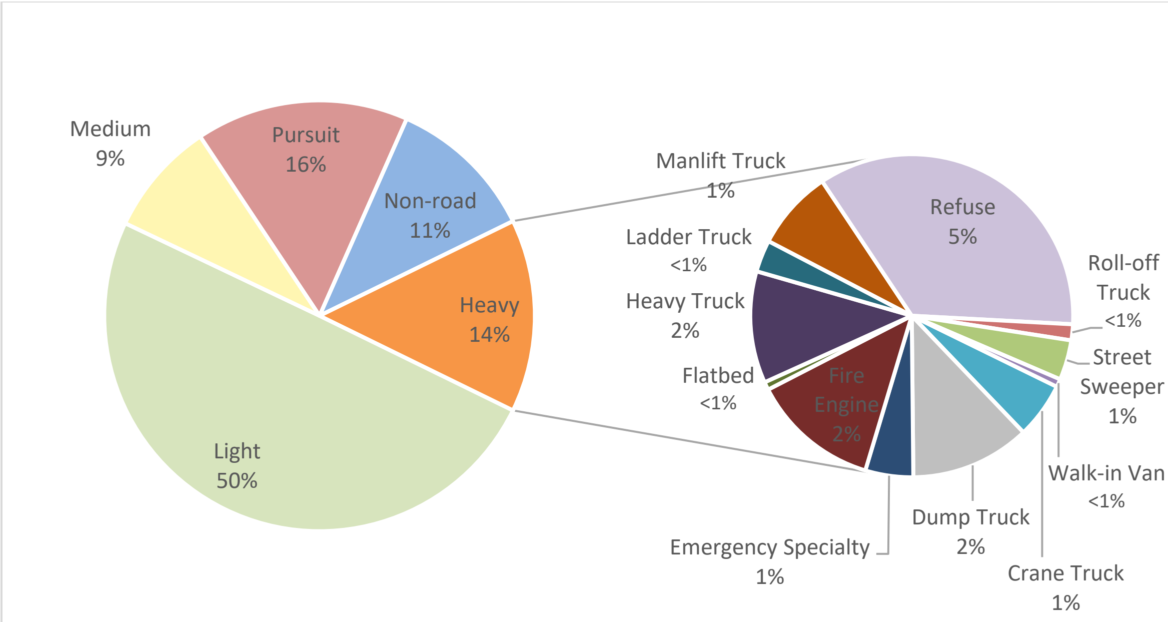

Figure A4. Glendale Fleet's Heavy-Duty Vehicle Makeup

The Glendale also has police pursuit vehicles that make up 16% (138) of the fleet – 15% (127) of which are SUVs and the remaining 1% (11) Sedans (Figure 5).

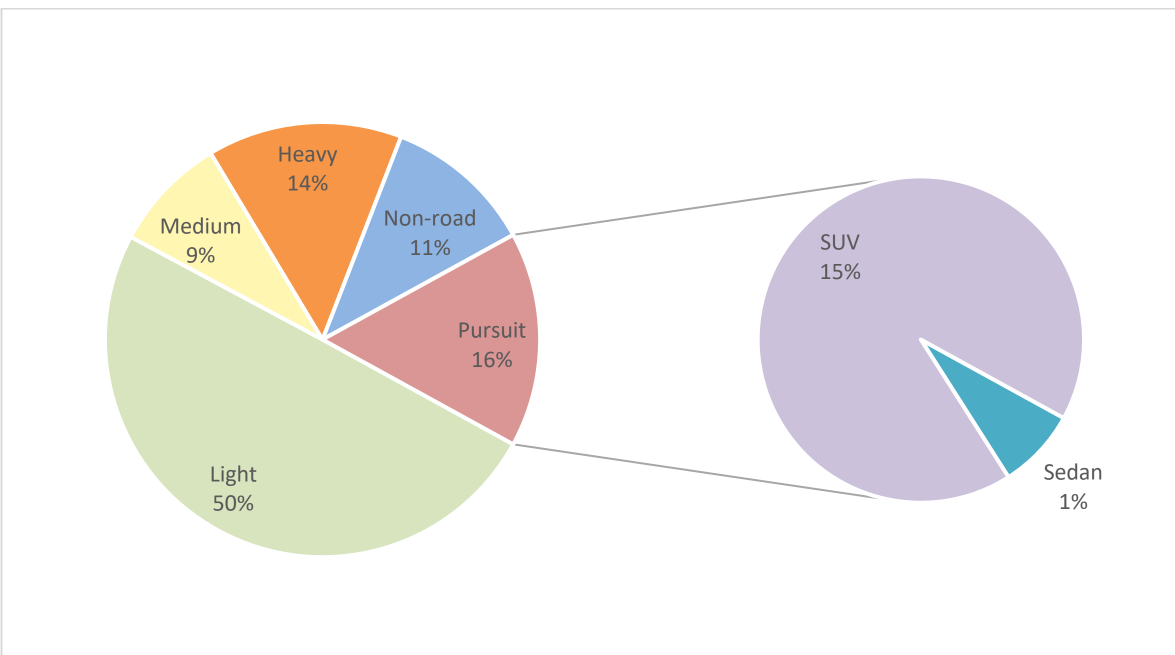

Figure A5. Glendale Fleet's Pursuit Vehicle Makeup

There are a variety of non-road vehicles within the Glendale fleet. See Figure 6 for a breakdown of the different types.

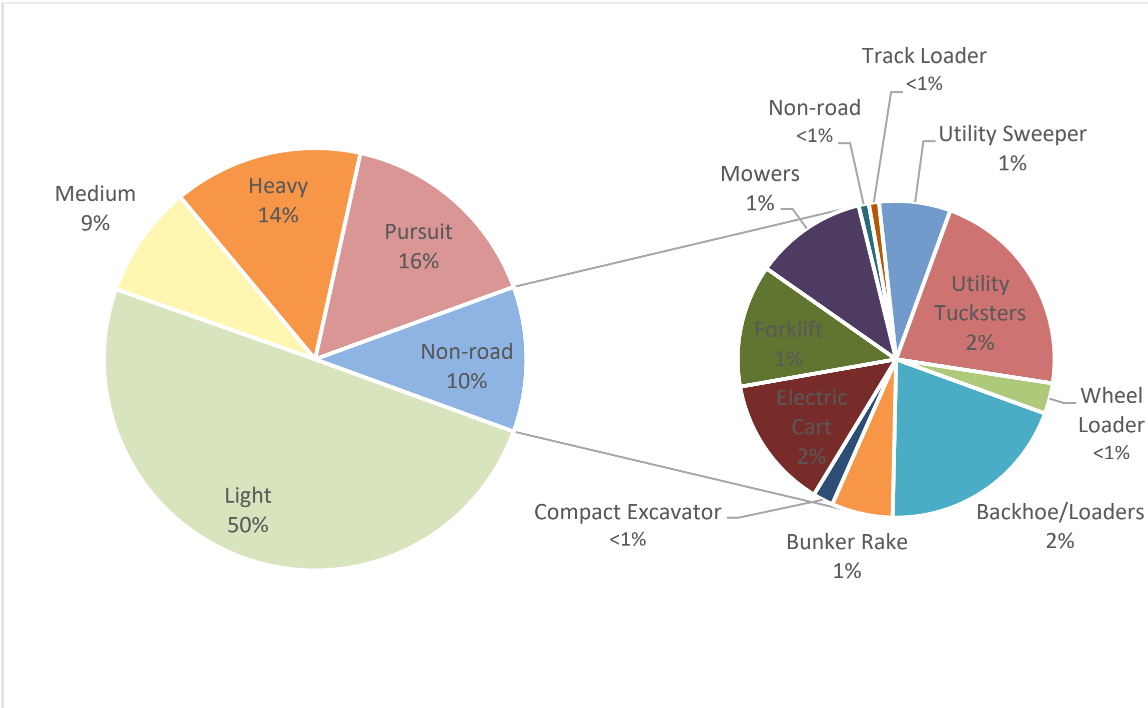

Figure A6. Glendale Fleet's Non-Road Vehicle Makeup

Types of Electric Vehicles

Battery Electric Vehicles

Battery Electric Vehicles (BEVs) are propelled by an electric motor using energy from a battery pack. The batteries are recharged by plugging into an electric power source, typically the local electric grid. BEVs emit no tailpipe emissions, however the well to wheel emissions depends on the source of energy to power the energy grid. All electric vehicles typically have a shorter range than conventional vehicle counterparts and can take several hours to fully charge once the battery is depleted. The technology continues to improve for longer range and high-power charging equipment is speeding up charging time.

Fuel Cell-Electric Vehicles

Fuel Cell-Electric Vehicles (FCEVs) like battery electric vehicles—are propelled by an electric motor. The difference between an FCEV and a BEV is that FCEVs generate power on board the vehicle using hydrogen and a fuel cell. The only tailpipe emission produced by this process is water vapor, making FCEVs a tank-to-wheel zero-emission vehicle. If the hydrogen consumed by an FCEV is produced using renewable energy, then the upstream emissions are close to zero.

In addition to environmental benefits such as zero tailpipe emissions and quieter operations, FCEVs possess other operational advantages. Because FCEVs generate power on board, they have an operational range similar to diesel buses with the same passenger capacity and performance in all weather and topographies. This similarity translates to a one-to-one FCEV-to-diesel replacement ratio, eliminating the need for an agency to change routes or schedules.

As a new technology, FCEVs come with two significant challenges—high capital costs and hydrogen availability. Commercial hydrogen production is relatively uncommon, operators often need to invest in their own fueling infrastructure. These high capital and operating costs are the primary reasons that more FCEVs have not been deployed by transit agencies in North America. In future years, there may be opportunity for the City of Glendale to pilot FCEVs as procurement and fuel logistics are addressed. For the time being, battery-powered electric vehicles have eclipsed FCEVs in terms of production and availability, especially for light-duty passenger vehicles.

Plug-In Hybrid-Electric Vehicles

Plug-in hybrid-electric vehicles (PHEVs) have generally been considered an important part of the light-duty passenger electric vehicle future. PHEVs typically allow vehicle owners to make short-range trips with the vehicle’s electric motors, while also providing the range security of a fossil fuel engine for longer trips. These capabilities mean drivers can reduce their fossil fuel consumption without making major travel behavior changes.

The PHEV's place in the future of light-duty passenger electric vehicles may be fading, however. Ongoing reductions in the per-kWh cost of vehicle batteries, significant consumer demand for long-range electric vehicles, and increases in the number of extended-range electric vehicle models are likely contributing to the current decline in PHEV sales and increasing plug-in electric vehicle (PEV) sales.

Plug-In Electric Vehicles

Plug-in electric vehicles are any vehicles that are recharged from an external source of electricity. Automakers appear to be projecting consumer demand for electric vehicles as favoring PEVs in the future and responding by shifting toward manufacturing extended-range PEVs. Electric automaker Tesla offers only PEVs, and the Chevrolet Volt, which was one of the top-selling North American light-duty passenger EVs, has been discontinued. As of the end of 2019, the Tesla Model 3, a PEV, was the top-selling light-duty passenger electric vehicle in the United States. Because PHEVs use the same plug-in charging infrastructure as PEVs, infrastructure development for an eventual 100% PEV fleet could be executed during a PHEV bridge period.

As of mid-2020, very few high-capacity, light-duty passenger PHEV models are on the market. The limited number of high-capacity, light-duty passenger PHEV models and automakers' growing preference for manufacturing extended-range PHEVs suggests that if City of Glendale were to use PHEVs as a bridge light-duty vehicles, their tenure would likely be short, and vehicle options would be limited.

Vehicle Type Availability

One of the most important factors for transition feasibility is electric vehicle availability. The market for electric vehicles varies greatly depending on the type of vehicle. A number of light-, medium-, and heavy-duty all-electric vehicles, plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs) are available from numerous automakers. However, there are some vehicle types that are still being piloted or tested.

Table A1 discusses vehicle availability for numerous vehicle types in the Glendale fleet.

Table A1. Key Findings for Vehicle Availability

Vehicle Availability Findings
Glendale's fleet is made up of a diverse array of vehicles, all of which have varying degrees of electric models currently available. We anticipate that electric vehicles will become more available over the coming years.
Light-Duty Vans: Currently, the only fully electric light-duty van commercially available is the 2022 Ford-E Transit Van. Other models like the Arrival Van, Brightdrop EV600 van, and ELMS Urban Delivery Van are set to launch in late 2022, however, they likely will not be commercially available until 2023 or 2024. Chrysler also announced that it will have a fully electric minivan on the market by 2024 as part of their move to transition to 100% electric. One alternative option to achieve lower emissions is to purchase plug-in hybrid (PHEV) minivans for the current life-cycle replacement. Using the PHEV minivans will not only allow drivers to learn more about electric vehicles without sacrificing range, but it will also encourage Glendale to start the infrastructure investments as well as reduce carbon emissions.
Passenger Cars: There are various electric vehicle options available to replace Glendale's current passenger vehicle fleet. There should be no limitation to transitioning Glendale's passenger cars to electric vehicles in the near term.
Pickup Trucks: Electric pickup trucks are on the brink of entering the market. It is expected that more models will be developed and become commercially available over the next few years. Currently the Rivian R1T and Lordstown Endurance are available for preorder, Tesla offers a cybertruck that will be available in 2023, GMC is releasing a pricier Hummer pick-up in late 2022, and Ram announced in early 2022 that they expect to launch a fully electric pick-up truck in 2024. Ford released the 2022 Lightning pickup that has an estimated 230 mile range and is currently available for preorder.
Sport Utility Vehicles (SUVs): The Hyundai Kona Electric SEL and Kia Niro EV are the largest electric passenger vehicles currently available. As the market develops, we fully anticipate to see more electric SUVs and electric 4-wheel drive vehicles become available. Based on the available technology, it is feasible to transition Glendale's SUVs to electric technology.
Medium-Duty Trucks: There are multiple medium duty electric chassis available on the market, though their price point is about 4 times that of their diesel equivalents.
Medium-Duty Vans: Few battery-electric alternatives are currently available for 12- or 15-passenger vans and minivans, and all are likely to cost over $200,000. However, electric cargo and passenger vans are available.

Heavy-Duty Trucks: Currently, the BYD 8TT, Lion 8, and Volvo VNR are fully electric Class 8 truck options. However, the electrification of this segment has been slower as a result of the higher energy needs. There are various pilot projects and early announcements from established manufacturers for electric Class 8 trucks happening now.

Pursuit Vehicles: There are no currently available pursuit rated vehicles, however, there are high performing vehicles (Tesla models and the Ford Mach-E) that can be upfitted to perform as needed. Cities around the country have started experimenting with different EV's as pursuit vehicle options. While the Nissan Leaf and Chevy Bolt are amongst some of the more popular vehicles for administrative purposes, the Tesla Model S and Model Y have become common pursuit vehicle replacements. Many of these electric pursuit vehicles are still being put through pilot programs. For example, NYPD is piloting a Tesla Model S, Menlo Park PD is piloting a Tesla Model Y, Westport Connecticut PD purchased a Tesla Model 3, Boulder PD purchased a Tesla Model Y Long Range, and Bargersville, Indiana PD purchased a Tesla Model S in 2018 and three more since then. The electric alternatives have shown to save money long-term, and cities have reported approval of the vehicles. However, outfitting and modifying the Tesla's for police use has presented a challenge across these different pilot programs and clear results from the pilot programs are still underway.

Attachment I: Market Research

EV Research

An industry review of battery-electric vehicles considered 35 road vehicles that could potentially support City of Glendale non-fleet services, as well as 42 battery electric non-road vehicles and equipment. The assessment considered 14 light-duty vehicles, 21 medium-duty vehicles, 7 heavy-duty vehicles, 7 pursuit vehicles, and 58 non-road vehicles and equipment. Vehicles identified in this report do not represent a complete inventory of available makes and models but represent promising battery-electric alternatives for existing City of Glendale fleets. Battery-electric vehicle options for service in Glendale's non-Bus fleets are described on the following pages and separated into five primary categories:

- **Light-duty vehicles** are small, light-duty, factory-direct passenger vehicles that accommodate up to seven passengers. Vehicles categorized as light-duty include light-duty vans, sedans, pickup trucks, and SUVs. Light-duty vans can be outfitted with wheelchair lifts but sedans typically cannot. These vehicle types are currently used in City of Glendale fleet programs.

- **Medium-duty vehicles** include medium-duty trucks, vans, and cutaways. Medium-duty trucks are motor vehicles that refer to truck Classes 6-7, which have a gross vehicle weight rating (GVWR) range of 19,501 to 33,000 lbs. Medium-duty trucks are used for lighter duty applications such as pickup and delivery trucks, small utility bodies, service bodies, small dump trucks, and lighter garbage truck applications requiring a tight turning radius. Medium-duty vans are on-road vehicles whose GVWR ranges from 10,001 lbs. to 26,000 lbs. Medium-duty vans can be used in passenger and cargo applications in transit vans. Cutaways are built on light truck chassis with specialized passenger cabs that accommodate ambulatory passengers, wheelchair passengers, or a mix of the two. These vehicles typically have wheelchair lifts and are commonly used for paratransit service.
- **Heavy-duty vehicles** include heavy-duty trucks—motor vehicles that refer to truck Class 8, which have a gross vehicle weight rating of 33,001+ lbs. Applications include 18-wheelers, sleeper cabs, dump trucks, and tractor trailers. [17]
- **Pursuit vehicles** refer to both SUVs and sedans that are pursuit-rated (program designed by Ford) for police interceptor applications. These vehicles can sit five passengers. Pursuit vehicles may also include flashing lights.[18]
- **Non-road vehicles** include a variety of vehicles that contain engines, but are designed for use on the roads. These vehicles include stockchasers, forklifts, golf carts, lawnmowers, manlifts, pallet jacks, pressure washers, push tractors, tractors, skid steers, and utility vehicles.

As part of this evaluation, CTE looked at high-level vehicle range per charge and cost ranges for the road vehicles which are provided in **Table A2** The information gathered came from a combination of manufacturer and seller marketing materials, press releases, and direct correspondence and conversations. Range figures in particular are often best-case scenarios and not always achieved on a consistent basis.

Table A2. Electric Vehicle Availability Summary Table

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[17] https://www.inlandtruck.com/blog/trucking-industry/heavy-duty-truck-classifications-explained/

[5]https://www.ford.com/police-vehicles/hybrid-utility/

[18] https://www.ford.com/police-vehicles/hybrid-police-responder/

Vehicle Type	Number of Models Assessed in This Document	Vehicle Range (miles)	Cost Range
Light-duty Vehicles	14	74-402*	$31,600-$69,900
Medium-duty Vehicles	21	66-190	$145,000-$300,000
Heavy-duty Vehicles	7	80-180	$250,000-$525,000
Pursuit Vehicles	7	46-391	$9,495-$105,000

Additional key findings include the following:

- **Electric medium- and heavy-duty vehicles are emerging markets in the U.S. that are in the early stages of development and use.** Battery-electric vehicles of these classes are just beginning to be used in the U.S., primarily by municipalities and transit agencies in California.
- **Many of the electric vehicles currently available in the medium- and heavy-duty vehicle classes are 'repowered,'** meaning they are built on an original equipment manufacturer (OEM) or factory truck chassis, such as those manufactured by Ford or Chevrolet. These vehicles are rebuilt with third-party electric drivetrains and have specialized passenger bodies installed. The process of rebuilding or 'repowering' an OEM chassis with an electric drivetrain involves removing the internal combustion engine and related parts and replacing them with an electric motor and drivetrain.
- **Not much experience exists to date with large-scale deployment.** There has not been widespread use of these vehicles in the transit industry to date and data is limited on cost and performance.
- **Vehicles have limited range and higher costs.** The vehicles currently available in the cutaway and van classes have limited driving range between charges and are comparably higher cost than the fossil-fuel alternative.
- **Few vehicles have been through federal testing.** The FTA conducts bus testing, often referred to as Altoona testing. To be eligible for federal funding, vehicles must successfully pass the FTA testing and must also satisfy Buy America guidelines. At the time of this report, one large van (the GreenPower EV Star) had successfully completed Altoona testing. To date, none of the repowered battery-electric ADA paratransit vehicles have yet been Altoona-tested or certified to meet the Buy America requirements.
- **Repowered vehicles offer a familiar configuration for customers.** Repowered vehicles often maintain the popular passenger body and ramp designs used by conventional ADA paratransit vehicles, and many of the non-drivetrain parts and systems are industry standard.
- **Third-party electrification repowers are generally performed by smaller companies that may not be able to offer the warranty, maintenance, and parts**

support that larger OEMs can provide for factory-direct battery-electric vehicles. Purchasing and maintaining vehicles from third-party repower manufacturers may be logistically challenging at the scale required to support Glendale's fleet.

Table A3. Light Duty Vehicle Data

Criteria	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Light-Duty Vehicles					
2022 Chevy Bolt A four-door hatchback that is widely available in the U.S.	Up to five ambulatory passengers, including driver	No	259 miles	Available	$31,995
2022 Hyundai Ioniq SE Standard Range Four-door sedan.	Up to five ambulatory passengers, including driver	No	220 miles	Available in CA	$39,700
2022 Hyundai Kona Electric A crossover SUV.	Up to five ambulatory passengers, including driver	No	258 miles	Available in CA	$34,000
2022 Kia Niro EV A subcompact crossover vehicle.	Up to five ambulatory passengers, including driver	No	239 miles	Available	$39,990
2022 Nissan Leaf S, SV, S Plus, and SV Plus A four-door hatchback in widespread use throughout the U.S; available in four models with varying cost, range, and features.	Up to five ambulatory passengers, including driver	No	149-226 miles	Available	$27,400-$43,970
2021 Toyota Mirai Fuel Cell A four-door fuel cell electric vehicle	Up to five ambulatory passengers, including driver	No	357-402	Available	$49,500-$66,000
2022 Hyundai Nexo Fuel Cell A four-door fuel cell electric vehicle with the highest estimated range of any fuel cell vehicle on the market	Up to five ambulatory passengers, including driver	No	380	Available in CA	$59,435

Ford Mustang Mach-e Select An electric compact crossover SUV produced by Ford. The car won the 2021 North American SUV of the Year Award	Up to five ambulatory passengers, including drivers	No	247-300	Available	$43,895
2021 Chrysler Pacifica Hybrid A seven-passenger plug-in hybrid electric vehicle. Although not a fully electric vehicle, its nameplate range without engaging the internal combustion engine is 32 miles.	Up to seven ambulatory passengers, including driver	No	32 miles using battery-only	Available	$36,240-$45,400
2021 Toyota Sienna Hybrid Minivan is built with a standard hybrid-electric powertrain	Up to seven ambulatory passengers, including driver	Yes, but must be installed in lieu of ambulatory seating	Not yet released	Available	$35,000
Lordstown Endurance A light-duty pick-up truck.	Up to five ambulatory passengers, including driver	No	250 miles	Limited availability-preorder only	$55,000
Tesla Cybertruc A light-duty pick-up truck.	Up to six ambulatory passengers, including driver	No	250-500 miles	Unavailable until 2023-Reservations are now open	$69,900
Rivian R1T Truck A light-duty pick-up truck.	Up to five ambulatory passengers, including driver	No	314 miles	Limited availability-preorder only	$67,500
Ford-E Transit Van A cargo van that can seat up to seven	Up to seven ambulatory passengers, including driver	Yes, but must be installed in lieu of ambulatory seating	74-126 miles	Available	$47,185

Light-Duty Vehicles

Light Duty: Sedans/SUV's

Chevy Bolt

The 2022 Chevy Bolt is a four-door hatchback that is widely available in the U.S. and has a range of up to 259 miles. The Chevy Bolt EV is smaller compared to the Chevy Bolt EUV which offers a smaller range of 247 miles.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	65kWh
Approx. nameplate single-charge range	259 miles
Length	~14'
Approx. cost	$31,995
Availability	Available

Source: https://www.chevrolet.com/electric/bolt-ev

Image source: https://www.chevrolet.com/content/dam/chevrolet/na/us/english/index/vehicles/2020/cars/bolt-ev/colorizer/01-images/2020-bolt-2lz-gpj-colorizer.jpg?imwidth=600

Hyundai Ioniq SE Standard Range

The Hyundai Ioniq is four-door, battery-electric sedan manufactured in South Korea. The 2022 Hyundai Ioniq is four-door, battery-electric sedan manufactured in South Korea. The 2021 edition offers a smaller range of 170 miles but is more affordable with a starting MSRP of $33,245.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	58kWh
Approx. nameplate single-charge range	220 miles
Length	15’
Approx. cost	$37,700
Availability	Available

Source: <https://www.hyundaiusa.com/us/en/vehicles/ioniq-electric>, <https://www.hyundaiusa.com/us/en/vehicles/ioniq-electric/compare-specs>

Image source: https://www.hyundaiusa.com/us/en/build/summary/#/379H1N3O1M0

Hyundai Kona Electric SEL

The Hyundai Kona is a crossover SUV manufactured in South Korea.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	64kWh
Approx. nameplate single-charge range	258 miles
Length	~14’
Approx. cost	$34,000
Availability	Available

Source: <https://www.hyundaiusa.com/us/en/vehicles/kona-electric>, <https://www.hyundaiusa.com/us/en/vehicles/kona-electric/compare-specs>

Image source: https://www.hyundaiusa.com/us/en/build/summary/#/368A1N1F1Q0

Kia Niro EV

The Kia Niro is a subcompact crossover vehicle manufactured in South Korea.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	64kWh
Approx. nameplate single-charge range	293 miles
Length	~14'
Approx. cost	$39,900
Availability	Available

Source: <https://www.kia.com/us/en/niro-ev>, <https://www.kia.com/us/en/niro-ev/specs>

Image source: https://www.kia.com/us/en/niro-ev/build

Nissan Leaf S, SV, S Plus, SV Plus, and SL Plus

The Nissan Leaf is a four-door hatchback in widespread use throughout the U.S. This vehicle is available in five (5) models with varying cost, range, and features, and is manufactured in Tennessee.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	40kWh-62kWh
Approx. nameplate single-charge range	149-226 miles
Length	~15'
Approx. cost	$27,400-$43,970
Availability	Available

Source: <https://www.nissanusa.com/vehicles/electric-cars/leaf.html>, <https://apps.des.wa.gov/CARS/ContractVehicleMenu.aspx>

Image source: https://www.nissanusa.com/vehicles/electric-cars/leaf/specs/compare-specs.html#modelName=S|40%20kWh,SL%20PLUS|62%20kWh

2021 Toyota Mirai

The 2021 Toyota Mirai is a zero-emission vehicle that has a range of up to 402 miles after roughly five minutes of refueling.

Specification	Specification Value(s)
Passenger capacity	Five, including driver
Lift-capable?	No
Battery size	n/a
Approx. nameplate single-charge range	402
Length	~16’
Approx. cost	$49,500- $66,000
Availability	Available

Sources: https://www.toyota.com/mirai/

Image source: https://www.toyota.com/mirai/

2022 Hyundai Nexo Fuel Cell

The 2021 Hyundai Nexo is the world’s first dedicated hydrogen-powered SUV with an estimated range of 380 miles. It is available at select California dealers.

Specification	Specification Value(s)
Passenger capacity	Five, including driver
Lift-capable?	No
Battery size	135 kW (95 kW stack + 40 kW battery)
Approx. nameplate single-charge range	380
Length	~15’
Approx. cost	$58,935
Availability	Available

Sources: https://www.hyundaiusa.com/us/en/vehicles/nexo/blue

Image source: https://www.hyundaiusa.com/us/en/vehicles/nexo/blue

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Ford Mustang Mach-E

The Ford Mustang Mach-e is a sport utility vehicle with a range between 211- 305 miles battery only. It was first released in 2021, but currently has a newer 2022 model.

Specification	Specification Value(s)
Passenger capacity	Up to five ambulatory passengers, including driver
Lift-capable?	No
Battery size	70 kWh
Approx. nameplate single-charge range	247-300 miles
Length	~15’
Approx. cost	$43,895
Availability	Available

Source: https://www.ford.com/suvs/mach-e/

Image source: https://www.ford.com/suvs/mach-e/

Light Duty: Mini- Vans

Chrysler Pacifica Hybrid

The Chrysler Pacifica Hybrid is plug-in hybrid electric vehicle (PHEV) manufactured in Windsor, Canada. Although not a fully EV, its range without engaging the internal combustion engine is 32 miles and has a 2021 and 2022 model.

Specification	Specification Value(s)
Passenger capacity	Up to seven ambulatory passengers, including driver
Lift-capable?	No
Battery size	16kWh
Approx. nameplate single-charge range	32 miles using battery-only
Length	~17'
Approx. cost	$36,240-$45,400
Availability	Available

Sources: https://www.chrysler.com/pacifica/hybrid.html

Image source: https://www.chrysler.com/pacifica/hybrid.html

2021 Toyota Sienna Hybrid

The 2021 Toyota Sienna minivan is built with a standard hybrid-electric powertrain, has an EPA-estimated 36 combined mpg rating, and 3500 lbs. of towing capacity

Specification	Specification Value(s)
Passenger capacity	Seven, including driver
Lift-capable?	Yes, but with reduction in ambulatory passenger capacity
Battery size	N/A
Approx. nameplate single-charge range	Up to 36 miles
Length	~17'
Approx. cost	$34,460

Availability	Available

Sources: https://www.toyota.com/sienna/

Image source: https://s3.amazonaws.com/toyota-cms-media/wp content/uploads/2020/05/2021_Toyota_Sienna_Limited_01.jpg

Light Duty: Pick-up Trucks

Lordstown Endurance

The Lordstown Endurance truck is a fully electric, light-duty pick-up truck that is available for preorder.

Specification	Specification Value(s)
Passenger Capacity	Up to 5
Battery Size	X
Approx. Nameplate Single-Charge Range	250+ miles
Length	X
Approx. Cost	$55,000
Availability	Limited availability- preorder only

Source:<https://insideevs.com/news/389264/lordstown-endurance-at-least-200-miles-epa/>
https://lordstownmotors.com/pages/endurance

Tesla Cybertruck

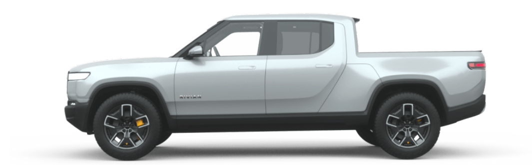
The Tesla Cybertruck is a fully electric, light-duty pick-up truck that is available for preorder.

Specification	Specification Value(s)
Passenger Capacity	Up to 6
Battery Size	Est. 200 kWh
Approx. Nameplate Single-Charge Range	250 – 500+ miles (EPA Est.)
Length	231.7"
Approx. Cost	$69,900
Availability	Preorder is available today, with the single motor rear-wheel drive production planned to begin in late 2022, and the dual and tri motor production in late 2021.

Source : <https://www.tesla.com/cybertruck>

https://www.cars.com/articles/tesla-cybertruck-impressive-specs-killer-price-polarizing-looks-413819/

Rivian R1T Truck



The Rivian R1T truck is a fully electric, light-duty pick-up truck that is available for preorder.

Specification	Specification Value(s)
Passenger Capacity	Up to 5
Battery Size	105 – 180 kWh
Approx. Nameplate Single-Charge Range	314 miles
Length	217.1"
Approx. Cost	$67,500
Availability	Limited availability- preorder only

Source : https://rivian.com/r1t/ https://www.caranddriver.com/rivian/r1t

Light Duty: Vans

Ford E-Transit

The 2022 E-Transit is a work-ready cargo van that comes with three roof heights, three (3) lengths, and chassis cab and cutaway models. It offers the same interior cargo dimensions and standard mounting points for continued integration with hundreds of upfitters and vehicle modifiers worldwide who provide compatible racks, bins and accessories on gas-powered Transit. E-Transit features both AC and DC fast charging, coming standard with a Ford Mobile Charger that can plug into a normal 120-volt outlet for slow and steady charging or into a 240-volt outlet for faster charging.

Specification	Specification Value(s)
Passenger capacity	Seven, including driver
Lift-capable?	Likely but with reduction in ambulatory passenger capacity
Battery size	N/A
Approx. nameplate single-charge range	74-126 miles
Length	~17’
Approx. cost	$47,185
Availability	Available

Sources: https://www.ford.com/commercial-trucks/e-transit/2022/?fmccmp=lp-commercial-mid-hp-etransit

Image source: https://www.foxnews.com/auto/ford-e-transit-electric-van

Medium Duty Vehicles (Cutaways, Shuttles, Chassis, Trucks)

Criteria	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Medium Duty Vehicles (Cutaways, Shuttles, Chassis, Trucks)					
Phoenix Motorcars Zeus 400 Shuttle Bus Electric cutaway that incorporates a Ford E-series chassis and Starcraft passenger body.	Up to two wheelchair and 12 ambulatory passengers.	Yes	Up to 160 miles	Available	~$300,000
Lightning Electric Ford E-450 Shuttle Bus An electric cutaway built on a Ford E-450 chassis.	Two wheelchairs and 12 ambulatory passengers	Yes	80 or 120 miles, depending on battery option.	Available	$230,000
Lightning Electric Ford F-550 Shuttle Bus Built on a Ford F-550 chassis, allowing for more passenger capacity than an E-450.	Two wheelchairs and 20-30 ambulatory passengers.	Yes	100 miles	Available	$270,000
Micro Bird DS-Series Paratransit The Micro Bird DS-Series electric shuttle bus is a lift-equipped cutaway built on a Ford or GM chassis.	Two wheelchairs and 12 ambulatory passengers	Yes	n/a	n/a	n/a
Motiv Power EPIC E-450 Shuttle Bus A Ford E-450 platform with a Champion passenger body.	More info needed from manufacturer	Yes. Wheelchair lift typically in the rear.	85 miles	Available	~$250,000
SEA E450 Shuttle Bus Built on a Ford E-450 chassis with the SEA-Drive 100 electric drivetrain.	Two wheelchairs and 12 ambulatory passengers	Yes	130-170 miles	Available	$200,000
BYD 5F Chassis Class 5 truck.	Up to two ambulatory passengers, including driver	No	155 miles	Available	$165,400
BYD 6F Chassis Class 6 truck.	Up to two ambulatory passengers, including driver	No	124 miles	Available	$165,400

Lightning Chevrolet 6500XD Low Cab Forward Class 6 truck built on Chevrolet 6500XD Low Cab Forward platform	Up to two ambulatory passengers, including driver	No	66-130 miles	Available	$180,000-$280,000
Lightning Ford E-450 Cutaway, Stripped Chassis A stripped, Ford E-450 chassis.	Up to two ambulatory passengers, including driver	No	80-120 miles	Available	$180,000
Motiv EPIC E-450 Box Truck Box truck built on Ford's E-450 platform.	Up to two ambulatory passengers, including driver	No	100 miles	Available	N/A
Motiv EPIC E-450 Work Truck Work truck built on Ford's E-450 platform and is available in several configurations.	Up to two ambulatory passengers, including driver	No	100 miles	Available	N/A
Motiv EPIC F-53 Specialty Vehicle A specialty vehicle built on an EPIC F-53 chassis and is available in several configurations.	N/A	Yes	105 miles	Available	N/A

Medium Duty Vehicles (Large Vans)

Criteria	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Medium Duty Vehicles (Large Vans)					
Greenpower EV Star ADA Large passenger van built entirely by Greenpower. Altoona testing completed in the winter of 2020.	Two wheelchairs and 12 ambulatory passengers	Yes – side or rear	77-150 miles	Available	$200,000
SEA Electric Ford Transit The SEA Electric Ford Transit is built on a Ford Transit chassis and incorporates a SEA-Drive 70 electric drivetrain.	Two wheelchair and 9 ambulatory passengers. Ambulatory positions can be eliminated to add wheelchair	Yes	190 miles	Available	$160,000
Lightning Electric Ford Transit The Lightning Electric Ford Transit is a large passenger van built on the Ford Transit platform. Also available as a cargo van.	One wheelchair and 4 ambulatory passengers, or up to 15 ambulatory passengers	Yes	60-120 miles	Available	$145,000-$173,000
Lightning Electric Ford F-59 Step Van Step Van bult on Ford's F-59 platform.	Up to two ambulatory passengers, including driver	No	110 miles	Available	$200,000
Motiv EPIC F-59 Step Van Step Van bult on Ford's F-59 platform.	Up to two ambulatory passengers, including driver	No	90 miles	Available	N/A
Motiv EPIC Ford E-450 Step Van Step Van bult on Ford's E-450 platform.	Up to two ambulatory passengers, including driver	No	100 miles	Available	N/A
Workhorse C1000 Step Van built entirely by Workhorse.	Up to two ambulatory passengers, including driver	No	150 miles	Available	N/A

Workhorse C650 Step Van built entirely by Workhorse.	Up to two ambulatory passengers, including driver	No	150 miles	Available	N/A
Xos SV01 Step Van Step Van built entirely by Workhorse.	Up to two ambulatory passengers, including driver	No	200 miles	Available	N/A

Medium-Duty Vehicles

Cutaways and Small Buses

Note: Because re-powered vehicles are not in widespread use and there have been few—if any—formal evaluations of their performance, specifications such as range and cost are not consistently available for these vehicles. Throughout this document, the letters N/A are substituted when information is not available or not considered reliable.

Phoenix Motorcars Zeus 400 Shuttle Bus

The Phoenix Motorcars Zeus 400 is an electric cutaway that incorporates a Ford E-series chassis and Starcraft passenger body. Phoenix Motorcars is a California-based company that electrifies vehicles in Ontario, CA. These vehicles are available with both rear or side lifts.

Phoenix offers the Zeus 400 with four battery pack sizes, from 63kWh to 156kWh. The weight of the largest battery pack reduces the number of passengers that can be accommodated in the vehicle due to maximum load restrictions of the chassis. More passengers can be included in a vehicle with a small battery pack.

This vehicle is currently being used in California and Texas airports, City of Redlands, and City of Santa Cruz.

Specification	Specification Value(s)
Passenger capacity	Up to two wheelchair and 12 ambulatory passengers with a 156kWh battery. The number of wheelchair positions can be increased if ambulatory positions are eliminated.
Lift-capable?	Yes, with rear or side configurations
Battery size	63kWh, 94kWh, 125kWh, and 156kWh
Approx. nameplate single-charge range	70 miles, 100 miles, 130 miles, 160 miles
Length	23’ to 25’
Approx. cost	$300,000[19]

[19] The cost of the Phoenix Motorcars electric drivetrain conversion is reported to be approximately $150,000, and the highest cost for a medium-duty 24-passegenger cutaway bus in Washington State’s current Department of Enterprise Services contract #04115 is approximately $150,000 (the lower end of the range is approximately $80,000). Using these figures, a conservative estimate for the cost of this vehicle is $300,000.

Availability	In use at California and Texas airports, City of Redlands, and City of Santa Cruz

Sources: <http://www.phoenixmotorcars.com/products/>
<https://www.latest.facebook.com/PhoenixMotorcarsZEUS/LightningElectric Ford E-450 Shuttle Bus>
<http://www.phoenixmotorcars.com/city-of-redlands-receives-1st-electric-shuttle-bus/>
Correspondence with Phoenix Motorcars and Creative Bus Sales, Image source:
http://www.phoenixmotorcars.com/wp-content/uploads/2017/08/vehicle-01.jpg

Lightning Electric Ford E-450 Shuttle Bus

The Lightning Electric Ford E-450 shuttle bus is an electric cutaway built on a Ford E-450 chassis. Lightning Electric is headquartered in Loveland, CO.

Specification	Specification Value(s)
Passenger capacity	Typically, two wheelchair and 12 ambulatory passengers, with a 129kWh battery pack. Ambulatory positions can be removed to add wheelchair positions.
Lift-capable?	Yes
Battery size	125kWh or 157kWh
Approx. nameplate single-charge range	80 or 120 miles, depending on battery size.
Length	25’
Approx. cost	$230,000
Availability	Available

Sources: <https://lightningsystems.com//lightningelectric-e450-shuttle/>,
<https://petaluma.granicus.com/MetaViewer.php?view_id=31&clip_id=2728&meta_id=424736>,
Correspondence with Lightning Systems

Image source: https://lightningsystems.com/wp-content/uploads/2019/11/E450_shuttle_600px.png

Lightning Electric Ford F-550 Shuttle Bus

The Lightning Electric Ford F-550 shuttle bus is a larger version of the Lightning Electric E-450 high-floor electric cutaway. The vehicle is built on a Ford F-550 chassis, allowing for more passenger capacity than an E-

450, in a similar vehicle. Lightning Electric is headquartered in Loveland, CO.

Specification	Specification Value(s)
Passenger capacity	Commonly, two wheelchair and 20-30 ambulatory passengers
Lift-capable?	Yes
Battery size	160kWh or 192kWh
Approx. nameplate single-charge range	100 miles
Length	32’
Approx. cost	$270,000
Availability	Available

Sources: <https://lightningsystems.com/lightningelectric-f-550-bus/>, Correspondence with Lightning Systems

Image source: https://lightningsystems.com/wp-content/uploads/2019/11/F550_bus2.png

Micro Bird DS-Series Paratransit

The Micro Bird DS-Series electric shuttle bus is a lift-equipped cutaway built on a Ford or GM chassis. The wheelchair lift on this vehicle is typically installed behind the rear axle. Micro Bird Bus is a joint venture between U.S. school bus manufacturer Blue Bird and Canadian bus maker Girardin. These vehicles are primarily manufactured in Canada. Further information on this vehicle is needed from the manufacturer.

Specification	Specification Value(s)
Passenger capacity	12 passengers + 2 w/c
Lift-capable?	Yes
Battery size	88kWh
Approx. nameplate single-charge range	N/A
Length	24’-29’
Approx. cost	N/A
Availability	N/A

Sources: <https://mbcbus.com/product/d-series/>

Image source: https://mbcbus.com/wordpress/wp-content/uploads/2014/09/Microbird-G5-with-Lift-Door-streamer_with-stripes-1140x676.jpg

Motiv Power EPIC E-450 Shuttle Bus

The Motiv Power Electric Powered Intelligent Chassis (EPIC) E-450 shuttle bus is built on the Ford E-450 platform with a Champion passenger body. The wheelchair lift on this vehicle is typically installed behind the rear axle. Motiv Power is based in Foster City, CA. Further information on this vehicle is needed from the manufacturer.

Specification	Specification Value(s)
Passenger capacity	N/A
Lift-capable?	Yes
Battery size	127kWh
Approx. nameplate single-charge range	85 miles
Length	N/A
Approx. cost	$250,000[20]
Availability	In use in Mountain View, CA and other California locations.

Sources: <https://www.motivps.com/motivps/portfolio-items/epice450-allelectric-shuttlebus/>,
<https://www.trucks.com/2018/05/30/motiv-profits-demand-electric-trucks-buses/>,
Correspondence with Creative Bus Sales

Image source: <http://www.motivps.com/motivps/wp-content/uploads/2019/06/E450-Champion-shuttle-right-edited-NEW-1000x700.png>

SEA E450 Shuttle Bus

The SEA Electric E450 shuttle bus is built on a Ford E-450 chassis with the SEA-Drive 100 electric drivetrain. Although SEA Electric is an Australian company, this vehicle is primarily manufactured in the U.S.

Specification	Specification Value(s)

[20] The cost of the Motiv Power electric drivetrain conversion is reported to be approximately $150,000, and the highest cost for a light-duty 12-passegenger cutaway bus in Washington State's current Department of Enterprise Services contract #04115 is approximately $100,000 (the lower end of the range is approximately $60,000). Using these figures, a conservative estimate for the cost of this vehicle is $250,000.

Passenger capacity	Typically, two wheelchair and 12 ambulatory passengers. Ambulatory positions can be eliminated to add wheelchair positions.
Lift-capable?	Yes
Battery size	100kWh
Approx. nameplate single-charge range	130-170 miles
Length	N/A
Approx. cost	$200,000
Availability	Available

Source: <https://www.sea-electric.com/wp-content/uploads/2019/10/E4B-Commuter-Bus-ebrochure-AU.pdf>, <https://www.carsales.com.au/editorial/details/aussie-ev-maker-plans-new-production-facility-in-latrobe-valley-115381/>

Image source: <https://www.sea-electric.com/wp-content/uploads/2019/10/SEA-E4B-FRONTFWY.jpg>

Xos SV01 Battery-Electric Step Van

The Xos SVO Battery- Electric Truck is a class 6, 100% zero emissions delivery van. It is built on an X-Platform 1 chassis which is specifically designed to accommodate a variety of medium duty bodies such as last mile parcel, textile & linen and food & beverage.

Specification	Specification Value(s)
Passenger capacity	2
Lift-capable?	n/a
Battery size	90 kWh, 120 kWh, 150 kWh, 180 kWh
Approx. nameplate single-charge range	200 miles
Length	N/A
Approx. cost	$XX
Availability	Available

Source: https://californiahvip.org/wp-content/uploads/2020/09/MY20-Xos-SV01-ZE-200702.pdf

Image source: https://californiahvip.org/vehicles/xos-sv01-battery-electric-truck/

Large Vans

GreenPower EV Star ADA

The EV Star ADA vehicle is a large passenger van built entirely by GreenPower. This vehicle recently passed Altoona testing, which provides some demonstrated range figures.[21] During the testing process, this vehicle was tested under Manhattan, Orange County, and EPA Heavy-Duty Urban Dynamometer Driving Schedule (HD-UDDS) testing conditions, achieving ranges of 96, 120, and 153 miles, respectively. The Manhattan test cycle simulates a low average speed urban driving context, while the Orange County test cycle simulates a combination of highway and urban driving conditions. The EPA HD-UDDS test simulates longer periods of higher-speed driving.

EV Star vehicles undergo final assembly in California and are Buy America-compliant. At the time of this report, GreenPower estimates manufacturing capacity to be 30 vehicles per month with a 180-day lead time. The lithium-ion battery is warrantied to 80% of its nameplate capacity for five years or 100,000 miles and is rated for 4,000 use cycles. The wheelchair lift can be installed as side- or rear-operating.[22]

Specification	Specification Value(s)
Passenger capacity	Two wheelchair and 14 ambulatory passengers but can be reconfigured with more wheelchairs and fewer ambulatory passengers
Lift-capable?	Available with side or rear lift
Battery size	118kWh
Approx. nameplate single-charge range	96-150 miles
Length	25’
Approx. cost	$200,000
Availability	In use at the Port of Oakland, Sacramento Regional Transit District, and Antelope Valley Transit Authority

Sources: <https://www.greenpowerbus.com/product-line/>, Correspondence with GreenPower

Image source: <https://www.greenpowerbus.com/wp-content/uploads/2019/01/shuttle-buses.jpg>

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[21] Federal Transit Administration. April 2020. *Federal Transit Bus Test Report Number LTI-BT-R19113*. <http://apps.altoonabustest.psu.edu/buses/reports/515.pdf?1586273484>

[22] Phone correspondence with GreenPower representative. June 23, 2020.

SEA Electric Ford Transit

The SEA Electric Ford Transit is built on a Ford Transit chassis and incorporates a SEA-Drive 70 electric drivetrain. This vehicle has double rear wheel assemblies to accommodate battery weight. This vehicle is currently being tested by the United States Postal Service.

Specification	Specification Value(s)
Passenger capacity	Two wheelchair and nine ambulatory passengers. Ambulatory positions can be eliminated to add wheelchair positions.
Lift-capable?	Yes
Battery size	88kWh
Approx. nameplate single-charge range	190 miles
Length	18’-22’
Approx. cost	$160,000
Availability	Available.

Sources: < https://www.sea-electric.com/products-old/transit-ev/>, Correspondence with SEA Electric

Vans and Trucks

BYD

The BYD 5F chassis and 6F chassis are class 5 and class 6 battery electric chassis, respectively. Both can be outfitted for specific purposes.

Specification	5F Chassis	6F Chassis
Passenger capacity	**2**	**2**
Battery size	**145 kWh**	**148.5 kWh – 221 kWh**
Approx. nameplate single-charge range	**155 miles at half load**	**124 miles**
Length	**~19.6’**	**XX**
Approx. Cost	**$165,429.00**	**$165,429.00**
Availability	**Available on WA State Contract**	**Available on WA State Contract**

Source: <https://en.byd.com/truck/>

Lightning

Lightning Motors has a variety of battery electric, medium-duty vehicle options available now. The ones listed in the table below are built on Ford or Chevrolet chassis.

Specification	 Ford Transit	 Ford F-59 Van	 Class 6 Chevrolet Low-Cab Forward	 Electric Ford E-450 Stripped Chassis
Passenger capacity	14-15 passengers	2 passengers	2 passengers	2 passengers
Battery size	43 - 86 kWh	128 kWh	96 - 192 kWh	86 – 129 kWh
Approx. nameplate single-charge range	60 – 120 miles	110 miles	66 – 130 miles	80 – 120 miles
Length	266.1"	351.2"	XX	27'
Approx. Cost	$173,000	$200,000	$180,000-$280,000	$180,000
Availability	Available	Available	Available	Available

Source: <https://lightningsystems.com/electric-commercial-vehicles/> <Correspondence with Charlie at Lightning Systems><https://lightningsystems.com//lightningelectric-e450-cutaway/>

Motiv

Motiv has a variety of battery electric, medium-duty vehicle options available now. All of the vehicles listed in the table below are built on Ford chassis.

	 EPIC F-59 Step Van	 EPIC Ford E-450	 EPIC E-450 Box Truck	 EPIC E-450 Work Truck	 EPIC F-53 Specialty Vehicle
Platform	Ford F-59	Ford E-450	Ford E-450	Ford E-450	Ford F-53
Battery size	127 kWh	106 kWh or 127 kWh	106 kWh or 127 kWh	106 kWh or 127 kWh	127 kWh

Approx. nameplate single-charge range	90 miles	100 miles	100 miles	100 miles	125 miles
Length	XX	XX	XX	XX	XX
Approx. Cost	$XX	$XX	$XX	$XX	$XX
Availability	Available	Available	Available	Available	Available

Source: <https://www.motivps.com/motivps/#EPIC>

Workhorse

Workhorse offers two battery electric step vans with the C^{1000} having 1000 cubic feet of space and the C^{650} having 650 cubic feet of space.

Specification	C^{1000}	C^{650}
Passenger capacity	2	2
Battery size	105 kWh	70 kWh
Approx. nameplate single-charge range	150 miles	150 miles
Length	~27’	~20’
Approx. Cost	$XX	$XX
Availability	Available	Available

Source : https://workhorse.com/cseries.html

Heavy Duty Vehicles (Cutaways, Shuttles, Chassis, Trucks)

Criteria	Capacity	Wheelchair Accessible	Range	Use/Availability	Cost
Cutaways, Shuttles, Chassis, Trucks					
BYD 8TT A class 8 semi-truck.	Up to two ambulatory passengers, including driver	No	124 miles	Available	Not released
Global M4 Class 7 street sweeper.	Up to two ambulatory passengers, including driver	No	11 hours battery operational range	Available	$525,000
Lion 8 Class 8 truck.	Up to two ambulatory passengers, including driver	No	180 miles	Available for preorder	$250,000-$450,000
Volvo VNR Class 8 semi-truck.	Up to two ambulatory passengers, including driver	No	150 miles	Available	Not released
BYD 6R/8R A class 6 and class 8 refuse truck	Up to two ambulatory passengers, including driver	No	N/A	Available	Not released
Peterbilt 520 EV Battery Electric Truck A refuse straight truck	Up to two ambulatory passengers, including driver	No	80 miles	Available	Not released

BYD 8TT

The BYD 8TT is a battery electric class 8 chassis that can be outfitted for specific purposes.

Specification	Specification Value(s)
Passenger capacity	2
Battery size	435 kWh
Approx. nameplate single-charge range	124 miles
Charge Time	DCFC: 3 hours
Length	XX
Approx. Cost	$XXX
Availability	Available

Source: *<https://californiahvip.org/vehicles/byd-8tt-tandem-axle-tractor/>*

Global M4

The M4 is a class 7, heavy-duty, battery-electric street sweeper.

Specification	Specification Value(s)
Passenger capacity	2
Battery size	Proprietary Information
Approx. nameplate single-charge operational	9-12 hours
Charge Time	9-12 hours
Charge Power	240V
Length	~15'
Approx. Cost	$525,000
Availability	Currently available for order and delivery (3 months)

Source: <https://globalsweeper.com/news/latest-news/item/120-global-introduces-1st-100-electric-heavy-duty-street-sweeper-in-the-world><Correspondence with Scott Smits>

Lion 8

The Lion 8 is a class 8, battery electric commercial truck that is available for preorder.

Specification	Specification Value(s)
Passenger capacity	2
Battery size	Up to 336 kWh
Approx. nameplate single-charge range	180 miles
Charge Time	DCFC: 1.5 hours
Charging Power	19.2 kW AC
Length	XX
Approx. Cost	$250,000-$450,000
Availability	Available for preorder

Source : < https://thelionelectric.com/documents/en/Lion8_all_applications.pdf>

Volvo VNR

The Volvo VNR is a class 8, battery electric commercial truck. It comes in the following sizes: 4x2 Straight, 6x4 Straight, 4x2 Tractor, 6x2 Tractor, and 6x4 Tractor.

Specification	**Specification Value(s)**
Passenger capacity	2
Battery size	264 kWh
Approx. nameplate single-charge range	150 miles
Charge Time	70 min (80% charging at 150kW)
Charging	Up to 150kW DC charge rate with CCS1 or CCS2
Approx. Cost	Not released
Availability	Available

Source : https://californiahvip.org/wp-content/uploads/2021/04/MY21-Volvo-VNR-Straight-Truck-ZE.pdf>

BYD 8R/6R

The BYD 8R and BYD 6R are class 8 and class 6 heavy-duty refuse trucks.

Specification	 8R	 6R
Passenger capacity	2	2
Battery size	281 kWh, 403 kWh	221 kWh
Approx. nameplate single-charge range	XX	XX
Charging Time	2.5 hrs (ER 3.5 hrs)	2.5 hours
Charging	CCS1	DC 120 kW CCS1
Approx. Cost	Not released	Not released
Availability	Available in CA	Available in CA

Source : < https://en.byd.com/truck/>

Peterbilt 520EV Battery Electric Truck

The Peterbilt 520EV Battery Electric Truck is ideal for commercial and residential refuse applications. Up to 1,100 residential trash bins can be picked up by the 520EV on a single charge.

Specification	Specification Value(s)
Passenger capacity	2
Battery size	396 kWh
Approx. nameplate single-charge range	80 miles
Charging Time	Up to 3.5 hours
Approx. Cost	Not released
Availability	Available

Source : < https://californiahvip.org/wp-content/uploads/2020/11/MY20-Peterbilt-520EV-201030.pdf/>

Pursuit Vehicles

There are currently no pursuit rated electric vehicles on the market, however Tesla's models have the specifications that are closest to pursuit rated vehicles.

Source : https://www.tesla.com/compare/redirect=no?redirect=no

Specification	 Model S	 Model 3	 Model X	 Model Y
Passenger Capacity	5	5	7	7
Battery Size	100 kWh	100 kWh	100 kWh	100 kwh
Approx. Nameplate Single-Charge Range	348 – 391 miles	250 - 322 miles	305 – 351 miles	315 – 316 miles
Approx. Cost	$94,940	$36,743	$84,990 - $104,990	$52,990 - $60,990
Availability	Available on WA State Contract	Available on WA State Contract	Available	Available

Pursuit Motorcycles

Zero motorcycles lead electric motorcycles in North America. Zero produces a line of police-specific e-motos based on both the DS and DSR (dual sport) platform and the FX (supermoto) platform. These bikes are known as the DSP, DSRP, and FXP. The Janesville Police Department in Janesville, Wisconsin currently operates two Zero motorcycles outfitted for police needs and Los Angeles Police Department currently operates six Zero motorcycles.

Source : https://www.zeromotorcycles.com/model/

Specification	 **Model FX**	 **Model DS**	 **Model DSRP**
Battery Size	3.6 kWh	7.2 kWh	14.4 kWh
Approx. Nameplate Single-Charge Range	46 miles	82 miles	163 miles
Approx. Cost	$9,495	$11,195	$15,695
Availability	Available	Available	Available

Non-Road Vehicles/Equipment

Golfcarts

There is a wide variety of electric golf carts on the market. The table below provides a summary of the specifications for many of the electric golf cart models available. The list may not be comprehensive of the entire market, but it provides information on various available options.

OEM	Passenger Capacity	Battery Size	Approx. Nameplate Single-Charge Range	Length	Approx. Cost	Availability
Club Car	6	48 – 85 V	n/a	92”-144”	$7,789-$13,528	Available
Yamaha	6	48 V	n/a	93” – 161”	$6,692 - $9,000	Available
E-Z-GO	6	48V-168V	n/a	91”-137.5”	$6,399 – $12,999	Available
Cushman	8	48V-96V	n/a	110”-167.5”	X	Available
HDK Electric Vehicles	6	n/a	49.7 miles	88.6”-148”	X	Available
Global Electric Motors	6	48 V	10-95 miles	103”-167”	$9,400 - $14,786	Available through WA State Contract (some models)
Columbia	6	48 V	Up to 40 miles	94.5”-140”	X	Available
Star Electric Vehicles	8	36/48 V	Up to 60 miles	94”-146”	X	Available

Source: <https://www.clubcar.com/us/en/home.html> <https://www.yamahagolfcar.com/golf-car/golf/the-drive-2/> <https://ezgo.txtsv.com/><https://cushman.txtsv.com/golf-proturf><http://www.hdkexpress.com/><https://gem.polaris.com/en-us/vehicles/#passenger-hero><https://www.columbiavehicles.com/our-vehicles/journeyman><https://golfcartresource.com/golf-cart-review/star-electric-vehicle-classic-48v-review/><https://gem.polaris.com/en-us/em1400-lsv/#packages>

Utility Vehicles

Polaris

Specification	 GEM eL XD	 GEM eM 1400 LSV
Payload Capacity	1,400 lbs.	1,400 lbs.
Tow Capacity	Up to 1,100 lbs.	Up to 1,250 lbs.
Battery Capacity	48 V	48 V
Range	12-68 miles	Up to 45 miles
Max. Speed	25 mph	25 mph
Approx. Cost	$14,049	$11,543
Availability	Available through local dealerships	Available through WA State Contract
Passenger Capacity	2	2

Source: <https://gem.polaris.com/en-us/em1400-lsv/#packages

Hisun Motors

Specification	 Sector E1
Payload Capacity	500 lbs.
Tow Capacity	Up to 1,500 lbs.
Battery Capacity	48 V
Range	42 miles
Max. Speed	25 mph
Approx. Cost	$11,299
Availability	Available
Passenger Capacity	2

Source : https://www.hisunmotors.com/products/vehicle/29/electric/sector-e1

Club Car

Specification	 Transporter	 Villager	 Carryall	 Tempo	 Club Car
Payload Capacity	1,000 lbs.	550 – 1,500 lbs.	800 – 1,500 lbs.	800 lbs.	1,100 lbs.
Tow Capacity	1,500 lbs.	1,105-1,205 lbs.	1,500 lbs.	N/A	N/A
Battery Capacity	48 V	48 V	48 V	48 V	72 V
Range	30-50 miles	30-50 miles	30-50 miles	30-50 miles	50 miles
Max. Speed	15 – 17 mph	5 – 23 mph	15 – 25 mph	5 – 15 mph	25 mph
Approx. Cost	$12,952	$9,856 - $12,339	$7,099 - $15,579	$10,455	$19,999
Availability	Available	Available	Available	Available	Available
Passenger Capacity	2 - 8	2 - 8	2 - 4	4	2

Forklifts

Komatsu America Corporation

Specifications	 AE50 Series	 AM50 Series	 BBX50 Series
Capacity	3,000 – 4,000 lbs.	3,000 – 4,000 lbs.	4,000 – 6,500 lbs.
Battery Voltage/Capacity	48 V	48 V	36/48 V
Maximum Travel Speed (loaded)	9 - 10 mph	9 – 10 mph	7.5 – 10.9 mph
Maximum Fork Height	129.9”	129.9”	128”
Approx. Cost	X	X	X
Availability	Available	Available	Available

Source: <https://www.komatsuamerica.com/equipment/forklift/electric-riders#page=0&sortby=sortorder&sortdir=Asc>

Linde Material Handling

Specifications	 E12 – E20 EVO	 E16 – E20 EVO	 E20 – E35	 E20 – E35 R	 E35 – E50	 E60 – E80
Capacity	2400 – 4,000 lbs.	3,200 – 4,000 lbs.	4,000 – 7,000 lbs.	4,000 – 7,000 lbs.	6,400 – 9,980 lbs.	12,000 – 16,000 lbs.
Voltage	24/48 V	48 V	80 V	80 V	80 V	80 V
Maximum Travel Speed (loaded)	7.7 – 9.9 mph	12.4 mph	12.4 mph	12.4 mph	11.1 mph	9.9 mph
Maximum Fork Height	110” – 124”	110” – 124”	123” – 161.2”	123” - 137”	114” – 166”	120” – 151”
Approx. Cost	X	X	X	X	X	X
Availability	Available	Available	Available	Available	Available	Available

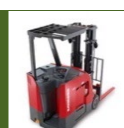
Source: <https://www.linde-mh.com/en/Product-Finder/?offerType=new&sorting[field]=productType&sorting[direction]=ASC&productTypes[]=2377>

Mitsubishi Forklift Trucks

Specifications	 FB16PNT-FB20PNT	 FBC15N-FBC18LN	 FBC23N-FBC30LN	 FBCS14N-FBCS18N
Capacity	3,000 – 4,000 lbs.	3,000 – 4,000 lbs.	4,500 – 6,500 lbs.	3,000 – 4,000 lbs.
Battery Voltage/Capacity	36/48 V	36/48 V	36/48 V	36 V
Maximum Travel Speed (loaded)	10 mph	9.3 – 11.3 mph	9.3 – 11.3 mph	8 mph
Maximum Fork Height	258.5”	217”	131.5”	188”
Approx. Cost	X	X	X	X
Availability	Available	Available	Available	Available

Source: <https://www.mcfa.com/en/mit/all-forklifts#>

Raymond Corporation

Specifications	 4000 Series Counter-Balanced Trucks Stand-Up	4000 Series Counter-Balanced Trucks Sit-Down 
Capacity	3,000 – 5,000 lbs.	3,000 – 6,500 lbs.
Battery Voltage/Capacity	36 V	36 V and 48 V
Maximum Travel Speed (loaded)	7.2 – 8.0 mph	9.6 – 12 mph*
Maximum Fork Height	227” – 270”	227” – 278”
Approx. Cost	X	X
Availability	Available	Availalbe

*Specification document only listed unloaded travel speed.

Source: <https://www.raymondcorp.com/lift-trucks/reach-fork-trucks>

Toyota

Specifications	 3-Wheel Electric	 Core Electric	 Large Electric	 Stand-Up Rider	 Electric Pneumatic	 High-Capacity Electric Cushion
Capacity	3,000 – 4,000 lbs.	3,000 – 6,500 lbs.	8,000 – 12,000 lbs.	3,000 – 4,000 lbs.	4,000 – 7,000 lbs.	15,000 – 40,000 lbs.
Voltage	36/48 V	36/48 V	36/48 V	36 V	80 V	72/80 V
Maximum Travel Speed (loaded)	9.5 – 9.9 mph	11.3 – 11.5 mph	7.5 – 10.5 mph	7.5 mph	11.8 mph	4.6 – 5.2 mph
Maximum Fork Height	100” – 277.5”	80” – 278”	120” – 239”	128” - 277”	118” – 258”	69” – 327”
Approx. Cost	$20,690 – $22,107	$22,879 - $26,728	X	$30,059 - $30,781	$30,638 - $36,426	X
Availability	Available on WA State Contract	Available on WA State Contract	Available	Available on WA State Contract	Available on WA State Contract	Available

Source : <https://www.toyotaforklift.com/lifts/electric-motor-rider-forklifts>

Manlifts

There is a wide variety of electric manlifts on the market. The table below provides a summary of the specifications for many of the electric manlift models available. The list may not be comprehensive of the entire market, but it does include a sample of available options.

OEM	Max. Working Height	Platform Capacity	Max. Horizontal Reach	Approx. Cost	Availability
Genie	35’ – 46’5”	440 - 500 lbs.	18’3” - 22’8”	XX	Available
JLG	20’4” – 60’3”	500 lbs.	6’5” – 43’3”	XX	Available

Source : https://www.genielift.com/en/aerial-lift/electric-bi-energy https://www.jlg.com/en/equipment/electric-hybrid-boom-lifts

Pallet Jacks

There is a wide variety of electric pallet jacks on the market. The table below provides a summary of the specifications for many of the electric pallet jack models available. The list may not be comprehensive of the entire market, but it does include a sample of available options.

OEM	Capacity	Fork Length	Fork Width	Approx. Cost	Availability
Vestil	3,300 – 4,500 lbs.	47” – 48”	20” – 27”	XX	Available
Toyota	4,500 lbs.	29.5” – 57.5”	26.6”	$3,992 - $9,794	Available on WA State Contract (some models)
Raymond	4,500 - 8,000 lbs.	“Available in multiple lengths”	“Available in multiple widths”	XX	Available
Crown	4,500 lbs.	36-48”	25.8”	$3,762 – 13,931	Available on WA State Contract
Big Joe	2,600 -4,400 lbs.	48”	27”	XX	Available
Hyster	4,500 – 10,000 lbs.	34” – 94.9”	26.4” – 28”	$3,371 – 10,857	Available on WA State Contract (some models)

Source: <https://www.vestil.com/product.php?FID=342> <https://s3.amazonaws.com/toyotaforklifts/wp-content/uploads/2018/03/19192034/ElectricWalkie_SpecSheet.pdf><https://www.raymondcorp.com/lift-trucks/pallet-trucks>

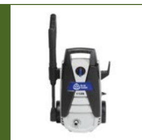
<https://www.crown.com/en-us/forklifts/pallet-trucks/wp-pallet-truck.html><https://bigjoeforklifts.com/pages/products>

<https://www.hyster.com/north-america/en-us/products/pallet-trucks/>

Pressure Washers

Annovi Reverberi (AR)

Source: <https://www.arnorthamerica.com/pages/ar-blue-clean-power- washers/#section3>

Specifications	 AR2N1	 S-Line	 Industrial Line	 B-Line
Max PSI	2,050	1,500 – 2,000	1,350 – 1,900	1,600 – 1,900
Motor Amperage	13 Amps	12 – 14 Amps	15 – 19 Amps	11 – 14 Amps
Max GPM	1.4	1.4	1.9 – 2.2	1.51 - 1.58
Approx. Cost	$259-309	$119-249	$549-779	$179
Availability	Available	Available	Available	Available

Ryobi

Specifications	Electric Series
Max Pressure	1,600 – 2,300 PSI
Motor Amperage	13 amps
Max Flow Rate	1.2 GPM
Approx. Cost	$99 - $299
Availability	Available

Source:<https://www.ryobitools.com/outdoor/products/pressure-washers>

Karcher

Specifications	Electric Series
Max Pressure	1,600 - 2,000 PSI
Motor Amperage	13 amp
Max Flow Rate	1.25 - 1.4 GPM
Approx. Cost	$129 - $459
Availability	Available

Source:<https://www.kaercher.com/us/online-shop-en/general-result-page/~20035386-electric-pressure-washers.html>

Greenworks

Specifications	Electric Series
Max Pressure	1,500 - 2,700 PSI
Motor Amperage	13 – 15 amp
Max Flow Rate	1.1 – 2.3 GPM
Approx. Cost	$90 - $350
Availability	Available

Source:<https://www.greenworkstools.com/shop-by-tool/pressure-washers>

Briggs and Stratton

Specifications	Electric Series
Max Pressure	1,700 – 2,200 PSI
Motor Amperage	X
Max Flow Rate	1.2 – 3.5 GPM
Approx. Cost	X
Availability	Available

Source:<https://www.briggsandstratton.com/na/en_us/products/pressure-washers.html>

Yard Force

Specifications	Electric Series
Max Pressure	1,600 – 2,200 PSI
Motor Amperage	13 amp
Max Flow Rate	1.2 – 1.25 GPM
Approx. Cost	X
Availability	Available

Source:<https://www.yardforceusa.com/pressure-washers>

Tractors

Solectrac

Specifications	 Compact Electric Tractor (CET)	 eUtility Electric Tractor	 eFarmer Electric Tractor
Horsepower	30 HP	40 HP Continuous, 50 HP Peak	30 HP
Battery Size	22 kWh	28 kWh	28 kWh
Traveling Speeds	4 Wheel Drive	2 Wheel Drive	
Battery Runtime	3-6 hrs. depending on load.	4-8 hrs. depending on loads	4-8 hrs. depending on loads
Approx. Cost	$25,800 - $33,000	$45,000 - $75,000	$45,000 - $56,175
Availability	Initial sales will be limited to California and Canada, and expanded as interest in other states grows.	Available now on a first to deposit basis.	Will be available in late 2020

Source : <https://www.solectrac.com/>

Appendix B: Charging Infrastructure Market Analysis

This market analysis discusses the different types of electric vehicle charging infrastructure available for light, medium, and heavy-duty vehicles, as well as different strategies to consider when charging vehicles. The information was collected from various websites and charger OEM specification sheets.

Charging Types and Rates

Electric Vehicle Supply Equipment (EVSE) – essentially an electric vehicle charger - is the equipment used to deliver electrical energy from an electricity source to an electric vehicle (EV). The charging equipment communicates with the EV to ensure that an appropriate and safe flow of electricity is supplied. EV chargers are classified into several categories based on the rate at which the batteries are charged. Level 1 and Level 2 chargers provide alternating current (AC) electricity to the vehicle, with the vehicles onboard equipment converting AC to the direct current (DC) needed to charge the batteries. The other type of chargers, often referred to as DC fast chargers, provide DC electricity directly to the vehicle. Charging times range from 20 hours or more to less than 30 minutes depending on the type of EVSE, the battery's capacity, state of charge, and the vehicle's acceptance rate or charging speed. Level 1 and 2 chargers recharge batteries at a slower rate, while DC Fast Chargers charge vehicles more quickly. Different EVs have different power needs – with heavier duty vehicles requiring higher levels of electricity to charge. Plug-in electric hybrid vehicles (PHEVs), which are hybrid has-electric vehicles, are also recharged with vehicle chargers. Electric vehicles generally have more capacity than PHEVs, meaning they can travel farther on a single charge, but they take longer to fully charge.

EV chargers are identified by their input voltage and are designed and sold by many manufacturers with different prices, applications, and functionality. **Figure B1** illustrates the difference in charging speeds (miles of range added per hour) from the three charging levels.

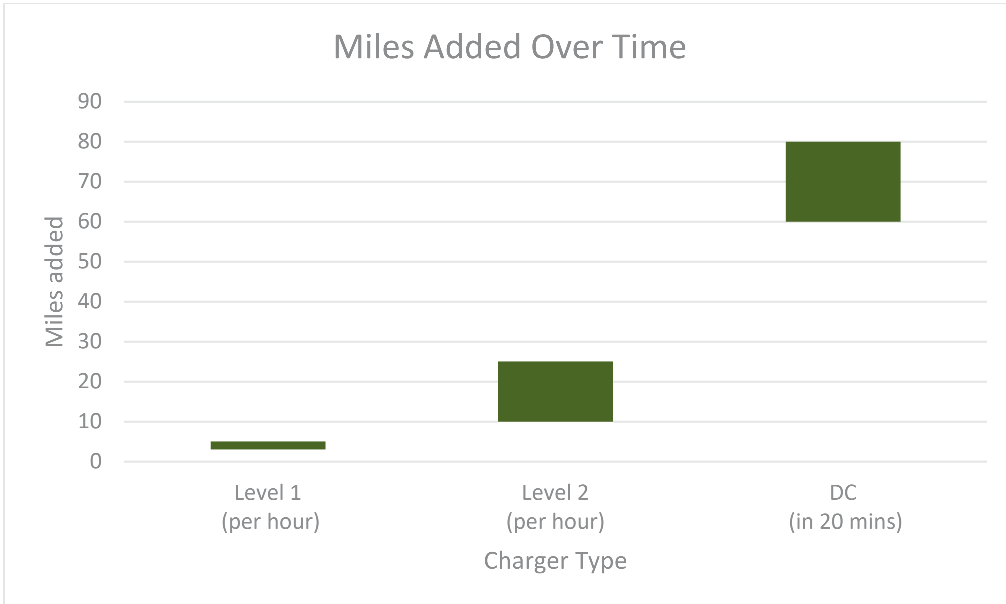


Figure B1: EV Charger Speed Comparison

Level 1 Charging

Level 1 EVSE provides charging through a 120-volt (V) AC plug and requires a dedicated branch circuit. Most, if not all, EVs come with a Level 1 EVSE cord set, so no additional charging equipment is required. On one end of the cord is a standard 3-prong house plug (NEMA 5-15 Connector). The other end of the cord is a J1772 standard connector that plugs into the vehicle. Level 1 is typically used for charging when there is only a 120V outlet available – it provides a lower cost charging option by avoiding the cost of installing higher speed Level 2 EVSE. The main advantages of Level 1 EVSE are that they require little to no infrastructure investment and they are simple to use. The main disadvantage is slower charging and inability to collect data on electrical consumption. However, Level 1 EVSE transmits electricity at the consistent rate of 1.4 kW per hour which can be used to calculate energy usage and cost. While some of the City's equipment is expected to use low level charging, CTE does not recommend Level 1 charging for the City's vehicle fleet due to the time required to reach a full charge.

Level 2 Charging

Level 2 EVSE offers charging through a 240V (typical in residential application) or a 208V (typical in commercial application) AC plug and requires installation of charging equipment and a dedicated electrical circuit. Level 2 equipment uses the same J1772 connector on the vehicle as Level 1 equipment. Depending on the battery type, charger configuration, and circuit capacity, Level 2 charging adds about 10-25 miles of range per hour of charge time.

CTE recommends Level 2 charging for the City's light- and medium-duty vehicles. **Table B1** below lists a range of charging times for common electric vehicles Level 2 chargers.

Table B1. AC charging times by light-duty vehicle battery size

EV Model	Battery Capacity (kWh)	Hours (h) Required for Optimal (80%) Battery State of Charge Depending on Speed			
		3.6 kW	**7.2 kW**	**12 kW**	**19.2 kW**
Nissan Leaf	40	8.9	4.5	2.7	1.7
Nissan Leaf	62	13.8	6.9	4.1	2.6
Chevrolet Bolt	66	14.7	7.4	4.4	2.8
Lordstown Endurance	70	15.6	7.8	4.7	3.0
Ford Mustang Mach-E	98.8	22.3	11.2	6.7	4.2
Tesla Model X/S	100	22.0	11.0	6.6	4.2
Ford E-Transit	67	14.9	7.5	4.5	2.8

Level 2 EVSE is available at a range of price points. Prices starting with low cost, portable relatively low speed (3.8-7.7 kW) non-networked chargers such as Clipper Creek's entry level AmazingE charging cordsets to relatively fast (19.2 kW) full feature hard-wired smart chargers that use WiFi or cellular connection to transmit and track charging and financial data. This portable charger is small enough to be transported around in a small grocery bag. The installed cost is typically 2 to 5 times the cost of the hardware itself as explained below. The advantages of non-networked chargers are their low cost and simplicity. The benefits of higher cost chargers include faster charging speeds, ability to manage and share power loads, ability to schedule charging to take advantage of time of use charging rates and the ability to monitor charging data using on-line dashboards, smart phone apps. Higher cost chargers often include a mechanism for users to pay for their charging, which is essential for public-facing chargers.

DC Fast/High Powered Charging

DC fast charging EVSE (480V input to the EVSE) enables rapid charging. A 50kW DC Fast Charger, the most common public fast charger (other than Tesla's superchargers) adds 60-80 miles of range to a light duty vehicle in as little 20 minutes. High-powered chargers are high amperage DC fast chargers (150-350 kW) that are the fastest and most expensive type of EVSE. Tesla, EVgo, and Electrify America all deploy these in their public charging networks. These can provide 75 miles of charge in about 10 minutes. However, actual charging speeds are limited by each vehicle's acceptance rate. Lower-cost EVs such as the older Nissan LEAF and Kia Soul models, Chevy Bolts, VW e-Golfs, and Honda Clarity can charge no faster than at 50kW. Newer and higher end Nissan LEAF models and Jaguar's I-Pace can charge up to 100kW and only luxury EVs by Tesla, Audi, and Porsche can charge at faster rates of 250 and 350kW respectively. Acceptance rates will likely increase in the future as more high-power chargers are deployed and more EVs enter the market.[23]

High-power chargers require more space for installation – they typically require the space equivalent to at least six parking stalls plus an equivalent area for support infrastructure such as a dedicated transformer that can handle a 1-megawatt load at peak draw. They are also more expensive to purchase and install and require relatively large investments for electrical service upgrades. Glendale's fleet of heavy-duty vehicles will require this type of charger to effectively charge for the following day's service. The City's pursuit vehicles typically are operated non-stop and will also need fast charging.

Power Load Management

Power load management can help use electricity more efficiently and disperse power across multiple chargers. Charging networks like ChargePoint and Greenlots have dedicated software with customizable algorithms to intelligently share power among network ("smart") chargers so every EV charges as fast as possible without exceeding the site's rated electrical capacity. Networked smart chargers also provide data connectivity for tracking electrical consumption and customer payment collection but are usually higher cost and require monthly data fees.

There are lower cost load management alternatives that could be appropriate for fleet facilities and worksites. Some examples include hardware such as Cyber Switching (see **Figure B2**) and PowerFlex and software apps such AmpUp and Mobility House.

[23] https://insideevs.com/news/348233/electric-car-dc-fast-charging-comparison/)

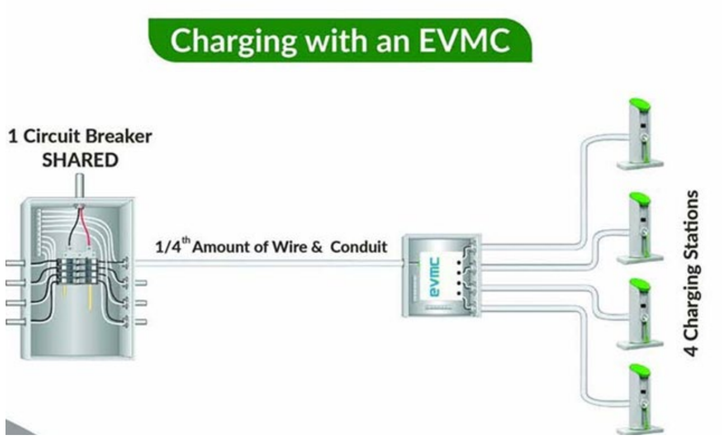


Figure B2. Hardware-based load management (Cyber Switching)

The hardware and software can be combined to provide load management benefits. For example, Cyber Switching uses electrical hardware including a control unit called the EVMC that switches power to multiple chargers in a "round-robin" scenario to alternate electrical current between chargers, allowing up to four chargers to share a single circuit. The EVMC first polls an individual EV to check its battery status, and if charged, moves on to the next EV in line. A single electrical line can feed up to four chargers and incrementally rotate the current to each charger on a programmable timed basis. Cyber Switching provides a relatively low-cost way to potentially quadruple the charging capacity of relatively small charging installations such as worksites with limited electrical service charging eight or fewer vehicles. One or two of these units could be installed supplying 4 to 8 chargers without typically needing to upgrade or replace the electrical service or panel. Cyber Switching hardware is typically paired with a software program such as AmpUp to perform such functions as controlling the charging session, managing the electrical load, metering the electrical consumption, and facilitating customer payment.

Load Management: The simplest and most cost-effective way to provide power for EV charging is to tap existing electrical capacity. Load management such as Cyber Switching can limit and balance power loads to avoid exceeding circuit capacity and avoid demand charges. Software like AmpUp can also reduce power across all chargers. Augmented by AmpUp, a charger's control unit serves as a virtual electric meter, avoiding the need for separate circuits or sub-meters for EV charging and lighting. The precision software can break down electric loads to each output. Depending on the granularity of the utility's electric meter, it may even measure electrical consumption more accurately, collecting data every few second rather than at intervals of 15 minutes used by many utility meters.

Another sophisticated load management software is ChargePilot, the Charging and Energy Management (CEM) system developed by The Mobility House. ChargePilot helps fleet managers manage loads and track the fleet's energy consumption while charging. This modular and scalable platform optimizes the use of available power and charging infrastructure by processing different parameters such as total available power, building load, electricity rates, vehicle battery state-of-charge (SoC), and electric vehicle schedules to optimize when and how much to charge each vehicle. The goal is to smooth out expensive peak loads ("peak shaving") and take advantage of low-cost charging windows. In areas with high demand charges, this can significantly reduce the cost of electricity. All chargers controlled by ChargePilot are physically connected to a local onsite controller via Ethernet allowing it to communicate using open-source communication protocols such as OCPP (Open Charge Point Protocol) and ensures charging processes can be controlled even if there are network or internet connectivity issues. This provides close to real-time response for smart charging and reliability in case of loss of connectivity or increased latency in cloud communication.

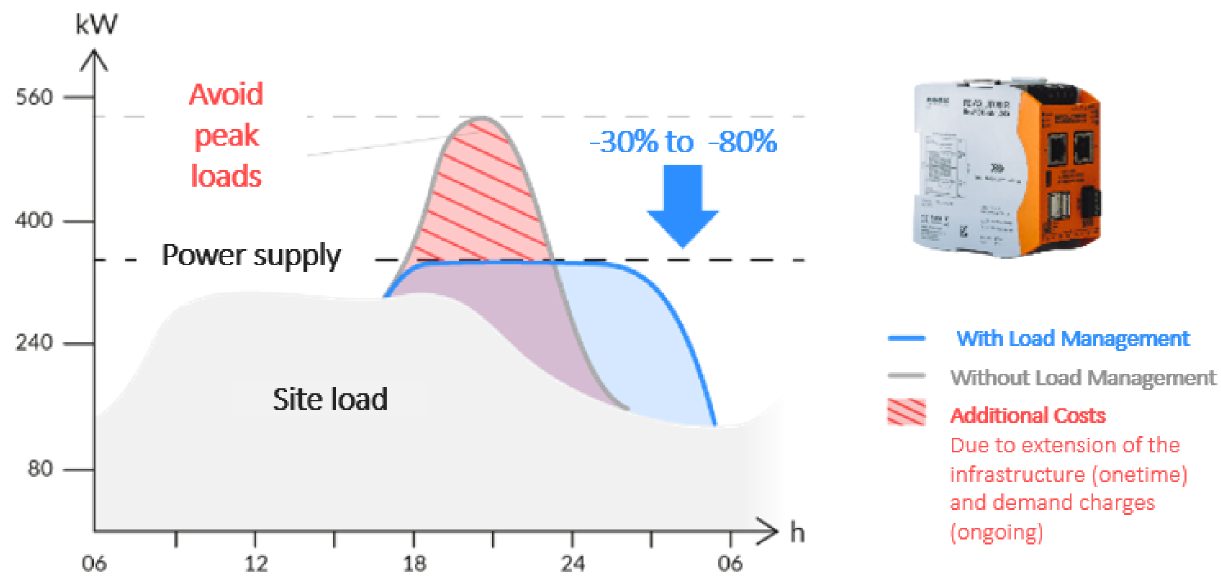


Figure B3. Peak shaving benefits from load management (The Mobility House)

Charging Strategy Options

Most of Glendale's fleet vehicles are driven during the day and parked overnight which provides ample dwell time for battery charging. The most notable exception is the Police pursuit vehicles. Currently available light-duty EVs typically used by fleets like the Chevy Bolt and Nissan Leaf Plus have 65 and 62 kWh batteries respectively, providing well over 200 miles of range and newer EVs are expected to have even greater range. Due to these relatively minimal power requirements, coupled with long overnight dwell times for most of Glendale's non-bus fleet vehicles, light-duty EVs could share chargers, or at least share power loads, through a power load management strategy. As a result, a range of currently available and emerging charging options that could be deployed in the near term at fleet facilities are discussed below. The options described are:

- Dedicated chargers, with and without load management
- Shared chargers with and without load management
- Mobile charging

Resiliency

Glendale should consider distributed energy resources (DER) and battery storage to provide resiliency for fleet fueling during power outages.

Currently available charging technologies appropriate to Glendale's vehicle fleet needs include the strategies discussed below and summarized in **Table B2.**

Dedicated Chargers

The basic way to charge a fleet is with individual chargers dedicated to each vehicle in the fleet. This approach to charging typically requires each fleet vehicle be assigned a parking stall and that each parking stall be equipped with its own charger. Fleets typically use Level 2 chargers to provide adequate range and deploy smart chargers to track electrical use by vehicle or department, similar to tracking diesel or gasoline consumption.

Vehicle operators pick up the vehicle at the assigned stall, manually disconnect the charger before using the vehicle, and later return the vehicle to the assigned stall and reconnect the charging cord. For fleet facilities with on-site staff or an automated parking management system, vehicles could be rotated between stalls because all stalls would be comparably equipped with EVSE.

Benefits: The primary benefit of this approach is its simplicity and predictability for fleet operators and drivers. It also provides flexibility due to the relative abundance of chargers, allowing for future expansion via implementation of load management systems or other options.

Disadvantages: A ratio of one charger per parking stall or per EV requires numerous charger installations, which is generally inefficient and can potentially be a more costly approach due to the expense of procuring and installing each charger. In addition to the cost, the parking facility is more heavily affected during the charging infrastructure construction period. [24]

With a one EV to one charger ratio, the capacity to charge other vehicles is wasted for two reasons: 1) the charger sits idle while the dedicated vehicle is in use, and 2) a fully charged EV in the assigned parking space blocks other vehicles from using the charger.

Operational costs of dedicated chargers can be higher as well. Simultaneously charging multiple EVs at fleet facilities, without managed charging or energy storage incorporated into the system, could result in costly demand charges if local utilities changed their rate structure in the future.

Network and data costs can also add up over time when smart chargers or third-party load management systems are deployed, and ongoing charger maintenance costs are usually proportionate to the quantity of chargers installed.

General Recommendations: Dedicated chargers generally make the most sense in the following circumstances:

- Locations that are currently equipped with significant quantities of chargers that could be dedicated to a unique parking space/fleet EV. These chargers, however, would not be available to the public when in use by Glendale's fleets.
- Facilities at which a limited number of EVs are domiciled and ample electrical capacity is available.
- When funds are not constrained

Dedicated Chargers with Load Management

One way to reduce the maximum power load to avoid or reduce needed electrical service upgrades or utility demand charges would be by splitting or balancing the power between chargers (load splitting or balancing), or load management systems. These systems allow fleet operators to control when and how each fleet EV is charged by distributing power between chargers.

With the extra capacity available in buildings, and by using a load management system, most fleet facilities would not need electrical service upgrades. Additionally, building upgrades that conserve electricity, such as replacing windows, installing air barriers or upgrading lighting, can significantly increase capacity for vehicle charging at fleet parking garages that share their electrical systems with buildings.

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[24] Installation costs typically include design, permitting, and electrical service upgrades.

Benefits: The primary benefit of load management is reduction of peak electrical load to reduce or avoid costly electrical service upgrades and utility demand charges.

Disadvantages: Load management requires networked smart chargers, which may have higher capital and/or operating costs and depends on the individual system and quantity of chargers. Third-party load splitting or management systems can operate with non-networked dumb chargers, but the equipment and service require additional capital and data costs.

General Recommendations: Adding load management to dedicated chargers generally makes the most sense in parking facilities with limited power supply where large numbers of heavily used EVs with long dwell times are domiciled. This does not apply to most of Glendale's parking locations; however, as Glendale adds more EVs to the fleet, the circumstance is expected to change.

Shared Chargers

While Glendale's analysis is based on a 1:1 vehicle to charger ratio, shared chargers could reduce the cost for transitioning to a 100% EV fleet. At facilities with shared chargers, a minimum number of Level 2 chargers are installed to serve all the fleet EVs domiciled by rotating charger use. This should be generally feasible for Glendale because most fleet vehicles travel relatively few miles per day and are parked and available for charging for at least 14 hours. Not needing to charge their batteries every night means fleet EVs could share chargers by taking turns based on a schedule or depending on a vehicle's state of charge. Additionally, a shared DCFC could supplement shared Level 2 chargers at large fleet facilities with multiple light, medium and heavy-duty vehicles. In cases where dwell times are limited to only four hours, the anticipated duration of charging would still be sufficient to charge the relatively small number of EVs that have shorter dwell times.

Benefits: The primary benefits are reducing peak demand charges, mitigating potential electric service upgrade costs, and reducing initial investment costs associated with the procurement and installation of chargers generally (e.g., reduced number of individual units required). This approach is also useful to leverage the constrained electrical capacity of certain sites to install more chargers that would share available electrical load.

Disadvantages: Sharing chargers requires careful management of fleet EVs to ensure that all vehicles maintain a sufficient state of charge for their intended daily use.

General Recommendations: Sharing chargers makes the most sense under the following circumstances:

- Facilities that serve fleet EVs that typically drive less than 40 miles a day and have dwell times longer than eight hours.

- Facilities with limited available electrical capacity to avoid the expense of electrical service upgrades.

Shared Chargers with Load Management

This is a variation on shared chargers that incorporates load management to provides flexibility. This could be achieved by networked smart chargers with integral load management or by a third-party add-on system.

Benefits: The primary benefits are reducing peak demand charges, mitigating potential electric service upgrades costs, and reducing initial investment costs associated with the procurement and installation of chargers generally (e.g., reduced number of individual units required). This approach is also useful to leverage the constrained electrical capacity of certain sites to install more chargers that would share available electrical load.

Disadvantages: It requires active parking/charging management by staff and poses a potential risk that fleet EVs may not be sufficiently charged if not managed properly.

General Recommendations: Adding load management to shared chargers makes the most sense at locations at which a load management system can serve multiple chargers needed in the future allowing the charging capacity of the fleet facility to expand over time.

Mobile Charging

Figure B4: Dannar MPS. Source Dannar

An alternative or possible complement to fixed EV chargers is mobile or semi-mobile charging. These consist of energy storage systems that draw power from the grid then dispense the electricity to EVs when needed. Two examples are Freewire Technologies, which has two mobile charging units, Mobi and Boost; and Danner, which has the Mobile Power Station (MPS). The MPS and Mobi units are literally mobile, equipped with wheels and operator controls, while the Boost is stationary and hard-wired but can be easily disconnected for re-location to another facility.

Each Mobi can charge up to eight light-duty EVs per shift and can be equipped with an optional Hydra unit that simultaneously charges seven vehicles (charging is at Level 1 speed). Boost is a larger unit that has 160 kWh of battery capacity and 120 kW output capable of charging 25 light-duty EVs per shift at 100kW.

Dannar's MPS can charge multiple types of batteries and replicate the function of a mobile generator. The DANNAR 4.00 base configuration comes standard with three 42 kWh Li-Ion battery packs (126 kWh total) and can be easily upgraded with up to nine additional packs for a total of 504 kWh of on-board electricity.

Another example of mobile charging includes portable battery-powered rescue chargers like SparkCharge. SparkCharge, is an innovative startup that produces a highly portable, modular DCFC. Its battery-powered chargers snap together like Lego blocks and yesprovide up to 20 miles of range per battery module. Fleets could also use this to augment short-range EVs or rescue EVs that run out of charge, which avoids the need to be towed to a charger or facilitating occasional longer distance trips.

Benefits: By being able to accept power from the grid at low voltage and/or during times when electrical demand is low or during the day when grid renewables and/or onsite solar (depending on the fleet's vehicle charging facility) generation is high, mobile energy storage platforms can help to avoid demand charges. Other benefits include the ability to:

- Charge additional fleet EVs than the facility's existing power capacity may support.
- Provide backup energy to fleet vehicles during power outages.
- Charge multiple EVs at the same site by moving the charger, rather than moving the vehicles.
- Relocating the charger from one facility to another to address changing needs or to provide flexible charging capacity at non-County owned facilities where fleet EVs may be domiciled such as for vanpools.

The Danner Mobile Power Stations can also be outfitted with auxiliary equipment such as lifts or loaders, allowing these units to function as fully electric off-road equipment. Both the Danner and Mobi can also perform the function of a generator by powering electrical equipment where no power outlets are available.

Disadvantages: The main disadvantage of this option is the large upfront costs. Using mobile charging units also requires active parking and charging management by City staff who will need to move the charger to individual fleet EVs and manually connect them. Mobile chargers take up space in the parking lot and staff may not be able to get the unit close enough to the EV in a crowded parking facility.

General Recommendations: Using mobile charging units is recommended in the following situations:

- Where large numbers of fleet EVs could otherwise result in significant costs associated with electric service power upgrades that may be needed for Level 2 chargers. Additionally, this facility has space constraints that may make installation of multiple individual chargers difficult.

- Facilities where fixed charging infrastructure near term is needed but may not be fiscally responsible because of site redevelopment plans in the future or that will be redeveloped.
- Fleet facilities that are not owned by Glendale, such as for contracted service providers, allowing Glendale to invest in charging infrastructure independent of the facility that can be cost-effectively relocated.

CTE's transition analysis does not include any mobile chargers for the City's primary locations, however the City should be aware of the potential for mobile chargers at other locations where smaller numbers of vehicles are housed.

Table B2. Charging Strategy Summary

	Dedicated chargers	Dedicated chargers with load management	Shared chargers	Shared chargers with load management	Mobile charging
Strengths:					
Convenience and simplicity	Yes	Yes	No	No	Yes
Capacity for future fleet expansion	Yes	Yes	No	No	Yes
Reduces peak demand and resulting service upgrades	No	Yes	Yes	Yes	Yes
Reduces CAPEX from fewer chargers purchased and installed.	No	No	Yes	Yes	Depends on facility scale
Challenges:					
Costs for hardware purchase, installation and load upgrades.	Yes	Yes	No	No	More cost effective for larger facilities
Initial cost of system plus data charges	No	Yes	No	Depends on provider	Yes

Requires active parking/charging management by City staff	No	No	Yes	Yes	Yes
Risk of vehicles not being charged	No	No	Yes	Yes	Yes

Resiliency Technologies

Local power congestion or disruption may occur when local power demand exceeds the power system's capacity. The local power supply is also vulnerable to interruption from severe weather events or other events causing grid failure. EV charging operations can be protected from power supply interruptions by conventional back-up generators or on-site renewable generation, like photovoltaic solar panels coupled with on-site energy storage batteries.

Back-up generators: The conventional approach to energy resiliency is the use of conventional fuel back-up generators, which are available in sizes up to 2,000 kW. These generators can be permanently installed at facilities for dependability and ease of operations or can be mounted on trailers to provide greater flexibility for fleet operators. They can be powered by diesel fuel or other liquid fuel sources like natural gas or propane. To help achieve Glendale's carbon reduction goals, renewable diesel—a hydrocarbon diesel fuel produced by hydro-processing of fats, vegetable oils, and waste cooking oils—could be substituted for standard petroleum diesel. According to industry sources like Neste, such a substitution reduces lifecycle emissions by up to 80% compared to petroleum diesel.

Figure B5. Trailer-Mounted 625-680 KVA mobile generator

(Source: https://criticalpower.com/inventory/generators/hipower/)

Solar: Solar power is becoming an increasingly viable source of power for EV charging because of improvements in energy collection and storage technology. Solar technologies provide environmental benefits due to a lack of carbon emissions and resiliency benefits from an ability to operate with independence from the electrical grid during disruptions or emergencies.

One example of this is a transportable turnkey vehicle charging station called EV ARC powered by a tracking solar canopy and lithium-ion battery storage developed by Beam, formerly Envision Solar International, that may be very appropriate for multiple non-bus fleet applications. This modular solar charging platform is designed to be operated independently from the grid or it can be grid-buffered. They require no construction nor ground-disturbance and therefore can be installed and set-up and quickly at the charging site without permitting and essentially no operating cost. The company has recently developed an upgraded version of the company's existing standard EV ARC shown in Figure 20, the High-Powered EV ARC, which can be equipped with 38-51 kWh of battery storage, 40 Amp power supply, and 8.4 kwh level-2 charge or a 12.5 kW three-phase 208 for DC fast charging. The charger can split or dynamically among one or by as many as six J1772 charging plugs. The High-Powered EV ARC is able to be daisy chained or stacked with surface cabling to support 50kwh DC Fast Charge, which is able to produce 1,000 miles per day on average, depending on site location and amount of sunlight.

Figure B6: EV ARC solar-powered EV charger with built-in backup energy storage

Source: Beam

The EV ARC can fit inside a standard legal sized parking space, takes up no additional parking, and can be installed as a single unit or can be scaled to provide charging for multiple EVs, e-bikes, e-scooters, or any electrical equipment which has mission critical functionality.

In addition to facilitating e-mobility, this technology enhances resiliency because it is grid independent and can generate its energy without the need for fossil fuel. It provides access to wireless communications or emergency power access to first responders including backup power for hospitals, police departments and other mission critical infrastructure. These stations can be moved quickly to avoid being damaged by flooding or to provide power where needed to support the community.

This kind of solar charger is considered by many municipalities as a resiliency hub of last or first resort. For example, the New York City's Department of Citywide Administrative Services has deployed almost 90 of them as part of the city's resiliency planning.

Stored energy: Along with distributed energy produced by engine-powered generators or photovoltaic panels, energy storage batteries are needed for resilience. The stored electricity could be used when the grid's power supply is interrupted. As previously described in the bi-directional charging section, energy can also be stored in PEVs, which collectively can act as a large battery. A smart charger would control the flow of energy and can send energy from the grid to vehicle batteries or draw energy from the car batteries back onto the grid. Along with cost, one challenge caused by energy storage is physical space as the area required for enough batteries to store the electricity produced may be prohibitive at many sites.

As discussed, there are a variety of options available for charging electric vehicles. **Table B3** outlines all the currently available charging stations with differentiating details.

Table B3: Electric Vehicle Charger Summary

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
Level 2 Chargers					
ChargePoint **CT 400** https://www.chargepoint.com/	30A	7.2 kW (240V AC @ 30A) x 2 3.8 kW (240V AC @ 16A) x 2 (Power share)	✓ LCD video screen ✓ Cable Management/retractors that automatically keep cable off of ground ✓ Mixed use capable – set up and manage access groups for public charging and specific fleet charging. ✓ Integrates with AssetWorks and vehicle telematics systems. ✓ Fuel management and tracking capabilities per vehicle.	✓ Utility vehicles/carts ✓ Publicly available charging	$3,604-$6,568 Sourcewell Contract
SemmaConnect **Series 6 public charging** https://semaconnect.com/	7.2kW	240VAC@ 30A	✓ Interactive LED lights ✓ Easy payment with smart card authentication ✓ Load Management Ready ✓ Wireless data communication ✓ Optional cable management	✓ Utility vehicles/carts ✓ Publicly available charging	
SemmaConnect **Series 7 for Fleets** https://semaconnect.com/	7.2kW	240VAC@ 30A	✓ Interactive LED lights ✓ Fleet Vehicle Management ✓ Fleet Access Control ✓ Fleet Manager Portal ✓ Late Plug-in/Plug-out Alerts ✓ Schedule Charge Start Time ✓ Session Data and Analytics ✓ State of Health Monitoring ✓ Load Management Ready	✓ Utility vehicles/carts ✓ Publicly available charging	$4,590 (1 year service) $5,920 (w/3-year service) $7,110 (w 5-year service)
Low-cost dumb chargers paired with AmpUp and Cyber Switching https://ampup.io/	7.2kW (Varies by car)	208/240VAC@ 40A	✓ Aggregated 4 to 1 network connection (lower cost) ✓ Networked smart solution ✓ Interactive app-based charging ✓ Per user reporting ✓ Manager reporting	✓ Utility vehicles/carts	$2,999 - $4,099 EVMC Stand Alone

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
http://www.cyberswitching.com/power/home/ https://www.clippercreek.com/			✓ Reservation charging ✓ Group assignment ✓ Priority Charging	✓ Publicly available charging	Feature EVMC w/ 2 YR Warranty $1,050 - $1,487 Clipper Creek Additional Pricing may Apply.
EVSE LLC and AmpUp https://ampup.io/ http://evsellc.com/	7.2kW and 9.6 kW	240VAC@ 30A and 240VAC@ 40A	✓ Modular hardware that provides many charging options ✓ Unique overhead and light pole mounted chargers ✓ Scheduling and dedicated access to multiple user groups ✓ Manage multiple locations with hierarchical administration capabilities ✓ Achieve net-zero operating costs by opening chargers to the public during off-hours ✓ AmpUp proactive monitoring minimizes ongoing site administration ✓ Schedule charging sessions and dedicate access to fleets during specific hours or day	✓ Utility vehicles/carts ✓ Publicly available charging	
Grizzle-e **Modular charging systems** https://grizzl-e.com/business-products/	9.6 kW	208-240 V, 40A Can also be configured to 16A, 24A, or 32A maximum current output	✓ Dynamically managed Power Sharing to limit maximum amperage ✓ Adjustable maximum current output to allow the use of a 50A, 40A, 30A, or 20A dedicated circuits ✓ Demand/Response capable ✓ one PCPH and 10-42 Nodes ✓ Collects telemetry of the charging sessions including date/time, user, session duration, KWH consumed, payments, usage, and profitability. ✓ Expandable by adding additional nodes	✓ Utility vehicles/carts ✓ Publicly available charging	$1,700-2,000 + $500 per node

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
Grizzle-e Classic **Low-cost residential chargers** **https://grizzl-e.com/home-products/**	9.6 kW	208-240 V, 40A Can also be configured to 16A, 24A, or 32A maximum current output	✓ Installs to a 14-50R (RV Plug) outlet ✓ Easily transportable mounting bracket allows transport between different locations. ✓ Indoor and Outdoor NEMA rated. ✓ 18-24' cables available	✓ Utility vehicles/carts ✓ Publicly available charging	$399-$439
Power Electronics **NB Wall & NB City** **https://power-electronics.com/electric-mobility/**	2 x 7.7 kW	240 V	✓ Bluetooth-based authentication activated by device proximity ✓ Multiple payment systems including RFID cards, credit/debit cards and smartphones. ✓ Smart power balancing for fleet management for at least 25 vehicles ✓ Dual Power Sharing functionality	Awaiting info	
Wallbox Quasar **DC Bi-directional chargers** **https://wallbox.com/en_us/**	7.4 kW	32A (adjustable amps with dynamic power sharing), 240V input	✓ V2G/V2H ✓ Available in mid 2021 ✓ Only available in ChadeMo but will be available in CCS in early 22022. ✓ UL certification in the US anticipated in mid-2021 ✓ Grid-tied only (island due late 2021 for residential)	✓ Utility vehicles/carts ✓ Publicly available charging	$4-5K depending on features
Wallbox Pulsar Plus **Affordable smart chargers** **https://wallbox.com/en_us/**	9.6 kW	40A output	✓ Smart charger with Bluetooth and Wifi, Alexa, Apple Watch, etc. for remote operations ✓ Demand Response for utility rates ✓ Dynamic Power sharing capable to modulate ✓ Hardwired or NNEMA 1450 ✓ NEMA 4 outdoor rating ✓ Wall-mounted Dual pedestals available ✓ Digital profiles: car or user identified ✓ Available in Q2 2021	✓ Utility vehicles/carts ✓ Publicly available charging	$649

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
Xeal **Evocharge**	32A/7.7kW at	240V, 40A output	✓ Load Management- Add more chargers with less capacity ✓ Wifi Networked System (nfc coming in Q1 2021) ✓ Cloud based dashboard portal (remote reports, monitoring, management, etc.) ✓ Get live updates on battery charge percentage ✓ Smart Phone App ✓ Reserve charging sessions function ✓ Mixed use application (private, public or both) ✓ Wall, Pedestal or dual mounted ✓ NEMA 4 Rated and UL Certified	✓ Utility vehicles/carts ✓ Publicly available charging	$1,500
Powerflex **Webasto Turbo DX**	32A/7.7kW at	240V, 40A output	✓ Adaptive Load Management- Monitors entire buildings' electrical capacity and diverts EXTRA, UNUSED available electricity to car charging. Updates in **real time.** ✓ No need for additional power/gear at most buildings. ✓ Wireless "mesh network" (ZigBee) or Wifi ✓ Save on Demand Charges with Proprietary Algorithms- Drivers input miles requested to be charged and time of departure ✓ Smart Phone App ✓ 1 LMC (load management controller) can manage up to100 + charging stations ✓ Cloud based dashboard for reports, monitoring and remote management ✓ Can work with Level 2, DC-Fast chargers or a combination ✓ NEMA 4 Rated and UL Certified ✓ Wall, pedestal or dual mounted	✓ Utility vehicles/carts ✓ Publicly available charging	LMC (load management controller) for entire system = $10,000 Charger= $1,500
Enel X https://www.enelx.com/n-a/en	32 amp (7.7KW, 208/240V)	JuiceBox Pro 32 = 208/240 (40-amp circuit).	✓ Cable Management/retractors that automatically keep cable off of ground ✓ Load Balancing/Load Management ✓ JuiceNet Enterprise Dashboard & Capabilities (Admin Log In) ✓ JuiceNet App. (QR Code/Account Tracking)	✓ Utility vehicles/carts ✓ Publicly available charging	ALL MSRP (discounting via quantity ordered):

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JuiceBox 2.01 Pro 32/40/48 **JuicePedestal (Add 2 JuiceBoxes with Cord Management System)** **JuiceStand (Add 1 or 2 JuiceBoxes)** **JuiceNet Enterprise (Software)**	40 amp (9.6KW, 208/240V) 48 amp (11.5KW, 208/240V)	JuiceBox Pro 40 = 208/240 (50-amp circuit). JuiceBox Pro 48 = 208/240 (60-amp circuit).	✓ NEMA-4 Rated ✓ Warranty already included in cost of stations (Base 3-year warranty) ✓ Turnkey, fast-to- deploy charging infrastructure ✓ OCCP 1.6J Compliant ✓ Connectivity (WIFI, Ethernet & Cellular) ✓ UPT (Unattended Payment Terminal for Public/High Volume needs) ✓ Different flavors (32/40/48) to accommodate any electrical capacity needs. ✓ Mobile app & dashboards include notifications, load balancing, optimized charging schedules. Smart Level 2 chargers eligible for significant rebates via Incentive programs	✓ Versatile use cases including resident charging, customer parking, and employee charging. Flexible mounting solutions, and plug-in and hardwire versions for 32A, 40A, 48A versions offer install versatility.	Single Unit, Wall Mounted: 32 ($1,369) 40 ($1,419) 48 ($1,449) JuiceStand ($499) JuicePedestal ($1,299) Dual-Port Units, Free Standing: 32 (Juicestand: $3,237/JuicePedestal: $4,037) 40 (Juicestand: $3,337/ JuicePedestal: $4,137) 48 (Juicestand $3,397/ JuicePedestal: $4,197)

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					JuiceNet Enterprise Software: +$120 per year/per JuiceBox (1–10-year packages available)
Level 3 DC Chargers					
ChargePoint ChargePoint Express CPE250 **https://www.chargepoint.com/**	200-1000A	62.5kW	✓ LCD Screen ✓ Modular architecture ✓ Simplified serviceability ✓ Built in redundancy ✓ Small charging footprint	✓ Light, medium, heavy-duty vehicles	$61k (WA State contract)
ChargePoint ChargePoint Express Plus	100A Power Module 200, 250, 300, 350, 500A Power Block	200-350kW	✓ Modular, scalable ✓ Simplified serviceability ✓ Built in redundancy ✓ Multiple configurations for charge ports ✓ Cable management	✓ Light, medium, heavy-duty vehicles ✓ Emergency vehicles	
Heliox **Flex 180** **https://www.heliox-energy.com/us/home**	250A (single); 83A (each triple)	180kW	✓ Charge up to 3 vehicles: sequential, parallel, or dynamic ✓ UL certified	✓ Light, medium, heavy-duty vehicles ✓ Emergency vehicles	$197k 1:3 charger to dispenser (FL state contract)
ABB **Tera 184**	230A	180kW	✓ Flexible architecture ✓ Compact footprint ✓ Fully compatible with current and future EVs ✓ Redundant power for maximum uptime	✓ Light, medium, heavy-duty vehicles	

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
				✓ Emergency vehicles	
Mobile and Portable Chargers					
Freewire Technologies **Mobi Dual L2** https://freewiretech.com/	11 kW, split between 2 J1772	Rechargers from 110v/ 220v outlet or directly from a J1772	✓ Battery integrated charger ✓ Intra site mobility ✓ Inter site mobility via trailer ✓ No infrastructure required ✓ ~320 miles of range per full charge ✓ Can discharge and recharge simultaneously ✓ Shifts load, reduces demand charges ✓ Cloud connected for status and reporting	✓ Light and medium-duty fleet	Rechargers from 110v/ 220v outlet or directly from a J1772
Freewire Technologies **Boost Charger DCFC** https://freewiretech.com/	120kW or 2 cars at 60kW simultaneously	Input power: 240v @ 80–150-amp service, or 208v 3 phase, @ 60–100-amp service. Uses low voltage input and provides high power output at up to 500 volts through standard connectors.	✓ Semi-permanent battery integrated fast charger ✓ Dual port parallel charging ✓ Configurable connectors (e.g., 2 CCs, or @ CHAdeMO or 1 of each) ✓ Easy to relocate ✓ RFID card, payment processor ✓ OCPP 1.6 ✓ 160kWH battery ✓ Shifts load, reduces demand charges	✓ Light and medium-duty fleet	$155k, Price includes 3-year warranty
SparkCharge sparkcharge.io	20 kW	40 ADC, 150 - 500 VDC	✓ Total Energy: 3.5 kWh ✓ Usable Energy: 3.2 kWh ✓ Power (max continuous) 20 kW ✓ Dimensions: 220 mm x 320 mm x 600 mm (8.7 in x 12.6 in x 23.6 in) ✓ Weight: 22 kg (48.4 lbs.)	✓ Rescue or backup charging for all electric vehicle types	$4,000 per unit or flexible lease to own: $1,000-3000 down + $450/month for 24 months

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Solar Chargers					
Beam (formerly Envision Solar) **EV Arc**	Up to 43kW		✓ Solar-powered with battery storage ✓ No design, permitting, utility/infrastructure upgrades or construction required ✓ Rapidly Scalable ✓ Can be moved ✓ Provides emergency backup power	✓ Due to the high purchase price, The EV Arc is a specialized application where electrical power is not available or to avoid large initial investments at non-City owned sites.	
Paired Power **SEVO SunStation**	Up to 16.8 kW	16.8 kW, 40 amp, 300-500 VDC	✓ 100% renewable energy (on-site) ✓ Off-grid or grid-connected options (net-meter solar) ✓ Zero utility bills (no demand or energy charges) ✓ Up to 6 configurable DC connectors (e.g., CCS or CHAdeMO) ✓ Fully resilient (still online after power outage or utility shutoff) ✓ Dynamically managed power sharing ✓ Cloud connection (cellular modem) to enable fleet vehicle management and session data and analytics ✓ Payment processor, credit/debit cards ✓ OCPP 1.6+ ✓ NEMA 4 outdoor rating ✓ Integral energy storage to be operational in 2021 ✓ V2G compatible for CHAdeMO connectors	✓ Light and medium-duty fleet ✓ Utility vehicles/carts	$20k per port (includes solar + installation) or $120K for 6 ports

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
Skyhook Solar **D2** **D4** **D6**	17kW	D2: 1kW D4: 2kW D6: 3kW	✓ Islanded but is developing grid-connected for resiliency ✓ Weighted base but movable with pallet jack ✓ Monitored remotely ✓ Can be equipped with sensors like air quality ✓ Can host advertising to cover cost ✓ No infrastructure upgrades nor permitting other than street use if in ROW ✓ D2: 3'x3' 2 panels 1kW for e-bike and e-scooter ✓ D4: 2kW 3'x6' L1 or L2 for up to 30ebikes or scooters or EVs (see website photo) ✓ D6: Larger 6 modules with 2 3kW L2 plugs for $40 = 60 miles	✓ Light-duty fleet ✓ Utility vehicles/carts	D2: $15k D4: $25K D6: $40K Can be leased for $300-$400/month
Mobile and Portable (Rescue) Chargers					
Freewire Technologies **Mobi Dual L2** **https://freewiretech.com/**	11 kW, split between 2 J1772	Rechargers from 110v/ 220v outlet or directly from a J1772	✓ Battery integrated charger ✓ Intra site mobility ✓ Inter site mobility via trailer ✓ No infrastructure required ✓ ~320 miles of range per full charge ✓ Can discharge and recharge simultaneously ✓ Shifts load, reduces demand charges ✓ Cloud connected for status and reporting	✓ Light and medium-duty fleet ✓ Utility vehicles/carts	Rechargers from 110v/ 220v outlet or directly from a J1772
Freewire Technologies **Boost Charger DCFC** **https://freewiretech.com/**	120kW or 2 cars at 60kW simultaneously	Input power: 240v @ 80–150-amp service, or 208v 3 phase, @ 60–100-amp service. Uses low voltage input and provides high power output	✓ Semi-permanent battery integrated fast charger ✓ Dual port parallel charging ✓ Configurable connectors (e.g., 2 CCs, or @ CHAdeMO or 1 of each) ✓ Easy to relocate ✓ RFID card, payment processor ✓ OCPP 1.6 ✓ 160kWH battery ✓ Shifts load, reduces demand charges	✓ Light and medium-duty fleet ✓ Utility vehicles/carts	$155k, Price includes 3-year warranty

Criteria	Charging Speed	Power Rating	Unique Features/Benefits	Applicability	Cost
		at up to 500 volts through standard connectors.			
SparkCharge sparkcharge.io	20 kW	40 ADC, 150 - 500 VDC	✓ Total Energy: 3.5 kWh ✓ Usable Energy: 3.2 kWh ✓ Power (max continuous) 20 kW ✓ Dimensions: 220 mm x 320 mm x 600 mm (8.7 in x 12.6 in x 23.6 in) ✓ Weight: 22 kg (48.4 lbs.)	✓ Fleet as rescue or backup charging for all electric vehicle types	$4,000 per unit or flexible lease to own: $1,000-3000 down + $450/month for 24 months