ZERO EMISSION FEASIBILITY STUDY

4/6/2023

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Study Overview

Many fleet operators are responding to regulatory, societal, economic, and environmental concerns by looking at deployment of zero emissions vehicles. These alternative fuel vehicles reflect a global trend to modernize fleets, reduce greenhouse gas emissions, and promote a cleaner, more environmentally friendly service to the community. The introduction of new technology has the potential to impact daily operations, infrastructure requirements, the workforce, and financial performance. This study evaluated these potential impacts and developed a strategic roadmap to facilitate a coordinated deployment.

The purpose of this study was to identify a zero emission strategy and develop a Fleet Transition Plan to incorporate battery electric vehicles (BEVs) and/or hydrogen fuel cell vehicles (FCEVs) into Rio Metro's current services and facilities. This study considered Rio Metro's operational characteristics, regulatory requirements, government policies and incentives, and evolving technology. This analysis included a technology review of the current market to identify comparable vehicles available, stakeholder engagement, energy modeling to determine operational feasibility, key site modifications, energy delivery and infrastructure requirements, and forecasted capital and operating costs associated with the transition.

Technology Review

Battery electric passenger vehicles and full-size transit buses are readily available on the market today, with a growing presence for light-, medium-, and heavy-duty trucks and cutaway buses. Electrical infrastructure to support vehicle charging is already well developed, can support the current demand for electric vehicle charging, and can be scaled to meet the growing needs of the vehicle and fuel markets.

Hydrogen fuel cell electric vehicles are gaining ground in the transit market sector, with heavy duty full size transit buses entering the market, but there is virtually no market for hydrogen fuel cell passenger or specialty utility vehicles. In addition to the lack of hydrogen-fueled technology, there is also a lack of hydrogen-fueling infrastructure necessary to produce, distribute, and store hydrogen fuel. The infrastructure for compressed natural gas is greater than that of hydrogen-fueling and continues to grow as the vehicles are viewed as a viable alternative to battery electric vehicles (BEVs).

Compressed natural gas (CNG) cutaways and full size transit buses are currently available and have some tenure in the transit market but are slowly being phased out as battery electric and hydrogen fuel cell vehicles enter the market as zero emissions alternatives to CNG, which is not a zero emission fuel. That is to say, CNG vehicles are still being produced and deployed in transit settings, but vehicle manufacturers are transitioning to development of zero emission buses rather than further developing new models of CNG buses.

Battery Electric Vehicles

Battery electric vehicle (BEV) technology is rapidly changing, and while many vehicle options exist on the market today, the expectation is that more vehicle categories and classes will be electrified and scaled for mass production in the next few years. Passenger vehicles, fleet vehicles, utility/specialty trucks, cutaways, and full-size transit buses can be electrified in two different ways. The first is to have a vehicle with an original equipment manufacturer (OEM) electric powertrain from the manufacturer that is sold as a complete vehicle from the production plant. Virtually all battery-electric passenger cars and light-duty trucks are manufactured in this manner, and this allows for the whole vehicle to be covered by a single factory warranty. For heavy duty, full size transit buses this is also largely true.

Alternatively, vehicles can be "repowered," which is accomplished by a brand-independent manufacturing partner acting as a contractor that supplies OEMs with electric powertrains but do not have their own car brand. While some OEMs are beginning to manufacture light-duty pickup trucks (Ford F-150 or similar), there is currently no market share of battery electric medium- (Ford F-250 or similar) and heavy-duty (Ford F-350, F-450, F-550 or similar) vehicles manufactured by an OEM. Several manufacturers are beginning to contract with companies that design and produce electric powertrains custom to OEM medium- and heavy-duty truck chassis. These vehicles can be sold new as a whole vehicle, and since the vehicles are produced in conjunction with OEMs, key features like tow capacity are minimally compromised. In addition to medium- and heavy-duty vehicles, many cutaways are also becoming available as repowered vehicles as cutaways are typically built on modified heavy-duty truck chassis.

Table 1 shows the BEVs that are commercially available today. For light- and medium-duty passenger vehicles, OEMs are familiar names as they are producing an electric vehicle on their own chassis, the same as their gasoline and diesel vehicles. For cutaways, the manufacturers may be unfamiliar because they electrify vehicles through repowering, where the vehicle may be on a Ford chassis but powertrain and other internal components are a product of the repower OEM. As the market continues to grow and more vehicle types are being electrified, this vehicle list is expected to expand significantly over the next 5-10 years. Although there is no set timeline, many OEMs that are now beginning to produce BEVs from the factory, like Ford and GM, will expand and diversify their vehicle line-up to include heavy-duty vehicles in the future which will provide more options for agencies looking to convert their fleets.

Table 1. Market Available BEVs

Make	Model	Range (Miles)	Battery Capacity	DC Charging Rate
Cutaway Buses				
Green Power	EV STAR+	118 kWh	150	61 kW
Lightning Electric	FE4-86	86 kWh	80	80 kW
Lightning Electric	FE4-129	129 kWh	120	80 kW
Motiv / TurtleTop	EPIC 4	Up to 127 kWh	105	50 kW
Phoenix Motorcars	ZEUS 400	Up to 156 kWh	160	50 kW
Lightning Electric	E-450	125 kWh	130	80 kW
US Hybrid	Ford Transit T-350HD DRW	180 kWh		
Optimal EV	S1LF (E-450 Chassis)	113 kWh	125	60 kW
Green Power	AV Star	118 kWh	150	
Forest River	E-450 EV Shuttle	Up to 157 kWh	160	80 kW
Forest River	F-550 EV Shuttle	128 kWh	120	80 kW
Forest River	Transit Passenger Van EV	Up to 120 kWh	170	80 kW
Light/Medium Duty (Non-Revenue) Vehicles				
GMC/Magna	Sierra 3500	–	180 kWh	150 kW
Ford	E-Transit	110	68 kWh	115 kW
GMC	Sierra 1500 EV Denali	400	200 kWh	350 kW
Ford	F-150 Lightning	300	131 kWh	150 kW
Chevrolet	Silverado EV	430	200 kWh	350 kW
Chevrolet	Bolt EV	259	65 kWh	55 kW
Ford	Mustang Mach-E	270	88 kWh	100 kW
Kia	Niro Electric	239	64 kWh	77 kW
Mazda	MX-30 EV	100	36 kWh	50 kW
Nissan	LEAF Plus	226	62 kWh	50 kW

Level 2 Charging Infrastructure

Level 2 plug-in charging provides light duty vehicles charging over extended periods of time with an average sizing of 3.5-19.2 kW of power. Level 2 charging is limited by the capabilities of the vehicles internal equipment for rectifying the received AC single-phase power to DC for the battery system. Required infrastructure to support a Level 2 charger includes introducing or upgrading standing electrical to support 208 or 240 volt capabilities. BEVs reviewed can receive a Level 2 input charge of 11.5 kW, establishing the max power output desired from a BEV Level 2 charger. Each of the Level 2 chargers reviewed have an anticipated rate of charge of 20 miles of range per hour of charging based on charger output, regardless of vehicle type, which offers adequate overnight charging for most vehicle demands within a BEV.

Table 2. Market Available Level 2 AC Chargers

Manufacturer	Model	Power Output
ChargePoint	CPF50	12 kW
ClipperCreek	HCS-60	11.5 kW
Wallbox	Pulsar Plus (48A)	11.5 kW

The Level 2 chargers in Table 2 are each from recognized companies within the United States and worldwide. Several of the level 2 chargers available on the market today are Buy America compliant, though this information is not always explicitly available on manufacturer websites; compliance would need to be verified with vendors. Due to the near equivalent power output of each Level 2 charge unit reviewed, a generalized 12 kW charge unit will be referenced within the energy modeling study.

Level 3 DC Fast Charging (DCFC) Infrastructure

DCFCs utilize AC 3-phase power to provide fast charging at 50-450 kW. BEVs possess independent capabilities for the high-powered DC supplied by DCFC charging. For this review of available chargers, it's assumed that the vehicles shared a common maximum power acceptance of 80 kW. The cost for infrastructure on a DCFC system is greater than Level 2 systems due to the higher level of power exchanged which requires larger and more expensive equipment. Unlike with the Level 2 chargers, power output from each charging cabinet can be divided with multiple dispenser connections. In the effort to remain economically considerate and provide sufficient power output, DCFC units that possess capabilities for facilitating plug-in charging under 80 kW to multiple vehicles at the same time were of focus for this review. For an expected DCFC power output of 60 kW, the anticipated rate of charge for the BEV is 100 miles per hour, offering sufficient charging for quick turnover during the BEV fleet's operating hours.

Table 3. Market Available Level 3 DCFCs

Manufacturer	Model	Power Output
Heliox	Flex 180	180 kW (3 x 60 kW)
FreeWire	Boost Charger 150	150 kW (2 x 75 kW)
BTC Power	L3R-100	100 kW (2 x 50 kW)
ABB	Terra 124	120 kW (2 x 60 kW)
Siemens	VersiCharge Ultra 175	175 kW (2 x 87.5 kW)

Hydrogen Fuel Cell Vehicles

Like BEVs, hydrogen fuel cell electric vehicles (FCEV) are also powered by battery packs, but the battery packs are much smaller. FCEVs have on-board hydrogen storage tanks that are used by the fuel cell to provide power to the battery packs as needed rather than having all of the energy stored within the battery packs.

El Dorado, also known as ENC, and New Flyer are the only two OEMs with Altoona Tested, Buy America compliant FCEVs that are comparable to Rio Metro's revenue fleet available on the market today. As hydrogen fuel supply becomes more accessible and reliable, the demand for FCEVs is anticipated to drastically increase. This increased demand may lead to additional OEMs in the FCEV market, but it is unclear which OEMs may produce FCEVs or what the timing of market entry of FCEVs could be. Though the available FCEVs are full size transit buses and are not a true equivalent for Rio Metro's cutaway fleet, they could be used as an alternative for the AAA buses. This review also included a review of Rio Metro's non-revenue fleet, but it was found that FCEV equivalents for these vehicles do not yet exist.

Table 4. Market Available FCEVs

Make	Model	Length	# Seats	# Wheel Chairs
Buses				
El Dorado (ENC)	Axess-FC	40'	37/33/27/31/29	2/2/3/2/2
New Flyer	Xcelsior Charge FC	40/60'	40/52	2/2

CNG Vehicles

Compressed natural gas (CNG) is a clean low emission energy option for vehicles that has been in place for decades. While the vehicle possesses an internal combustion engine, its fuel source is a dedicated pressure vessel of CNG, with the main component being methane. A number of CNG vehicles were found to be equivalent for Rio Metro's cutaway buses, but few readily available CNG equivalents were found for Rio Metro's non-revenue fleet vehicles. Historically, the market has seen production of some light duty CNG vehicles, like the Honda Civic NG that was discontinued in 2015[1], but this market space has increasingly dwindled. ENC provides CNG equivalent vehicles for the existing revenue fleet. The E-Z Rider II CNG bus is offered in 30', 33', and 41' lengths, while the Axess CNG bus has the lengths of 32', 35', and 40'. The New Flyer Xcelsior is offered in a 35', 40', and 60' length with the most seats at 61 with 2 wheelchair locations.

Table 5. Market Available CNG Vehicles

Make	Model	Length	# Seats	# Wheel Chairs
Buses				
ElDorado (ENC)	Axess CNG	32' / 35' / 40'	29 / 35 / 41	2 / 2 / 2
ElDorado (ENC)	E-Z Rider II CNG	30' / 33 / 41'	31 / 33 / 41	2 / 2 / 3
New Flyer	Xcelsior CNG	35' / 40' / 60'	32 / 40 / 61	2 / 2 / 2

[1] Honda to Discontinue CNG and Hybrid Civic Models - WSJ

Stakeholder Engagement

To inform Rio Metro's fleet transition strategies, a series of interviews with stakeholders were conducted to gather information on current Low/No Emissions Fleet Plans, proposed infrastructure and implementation timelines, and potential funding opportunities. The interviews included discussions of the "art of the possible," which will ultimately aim to align Rio Metro's fleet transition with what others are currently doing.

All Aboard America (AAA)

AAA has not made a commitment to a specific zero emission alternative fuel yet but has indicated that they will likely select battery electric as the primary technology and have begun piloting battery electric vehicles in a few locations. When discussing potential opportunities for partnership, AAA expressed an interest in cost sharing through various contract mechanisms, such as an extended contract term or rolling the cost of infrastructure into contract price, provided there was a return on investment for AAA by the end of the contract term.

ABQ Ride

ABQ Ride has begun planning for a zero emissions fleet through a transition study completed by CTE. The transition study completed evaluates only ABQ Ride's fixed-route transit fleet with depot charging only – the study excludes on-route charging and modeling of the paratransit fleet. Though on-route charging was not evaluated as part of the initial transition study, ABQ Ride has indicated an interest in pursuing the technology in the future and has earmarked 2040 as the goal for a 100% zero emissions fleet.

ABQ Ride is currently piloting 5 battery electric buses (BEBs) that entered revenue service in June of 2022. Most of the maintenance on these vehicles is completed by the vendor under warranty, but ABQ Ride is evaluating the workforce and facilities impacts once the agency takes over maintenance duties. If Rio Metro were to transition to BEBs, there may be a potential for shared maintenance facilities and fueling infrastructure.

New Mexico DOT (NMDOT)

NMDOT has not made a commitment to a specific zero emission alternative fuel yet but has indicated that they will likely select battery electric as the primary technology. A discussion around the potential for shared fueling infrastructure for battery electric vehicles through the NEVI program determined that there will not be any NEVI charging stations near the cities of Rio Rancho or Los Lunas in years 1-3 of the program, but there may be an opportunity for a station within one or both cities in years 4-5 after all interstate corridors are fully built out and certified. NMDOT also indicated that they are evaluating solar, battery energy storage systems (BESS), and hydrogen power in years 4-5 of the NEVI program build-out.

At the time of this interview, NMDOT was not aware of any new state legislation or funding mechanisms moving forward, but noted the following programs may be available in addition to possible funding options through the local MPO:

American Recovery and Reinvestment Act

$10 million; State accepted grant applications to award DC Fast Chargers (DCFCs) in 32 communities and these stations are currently being planned, designed, and/or implemented. Neither Rio Rancho nor Los Lunas were among the 32 communities that received funding through this grant.

State Appropriations

$2 million; New Mexico provided an additional $2 million to the $10 million in American Recovery and Reinvestment Act funding to build out community DCFC charging stations.

NEVI Discretionary Funding

$5.68 million; New Mexico was awarded a portion of the $2.5 billion NEVI Program. NMDOT believe that grant applications for funding may be submitted directly to DOT/FHWA without going through DOT/MPOs but is waiting to see what is announced in the upcoming notice of funding opportunity (NOFO). NMDOT indicated that the City of Los Lunas may be looking to submit for funding in 2023 and if so, Rio Metro may have the opportunity to partner on that effort.

Public Service Company of New Mexico (PNM)

The utility PNM is providing incentives to its customers for the transition and use of green energy technologies such as EV charging services. With residential and non-residential EV charging electric promotions, the non-residential rates are currently within a pilot period where PNM offers no demand charges, also known as a volumetric rate. This further reduces the cost of EV charging as the peak loading level will not negatively impact the per kilowatt-hour cost and instead be lumped into a time of use and time of year category for per kilowatt-hour charge.

PNM expressed it will continue to evaluate the market and provide electrification incentives for its customers. Further building on the PNM 2022-2023 Transportation Electrification Program:

PNM 2022-2023 Transportation Electrification Program

PNM also offers a commercial rebate for eligible infrastructure and installation costs of non-residential customers, with a total budget of $1,500,000. This budget includes infrastructure installation from the other side of the transformer to the base of the charge unit. The rebate can be extended for workplace and fleet charging infrastructure through the utilities as outlined in Article 7.2.3.2.2 of the approved PNM Transportation Electrification Program[2].

Non-Residential Charging Station Pilot Rate 3F

PNM has indicated they are developing an EV rate structure beyond the pilot program, but the terms of this future rate structure are still unknown. Per rate schedule No. 3F by PNM, an off-peak base rate of $0.0638779/kWh possesses an on-peak to off-peak ratio of 2:1 in the non-summer months and 3:1 in the summer months.

[2] 59f3d1d5-fe64-4a60-eabe-d2c49cb9dd85 (pnm.com)

Energy Modeling & Analysis

In addition to the technology review conducted for the transition of Rio Metro's standing internal combustion engine fleet to zero emission, energy modeling for a comparable battery electric and hydrogen fuel cell fleet was performed. This energy modeling considered the current route and operating hours of the vehicles to ensure the transition was equivalent to the currently operating fleet. For the battery electric vehicles (BEVs), a review of the required charge unit infrastructure was conducted and proved to produce three scenarios for transition. These scenarios are reviewed in detail for the equipment and cost benefits considered in a final decision. In addition to the battery electric review, the infrastructure design and availability required for hydrogen fleet were based on the modeling reviewed within this section.

Battery Electric Analysis

Methodology and Assumptions

This energy modeling effort was conducted to understand the feasibility of fleet operations using BEVs and to forecast the magnitude of infrastructure needed to support a transition to a BEV fleet. The modeling has been based on operating data provided to support the effort and the battery and charging specifications of each BEV equivalent identified in the Technology Review. Existing revenue vehicle average and maximum daily miles and hours were considered in the modeling, derived from provided monthly vehicle data. The total energy consumption of the BEV fleet is computed using both the average and worst-case vehicles, which allows overall site energy and fleet size impacts to be more accurately predicted.

The standard operation off hours included a one-hour safety buffer, for a total of 8 hours available for vehicle charging. This period was reduced to 6 hours for vehicles that are available for demand response services. This buffer not only provides a grace period for connecting any given vehicle to their charger, but also considers the change in charge rate that occurs as a battery reaches full charge (Figure 1). To protect the life of the BEVs' batteries and avoid range anxiety, a minimum state of charge (SOC) of 20% and a maximum SOC of 90% to protect the life of the battery is assumed. These assumptions are reflected in the analysis by assuming a usable battery capacity equal to 70% of the vehicle's nameplate battery capacity.

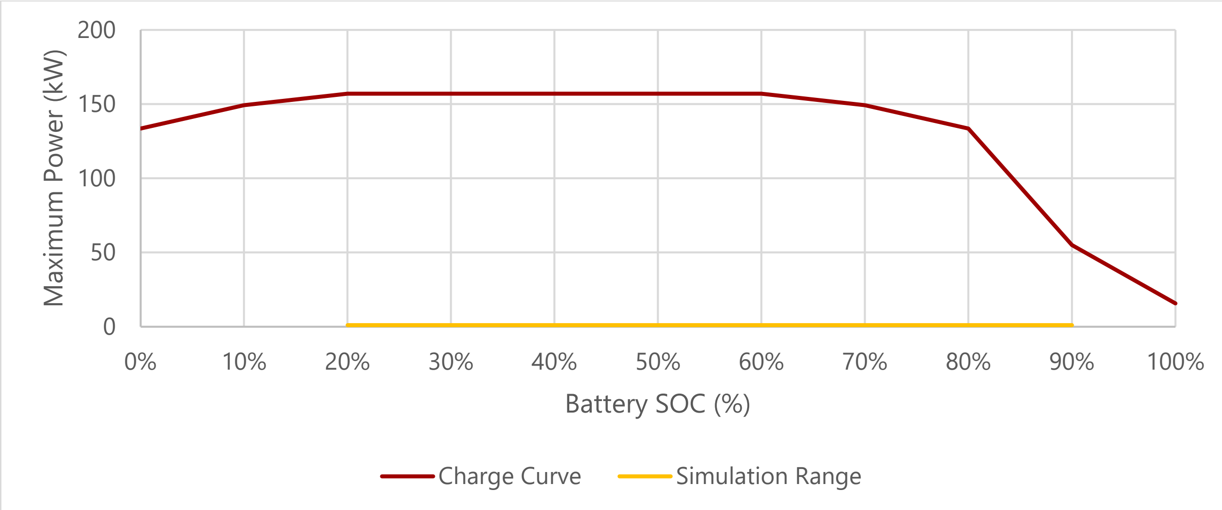

Figure 1. Forest River E450 Charge Curve (30A Level 2 Charger)

Use of accessory equipment and towing by some of Rio Metro's non-revenue vehicles can also impact energy consumption, but the impacts of each are difficult to predict. Accessory equipment with an average power consumption of less than 1 kW will not significantly impact the results but towing at the maximum capacity of the vehicle can nearly double its energy consumption. Towing lighter loads has a less significant impact. To account for these unknown additional energy requirements, a 25% energy consumption buffer was added to the daily energy needs of each vehicle type in the non-revenue fleet that may utilize accessory equipment or tow.

If the daily amount of energy required exceeds the available energy for that vehicle type, then the cases for an increase in fleet size or mid-day fast charging are considered. These additional cases facilitate protecting the vehicle's health while avoiding interruptions to normal operations. Three scenarios were considered: a base scenario, a scenario reflecting an expanded BEV fleet, and a scenario where the fleet is not expanded but daytime recharging is supported.

Model Inputs

To determine the estimated energy consumption of a BEV fleet, this model was informed by operational data of Rio Metro's current fleet, both revenue and non-revenue. Raw data was consolidated by vehicle make and model to reach aggregate values for service profile. Due to the diversity of Rio Metro's operational use case, this model examines both an average case and a maximum, worst case operational scenario. Table 6 and detail the fleet data that was used to inform this BEV analysis for Rio Metro's revenue and non-revenue fleets, respectively.

Table 6. Existing Revenue Fleet Data

Make & Model	Fleet Size	Avg. Monthly Miles	Max. Monthly Miles	Avg. Daily Miles	Max. Daily Miles	Avg. Monthly Hours	Max. Monthly Hours	Avg. Daily Hours	Max. Daily Hours
Valencia County Transit Facility									
Braun Entervan (Mini-Van)	3	475	564	24	28	25	28	1.3	1.4
Ford E450 Arboc SOF	4	634	1,680	32	84	44	110	2.2	5.5
Ford E450 Glaval Universal	16	2,332	2,772	117	139	124	139	6.2	7.0
Ford/Eldorado Aerotech 27'	3	634	1,680	32	84	44	110	2.2	5.5
Sandoval County Transit Facility									
Ford E450 Glaval Universal	5	1,624	1,902	81	95	102	117	5.1	5.8
Ford Glaval 26'	7	1,624	1,902	81	95	102	117	5.1	5.8
All Aboard America									
AMERITR M2 32'	2	4,393	4,831	220	242	164	180	8.2	9.0
STARCRAFT/ALL STAR XL 36'	2	4,393	4,831	220	242	164	180	8.2	9.0
STARTRANS M2 32'	3	4,393	4,831	220	242	164	180	8.2	9.0
TURTLETOP S2C-106 CAB 33'	1	4,393	4,831	220	242	164	180	8.2	9.0

Table 7. Existing Non-Revenue Fleet Data

Make & Model	# of Vehicles	Average Daily Miles	Maximum Daily Miles	Average Daily Hours	Maximum Daily Hours
Nissan Sentra	1	12	13	2	4
Ford Focus	5	70	91	3	6
Ford Escape	2	50	54	3	6
Ford Explorer	5	70	91	3	6
Ford F-150	9	110	126	3	6
Ford F-350	1	20	22	2	6
Chevy Express G2500	1	17	20	8	10
Dodge Ram 3500	1	40	46	2	6

Battery Electric Vehicle Equivalents

For each of the energy types reviewed, equivalent vehicles to the existing fleet were determined. The market is relatively well developed for revenue and non-revenue vehicle types for BEVs, but not all vehicles have an exact equivalent. In those instances, such as the AAA contract buses, the closest equivalent in size and application was chosen for modeling purposes. For each of the BEV equivalents selected, range capability, seat capacity, and wheelchair accessibility were prioritized.

Table 8. BEV Equivalents Used for Modeling

Revenue Fleet		
Existing Fleet	**Fleet Total**	**Battery Electric Equivalent**
Braun Entervan (Mini-Van)	3	Sunset Vans Electric Low Floor Minibus
Ford E450 Glaval Universal	21	Forest River E450 EV Shuttle
Ford Glaval 26’	7	Forest River E450 EV Shuttle/Optimal-EV S1LF
Ford/ElDorado Aerotech	3	Forest River E450 EV Shuttle
Ford E450 Arboc SOF	4	Optimal-EV S1LF
AMERITRANS M2 32’	2	ENC Axess-BEB 35’
TURTLETOP S2C-106 CAB 33’	1	ENC Axess-BEB 35’
STARTRANS M2 32’	3	ENC Axess-BEB 35’
STARCRAFT/ALLSTAR XL 36’	2	ENC Axess-BEB 40’
Non-Revenue Fleet		
Conventional Vehicle	**Fleet Total**	**Battery Electric Equivalent**
Nissan Sentra	1	Chevy Bolt EV
Ford Focus	4	Nissan Leaf Plus
Ford Escape	2	Nissan Leaf Plus
Ford Explorer	5	Ford Mach-E 88
Ford F-150	6	Ford F-150 Lightning
Chevy Express G2500	1	Ford E-Transit
Dodge RAM 3500	1	GMC/Magna Sierra 3500

Analysis Results

Through the completion of BEV energy modeling for revenue and non-revenue fleets, resulting values detailed the conditions of the transitioned fleets within a base scenario. The non-revenue fleet’s transition to recommended BEVs proved to successfully meet the modeling requirements. This said, the revenue fleet experienced some challenges in maintaining healthy battery capacity usage as well as meeting the hours until charged, resulting in the additional review of an expanded fleet scenario and mid-day charging scenario for energy modeling. Both alternative scenarios for the revenue fleet were designed to assist Rio Metro in successfully transitioning their current combustion fleet to battery electric with minimal disruptions or alterations to their standard operations.

Non-Revenue Vehicles

BEV equivalents for the non-revenue fleet were also modeled. Displayed by the energy modeling results, the entire non-revenue BEV fleet completed its routes without battery capacity challenges. The vehicles also completed charging in less than 6 hours, accommodating the on-call off hours’ time period (6 hours). The total peak load related to charging the non-revenue fleet is just 93.6 kW and total daily energy consumption for charging these vehicles is 794 kWh.

Table 9. Non-Revenue Fleet Charger Analysis

Make & Model	BEV Fleet Size	Minimum Charger Level and Output	Peak Load (kW)	Maximum Daily Energy Consumption (kWh)	Hours to Full Charge	Maximum % Daily Use on Battery
Ford F-150 Lightning	6	30A Level 2	43.2	417.8	3.6	64.4%
Ford E-Transit	1	15A Level 2	3.6	25.6	2.2	45.0%
GMC/Magna Sierra 3500	1	15A Level 2	3.6	32.1	1.7	24.8%
Ford Mach-E 88	5	15A Level 2	18.0	139.2	2.4	45.1%
Nissan Leaf Plus	6	15A Level 2	21.6	171.8	4.3	59.8%
Chevy Bolt EV	1	15A Level 2	3.6	7.4	1.0	17.4%

Total Number AC Level 2 Chargers	20
Total Number DC Fast Chargers	0
Total Peak Power Required	93.6 kW
Daily Energy Consumption	794.0 kWh
Current Fleet Size	20
Required BEV Fleet Size	20

Revenue Vehicles – Baseline Scenario

First, a baseline scenario was modeled to identify the number of vehicles and chargers required to support a BEV fleet based on current operating characteristics. The maximum percent daily use of the battery was calculated based on the total energy used by the vehicle on a worst-case service day and the BEV's battery capacity. In Table 10, battery use values over 65%, shown in orange, are approaching the available safe battery capacity of that vehicle. Values over 70% have exceeded this and are shown in maroon.

The baseline scenario models existing service data as-is, identifying which vehicles can be replaced without any modifications to service or fleet size and, for the vehicles that can be replaced without modification, the *minimum* infrastructure level required to maintain the same level of service. While 15A Level 2 chargers may be able to support some vehicles they are uncommon in practice; 30A Level 2 chargers are the most commonly used. For modeling the expanded fleet and mid-day charging scenarios, results are based on assuming 30A Level 2 chargers are used for all vehicles that can be served by a Level 2 charger.

Table 10. Revenue Fleet Base Scenario Charger Analysis

Make & Model	BEV Fleet Size	Minimum Charger Level and Output	Nameplate Battery Capacity (kWh)	Available Battery Capacity (kWh)	Maximum Daily Energy Used (kWh)	Maximum % Daily Use on Battery
Valencia County Transit Facility						
Sunset Vans Electric Low Floor Mini-Bus	3	15A Level 2	75	52.5	17.7	23.6%
Optimal-EV S1LF	4	15A Level 2	113	79.1	92.4	**81.8%**
Forest River E450 EV	16	30A Level 2	157	109.9	149.4	**95.2%**
Forest River E450 EV	3	15A Level 2	157	109.9	94.1	60.0%
Sandoval County Transit Facility						
Forest River E450 EV	5	30A Level 2	157	109.9	105.1	**66.9%**
Forest River E450 EV	2	30A Level 2	157	109.9	105.1	**66.9%**
Optimal-EV S1LF	5	15A Level 2	113	79.1	103.3	**91.4%**
All Aboard America						
ElDorado/ENC Axess-BEB 40'	2	50 kW DCFC	444	310.8	287.0	64.6%
ElDorado/ENC Axess-BEB 35'	2	50 kW DCFC	444	310.8	287.0	64.6%
ElDorado/ENC Axess-BEB 35'	3	50 kW DCFC	444	310.8	287.0	64.6%
ElDorado/ENC Axess-BEB 35'	1	50 kW DCFC	444	310.8	287.0	64.6%

This model illuminated challenges with some BEVs' ability to complete the service required of them on a single charge. The Forest River E450 BEVs and the Optimal-EV S1LFs experienced battery capacity utilization issues, leading to the need for additional fleet vehicles that could be swapped out during the day or support for mid-day recharging. Without these accommodations, these vehicles would use between 80 and 95 percent of their nameplate battery capacity, impacting battery health, increasing charge times, and potentially impacting normal service. With future advancements in battery technology, the nameplate battery capacity may increase which may decrease the number of DCFCs required under this scenario, but this model analyzes a worst-case scenario using currently available technology.

Revenue Vehicles – Expanded Fleet Scenario

The modeling effort identified the need for nine additional BEVs to meet existing fleet service levels. Therefore, the next set of results reflects purchasing 7 additional vehicles in Valencia County and 2 additional vehicles in Sandoval County. The resulting number of chargers, anticipated peak loads, and daily energy values reflect this increase in fleet size. Model outputs for average charge times at peak load are reported, with orange highlighting indicating values over the off-hours for demand response services (6 hours) and in red denoting if the value is over the standard off-hours (8 hours). The percent use of battery capacity for maximum percent daily use is indicated as previously mentioned, with orange detailing 65% or more and red for over 70%.

Table 11. Revenue Vehicles Expanded Fleet Scenario Charger Analysis

Make & Model	BEV Fleet Size	Minimum Charger Level and Output	Peak Load (kW)	Maximum Daily Energy Consumption (kWh)	Hours to Full Charge	Maximum % Daily Use on Battery
Valencia County Transit Facility						
Sunset Vans Electric Low Floor Mini-Bus	3	30A Level 2	21.6	38.0	1.37	23.6%
Optimal-EV S1LF	5 (+1)	30A Level 2	36.0	131.9	2.86	**65.4%**
Forest River E450 EV	22 (+6)	30A Level 2	158.4	1,650.2	**8.14**	**69.2%**
Forest River E450 EV	3	30A Level 2	21.6	100.7	3.64	60.0%
Sandoval County Transit Facility						
Forest River E450 EV	5	30A Level 2	36.0	366.4	7.95	**66.9%**
Forest River E450 EV	2	30A Level 2	14.4	146.6	7.95	**66.9%**
Optimal-EV S1LF	7 (+2)	30A Level 2	50.4	360.0	5.58	**65.3%**
All Aboard America						
ElDorado/ENC Axess-BEB 40′	2	50 kW DCFC	100.0	421.8	2.7	64.6%
ElDorado/ENC Axess-BEB 35′	2	50 kW DCFC	100.0	421.8	2.7	64.6%
ElDorado/ENC Axess-BEB 35′	3	50 kW DCFC	150.0	632.6	2.7	64.6%
ElDorado/ENC Axess-BEB 35′	1	50 kW DCFC	50.0	210.9	2.7	64.6%

	Valencia County Transit Facility	Sandoval County Transit Facility	All Aboard America
Total Number AC Level 2 Chargers	33	14	0
Total Number DC Fast Chargers	0	0	8
Total Peak Power Required	237.6 kW	100.8 kW	400.0 kW
Daily Energy Consumption	1,920.8 kWh	873.0 kWh	1,687.0 kWh
Current Fleet Size	26	12	8
Required BEV Fleet Size	33 (+7)	14 (+2)	8

By increasing the fleet size, the distance traveled by each vehicle is reduced. This in turn reduces the time required to charge and allows for safe battery capacity utilization. However, shown within the analysis results, the Forest River E450 BEVs require the entire standard off-hours period to charge. This charge time could exceed the available 8-hour period for charging, as the charge curve of a battery begins to flatten as full charge is approached; thus, causing a slight increase to the overall charge time. To reduce these vehicles' charge time, additional vehicles could be purchased or mid-day recharging could be considered. In this scenario, the total daily energy consumption of the BEV fleet is 4,480 kWh.

Revenue Vehicles – Mid-Day Charging Scenario

To identify the infrastructure needs of a BEV fleet supported by mid-day charging, another scenario was evaluated where the quantity of vehicles does not change from the current fleet, but some vehicles are brought back to a Rio Metro facility during the day to recharge. The vehicles requiring recharging are the Forest River E450 BEVs in Valencia County and the Optimal-EV S1LFs in both Valencia County and Sandoval County. Due to the rapid charging characteristics of DCFCs, when compared to Level 2 chargers, this mid-day charge would be accommodated by installing DCFCs.

Table 12. Revenue Vehicles Mid-Day Recharging Scenario Charger Analysis

Make & Model	BEV Fleet Size	Minimum Charger Level and Output	Peak Load (kW)	Maximum Daily Energy Consumption (kWh)	Hours to Full Charge	Maximum % Daily Use on Battery
Valencia County Transit Facility						
Sunset Vans Electric Low Floor Mini-Bus	3	30A Level 2	21.6	38.0	1.4	23.6%
Optimal-EV S1LF	4	50 kW DCFC	200.0	66.0	0.9	40.9%
Forest River E450 EV	16	50 kW DCFC	800.0	825.1	**1.4**	47.6%
Forest River E450 EV	3	30A Level 2	21.6	100.7	3.6	60.0%
Sandoval County Transit Facility						
Forest River E450 EV	5	30A Level 2	36.0	366.4	7.95	**66.9%**
Forest River E450 EV	2	30A Level 2	14.4	146.6	7.95	**66.9%**
Optimal-EV S1LF	5	50 kW DCFC	250.0	180.0	**1.24**	45.7%
All Aboard America						
ElDorado/ENC Axess-BEB 40'	2	50 kW DCFC	100.0	421.8	2.7	64.6%
ElDorado/ENC Axess-BEB 35'	2	50 kW DCFC	100.0	421.8	2.7	64.6%
ElDorado/ENC Axess-BEB 35'	3	50 kW DCFC	150.0	632.6	2.7	64.6%
ElDorado/ENC Axess-BEB 35'	1	50 kW DCFC	50.0	210.9	2.7	64.6%

	Valencia County Transit Facility	Sandoval County Transit Facility	All Aboard America
Total Number AC Level 2 Chargers	6	7	0
Total Number DC Fast Chargers	20	5	8
Total Peak Power Required	1,043.2 kW	300.4 kW	400.0 kW
Daily Energy Consumption	1,029.7 kWh	693.0 kWh	1,687.0 kWh
Current Fleet Size	26	12	8
Required BEV Fleet Size	26	12	8

Summary of Findings

The scenarios described previously detail that a fleet transition to BEVs is possible for both the revenue and non-revenue fleets. This said, the revenue fleet will require consideration for the purchase of additional vehicles or operation support for midday charging to meet energy modeling requirements for the fleet.

Maintaining the existing revenue fleet size will result in battery utilization concerns, which will impact the overall health of the battery and increase the time required to fully charge. To reduce the miles and hours each vehicle operates, achieving an acceptable battery utilization level, 7 additional vehicles would be needed at Valencia County Transit Facility and 2 additional vehicles would be needed at Sandoval County Transit Facility. While additional vehicles alleviates the need for additional charging infrastructure, non-revenue hours, miles, and staff labor hours for the revenue fleet would increase as a result.

Alternatively, DCFCs could be installed so vehicles that cannot complete their service on a single charge can partially recharge to complete daily routes. While this would allow the fleet size to remain, it would require installing 25 DCFCs. DCFCs are more expensive to purchase, install, and operate when compared to Level 2 chargers. The non-revenue fleet, however, can be accommodated by Level 2 AC chargers without the need for an increased fleet size or partial recharging mid-day.

Hydrogen Fuel Cell Analysis

Methodology and Assumptions

While the hydrogen vehicle market is expected to drastically expand in the near future, there are currently very few hydrogen vehicles available. Unlike the BEV market, where a complete profile of vehicle types and their specifications are known, hydrogen vehicle specifications aren't available to model fuel consumption in the same manner as the BEVs. In lieu of a complete profile of hydrogen vehicles available, hydrogen fuel consumption for Rio Metro's directly operated and contracted services was calculated by using the reported number of miles traveled, the gasoline gallon equivalent (GGE) energy content of hydrogen fuel, and the expected vehicle efficiencies in miles per gasoline gallon equivalent (MPGGE) for hydrogen vehicles (Eq. 1).

$$\boldsymbol{Eq}.1 \quad \boldsymbol{kg\ H_2} = \frac{\boldsymbol{Miles\ Driven}}{\boldsymbol{MPGGE}} * \boldsymbol{GGE}$$

Using the total mileage of the fleets, the equation above will determine the total quantity of hydrogen fuel that would be required to support Rio Metro's existing service profile. For this application, the expected MPGGE efficiency of a hydrogen fuel cell bus (FCEB) and the GGE energy content of one kg of hydrogen are 7.44 and 0.981[3], respectively, yielding a conversion factor of 7.5 miles per kg of hydrogen.

For Rio Metro's non-revenue fleet, a MPGGE efficiency of 25 for sedans and 12 for trucks/SUVs were assumed; these values are an estimated average based on the known fuel economy of gasoline-fueled sedans, trucks, and SUVs. The GGE energy content for the non-revenue fleet is assumed to be identical to the revenue fleet at 0.981 kg/GGE. While average metrics provide a good basis for this analysis,

[3] Fuel Conversion Factors to Gasoline Gallon Equivalent. [State & Alternative Fuel Provider Fleets: Fuel Conversion Factors to Gasoline Gallon Equivalents (energy.gov)](). Accessed December 2022.

actual efficiencies will vary based on additional factors such as, the age of the fuel cells, use case characteristics (i.e. idle time and driver habits), route terrain (% incline or decline experienced), and auxiliary loads (i.e. heating and cooling).

Model Inputs

To estimate the hydrogen fuel consumption required to support the existing fleet, reported operational data was consolidated. This reflected an aggregate average and maximum daily miles traveled for all revenue vehicles by location and non-revenue vehicles by location in Table 13 and Table 14, respectively.

Table 13. Revenue Fleet Model Inputs

Fueling Location	Fleet	Fleet Size	Average Daily Miles	Maximum Daily Miles
Sandoval County Transit Facility	Rio Metro	12	972	1,140
	AAA	8	1,760	1,936
Valencia County Transit Facility	Rio Metro	26	2,168	2,896

Table 14. Non-Revenue Fleet Model Inputs

Make & Model	MPGGE	Average Annual Miles	Average Weekly Miles
Sandoval County Transit Facility			
Ford Focus	25	5,818	112
		8,903	171
		3,118	60
Valencia County Transit Facility			
Ford Explorer	13	10,376	200
Ford Escape	25	9,998	192
Ford F-150	12	16,357	315
Ford F-350	12	1,026	20
Ford Focus	25	5,826	112
		13,992	269
NMRX Yard			
GMC Express G2500	12	3,434	66
Ford Escape	25	8,343	160
Ford Explorer	12	12,032	231
		12,546	241
Ford F-150	12	19,917	383
		12,293	236
		20,506	394
		20,580	396
		21,157	407
		22,042	424
		16,541	318
		14,469	278
RAM 3500	12	8,044	155
RMRTD			
Ford Explorer	12	9,681	186
Nissan Sentra	25	2,367	46

Analysis Results

Non-Revenue Vehicles

Estimated hydrogen fuel consumption for non-revenue vehicles is reported on a weekly basis, rather than daily. Non-revenue vehicles would not need to refuel daily, due to the consistently? low mileage operation of these vehicles. Non-revenue fleet fuel consumption is broken down by vehicle make and model at each assigned facility within Table 15. Vehicle refueling may not always occur at a single facility and is only inclusive of the average consumption since maximum mileage per vehicle was not available for use in this analysis.

Table 15. Non-Revenue Fleet Hydrogen Consumption

Make & Model	Fleet Size	Average Weekly Consumption (kg H_2)
Sandoval County Transit Facility		
Ford Focus	3	13
Valencia County Transit Facility		
Ford Explorer	1	16
Ford Escape	1	8
Ford F-150	1	26
Ford F-350	1	2
Ford Focus	2	15
NMRX Yard		
GMC Express G2500	1	5
Ford Escape	1	6
Ford Explorer	2	39
Ford F-150	8	232
RAM 3500	1	13
RMRTD		
Ford Explorer	1	15
Nissan Sentra	1	2

Revenue Vehicles

The daily hydrogen fuel consumption for Rio Metro's revenue fleet is estimated to be 360 kg H_2 on average and 405 kg H_2 on a worst case operation day at the Sandoval County facility. For Valencia County, these results were 286 kg H_2 on average and 382 kg H_2 on a worst case operational day. The Sandoval County total daily consumption estimates are inclusive of the AAA fleet, but a separation of Rio Metro's directly operated and contract service fleets is detailed below in Table 16. If Rio Metro were to exclude AAA vehicles from refueling at the Sandoval County facility, instead reserving stored hydrogen fuel exclusively for directly operated vehicles, the daily fuel requirements would decrease by approximately 45%.

Table 16. Revenue Fleet Hydrogen Consumption

Fueling Location	Fleet	Fleet Size	Fleet Size	Average Daily Consumption (kg H_2)
Sandoval County Transit Facility	Rio Metro	12	12	128
	AAA	8	8	232
Valencia County Transit Facility	Rio Metro	26	26	286

Summary of Findings

Per the required maximum kilograms of hydrogen required for bus fueling calculated above, possessing the assumption of five days standard operation capability, approximately 3,938 kg of hydrogen is required per week to support bus operation. Of the 3,938 kg of hydrogen, the buses stored at the Valencia County Transit Facility would require approximately 1,909 kg of hydrogen per week and the buses stored at the Sandoval County Transit Facility would require approximately 2,028 kg of hydrogen per week. Additionally, the non-revenue vehicles are expected to require an additional 392 kg per week.

As depicted in Figure 2, a hydrogen refueling station capable of supplying either the Valencia County facility or Sandoval County facility needs is expected to require approximately 3,000 sq. ft (~0.07 acres). The equipment in this area would include horizontal liquid hydrogen storage, cryogenic liquid hydrogen pumps, vaporizer, station module hydrogen dispenser and the hydrogen bus. This layout assumes one bus is refueled at a time to minimize the size of the hydrogen equipment and the number of hydrogen dispensers required. The liquid hydrogen storage tank is sized to provide two weeks of hydrogen storage (~4,400 kg).

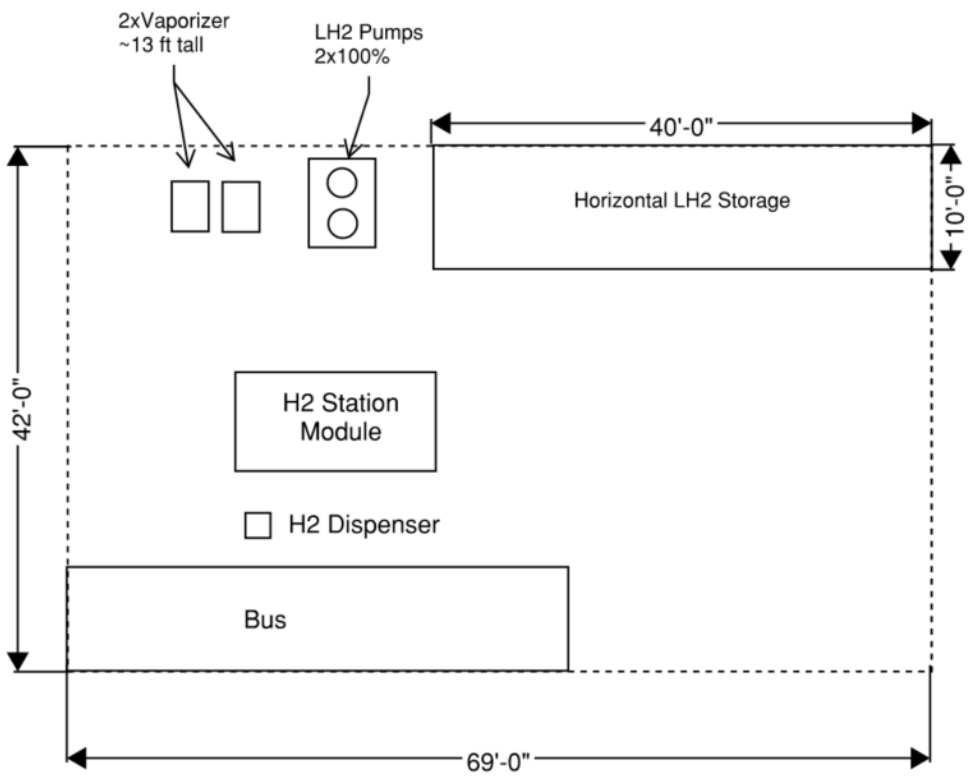

Figure 2. Hydrogen Fueling Station Layout (0.07 Acre)

It is important to note that the refueling rate will be a factor of the capabilities of the bus used and the number of refueling modules. For example, based on the daily hydrogen demand for Valencia County (382 kg/day) and the number of number vehicles being refueled at this station (26), the average refueling capacity is approximately 15.5 kg/bus. A normal refueling rate from a hydrogen dispenser is approximately 3.6 kg/min, therefore it would take approximately 4-5 minutes per bus, or 2 hours to refuel all buses at the Valencia County Transit Facility. At Sandoval County Transit Facility, it would also take approximately 2 hours to refuel all buses. The refueling windows can be reduced by adding additional equipment and/or increasing the capacity of the hydrogen refueling equipment. While these layouts provide a physical footprint of the refueling station, additional area on-site may be required for clearance requirements from property boundaries or other buildings/structures, required by the Authority Having Jurisdiction (AHJ).

If the AAA buses are not refueled at Sandoval County Transit Facility, the total daily hydrogen demand decreases to 533 kg/day. In this scenario, the daily hydrogen demand at Valencia County Transit Facility remains unchanged. This said, the daily hydrogen demand at the Sandoval County Transit Facility decreases from 405 kg/day to 150 kg/day. Two weeks of liquid hydrogen storage would translate to approximately 1,900 kg of hydrogen, resulting in a decreased tank size and an overall reduction of footprint at the Sandoval site from 2,835 sq. ft. to 1,684 sq. ft (~0.04 Acres). The updated site arrangement for the refueling station at Sandoval County Transit Facility is shown in Figure 3.

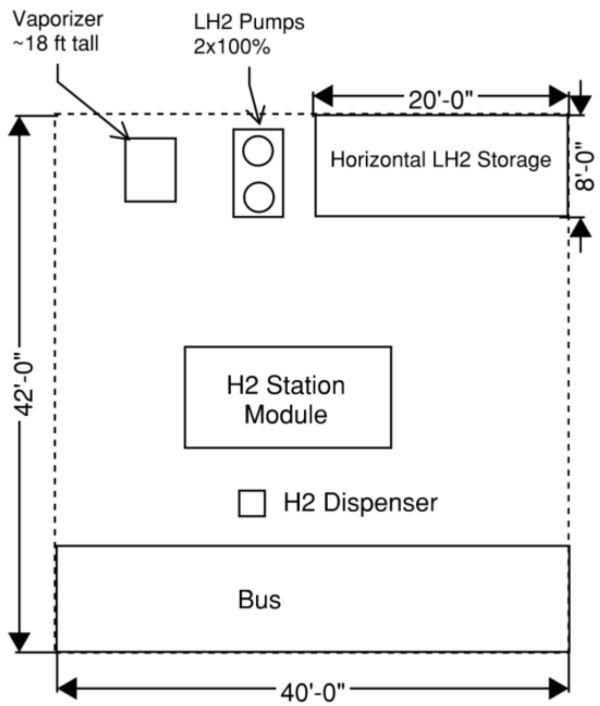

Figure 3. Hydrogen Fueling Station Layout (0.04 Acre)

Financial Analysis

This section evaluates the lifecycle costs associated with the zero-emission vehicle (ZEV) transition scenarios currently being considered by the Rio Metro Regional Transit District (Rio Metro) for its non-revenue and revenue vehicle fleets. The costs evaluated include capital, operating and maintenance (O&M), and fuel/electricity from 2023 to 2040. The scenarios being considered involve a full electric vehicle fleet transition and a mixed fleet transition of electric vehicles and hydrogen vehicles. These scenarios were compared to a third, baseline scenario in Rio Metro maintains a gasoline fleet and does not transition to zero emission vehicles. Both of the ZEV transition scenarios follow the same transition for non-revenue vehicles; the differences between the plans arise in the revenue vehicle transitions. Described in more detail in the key assumptions and vehicle transition scenario sections, the three scenarios reflect the following:

Baseline: This scenario assumes that all non-revenue and revenue vehicles are replaced with gasoline vehicles through 2040 according to their historical replacement schedules.

BEV Revenue Fleet at Valencia County Transit Facility: This scenario assumes all non-revenue vehicles at all three facilities will be transitioned from the current gasoline fleet to a fully electric fleet by 2032 and all revenue vehicles at both facilities will be fully electric by 2036. This scenario is referred to as BEV Revenue Fleet Scenario throughout the remainder of this section.

FCEV Revenue Fleet at Valencia County Transit Facility: This scenario assumes all non-revenue vehicles at all three facilities will be transitioned from the current gasoline fleet to a fully electric fleet by 2032, all revenue vehicles at Sandoval County Transit Facility will be battery electric by 2031, and all revenue vehicles at Valencia County Transit Facility will be hydrogen fuel cell by 2036. This scenario is referred to as FCEV Revenue Fleet Scenario throughout the remainder of this section.

Table 17 and Table 18 show the fleet makeup and operating statistics at the end of the analysis period, respectively.

Table 17. 2040 Fleet Composition by Fuel Type

	Gasoline Vehicles	BEVs	FCEVs
Non-Revenue Fleet			
Baseline Scenario	21	0	0
BEV Revenue Fleet Scenario	0	21	0
FCEV Revenue Fleet Scenario	0	21	0
Revenue Fleet			
Baseline Scenario	42	0	0
BEV Revenue Fleet Scenario	0	42	0
FCEV Revenue Fleet Scenario	0	16	26

Table 18. 2040 Annual Vehicle Miles

	Gasoline Miles	BEV Miles	FCEV Miles
Non-Revenue Fleet			
Baseline Scenario	240,744	0	0
BEV Revenue Fleet Scenario	0	240,744	0
FCEV Revenue Fleet Scenario	0	240,744	0
Revenue Fleet			
Baseline Scenario	855,786	0	0
BEV Revenue Fleet Scenario	0	855,786	0
FCEV Revenue Fleet Scenario	0	337,701	518,085

The remainder of this section reflects the following:

- An overview of the key assumptions that will be used in the analysis of both revenue fleet transition scenarios and the non-revenue fleet transition scenario.
- The capital and O&M requirements considered and analyzed for each of the transition scenarios.
- The lifecycle cost comparison results for each of the transition scenarios.
- Recommendations based on the lifecycle cost comparison outcomes.

Key Assumptions

Table 19 provides the general assumptions that are used through the lifecycle cost analysis. Discounting assumptions follow standard practice, while the electricity and hydrogen fuel equivalents are provided by the US Department of Energy.[4]

Table 19. General Assumptions

Item	Value	Unit	Source
General			
Discount Value	5.00%	percent decrease per year	Standard Assumption
Annualization	250	days per year	Rio Metro service days each year
Electricity Demand Gasoline Equivalent	33.7	kW Electricity per Gal of Gasoline	US Department of Energy Fuel Conversion Factors
Hydrogen Demand Gasoline Equivalent	0.13	kg Hydrogen per Gal of Gasoline	US Department of Energy Fuel Conversion Factors

[4] US Department of Energy, State & Alternative Fuel Provider Fleets: Fuel Conversion Factors to Gasoline Gallon Equivalents.

Replacement Cycle: All vehicles have been following replacement plans on an 8-year cycle, a trend which continues for zero emission vehicles.

Charging Equipment: The BEV fleet requires utility infrastructure and chargers have a unit cost and a respective implementation cost that is incurred each new charger. The chargers require a monthly O&M cost to keep the assets in good condition. This cost is $1,000 per month has been annualized to the $12,000 per year cost shown in the table below.

Utility Infrastructure: The electric fleets require utility infrastructure at each transit facility requires that will implement an electric fleet. These are modeled as a one-time purchase with no additional O&M over the period of analysis. Each of the utility purchases will be made (and are modeled to be incurred) the year prior to the first alternative fuel vehicle purchase to allow for necessary construction and installation. Purchases at the Valencia County transit facility are broken out for the non-revenue and revenue fleets. If Rio Metro follows the full electric transition plan, both the non-revenue and revenue utility infrastructure costs will be incurred to support a fully BEV fleet. If the FCEV fleet transition plan is followed, Valencia County won't have the need for BEB-related revenue utility infrastructure but will still need to purchase the transit facility upgrades to support the BEV non-revenue fleet. The infrastructure purchases at NMRX Yard and Sandoval County will support the BEV non-revenue and revenue fleets. They are shown in the non-revenue portion of the analysis as the cost and timing remain the same across ZEV transition plans.

Fuel and Electricity Costs: Current gasoline, electricity, and hydrogen prices are based off current market information if no Rio Metro specific data was acquired. Each fuel source has price inflation factor[5] which changes the unit cost of each fuel type over the analysis period. Gasoline and electricity prices dynamics are sourced from various US Energy Information Administration reports. Hydrogen price dynamics are less reliable, though a general decline in price has been widely agreed-upon in the market.

Fuel prices are provided by various sources[6] on a per-unit basis in 2022 dollars. Electricity prices are provided on an off-peak hour charge as the bulk of charging will be outside peak hours but has an additional per-meter monthly charge. The price of hydrogen is comprised of the base grey hydrogen cost in addition to the delivery cost, per the estimate from Air Products.

O&M Costs: The O&M costs for vehicles are driven by a per-mile operating charge, which is equal across gasoline vehicles, BEVs, and FCEVs and is sourced from the National Transit Database (NTD) entry for Rio Metro. In addition, a per-mile maintenance cost is added to complete the per-mile O&M cost for each vehicle type. General maintenance cost differences are sourced from the US Department of Energy Vehicle Technologies Office. These differences are used with NTD maintenance costs for revenue and non-revenue vehicles to estimate respective BEV and FCEV maintenance costs.

Table 20 and Table 21 give the key assumptions for various capital and O&M expenses.

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[5] Fuel price inflation measures are calculated as compound annual growth rates (CAGRs).

[6] Prices for gasoline is sourced from Rio Metro June 2022 purchase price per gallon, electricity from PNM (non-residential EV charging rate), and hydrogen from Air Products.

Table 20. Capital Cost Assumptions, 2022 Dollars

Item		Value	Unit
Vehicle Lifetime		8	years before replacement
FCEV Price Delta		185.9%	% difference between Gasoline and FCEV
EV Charger Infrastructure	**Unit Cost**	**Implementation Cost**	
7.2 kW Level 2 Charger	$5,000	$5,000	per charger
50kW DC Fast Charger	$30,000	$42,500	per charger
EV Utility Infrastructure	**Non-Revenue**	**Revenue**	
NMRX Yard	$1,090,996		per facility
Valencia County Transit Facility	$545,596	$1,578,652	per facility
Sandoval County Transit Facility	$1,999,266		per facility
FCEV Utility Infrastructure		**Revenue**	
Valencia County Transit Facility		$5,861,000	per facility

Table 21. O&M Cost Assumptions, 2022$

Item	Gasoline	BEV	FCEV	Unit
Capital Operations & Maintenance				
Vehicle Maintenance, Non-Revenue	$0.07	$0.05	$0.04	per vehicle mile
Vehicle Operating, Non-Revenue	$11.04	$11.04	$11.04	per vehicle mile
Vehicle Maintenance, Revenue	$0.09	$0.05	$0.04	per vehicle mile
Vehicle Operating, Revenue	$6.92	$6.92	$6.92	per vehicle mile
Utility Infrastructure			$12,549	per month
EV Charging Equipment		$12,000		per charger per year
Fueling Incremental Charges				
Fuel Cost	$5.55 per gallon	$0.06 per kWh	$9.14 per kG[7]	Variable
EV Per Meter Customer Charge		$81.91		per facility per month
Fuel Price Inflation	0.23%	0.03%	-0.07%	CAGR; per year change

Baseline Scenario

The baseline scenario is defined as the case where no zero emission transition takes place. This includes only gasoline vehicle replacements at Sandoval County Transit Facility, Valencia County Transit Facility, and the NMRX Yard. There will be no additional capital costs (no charging equipment or utility infrastructure) that are necessary to sustain the non-revenue and revenue vehicle fleets. The vehicle purchase schedule at each location is identical to those laid out in the zero emission transition scenarios, but with only gasoline vehicles being purchased. Table 22 summarizes the non-revenue and revenue vehicle purchase schedules, and associated costs are shown in Table 23.

O&M costs are comprised only of vehicle-based O&M charges and gasoline fuel expenditures. Demand for gasoline fuel stays static across the analysis period, so the increasing costs are driven by the increasing

[7] Air Products estimate for Grey Hydrogen, inclusive of the delivery cost.

price of gasoline. Fueling costs for both the revenue and non-revenue fleets are shown in Figure 5. Totals for each O&M subset are found in Table 24.

The annual cost breakdown for the baseline scenario over the analysis period is shown in Table 25 at the end of this section. The $68 million (2022 Dollars) in total costs reflect $7.6 million in capital expenditures, $59.7 million in vehicle O&M costs, and $0.6 million in fueling expenses.

Table 22. Baseline Scenario: Vehicle Purchase Schedule

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Non-Revenue Fleet																		
NMRX Yard	2		2	2	1	1		2	3		2	2	1	1		2	1	
Valencia County Transit Facility	2	1		1	2		1		3	1		1	2		1		1	
Sandoval County Transit Facility			1	1							1	1						
Revenue Fleet																		
NMRX Yard																		
Valencia County Transit Facility	5		12	3		2		5	6		10	3				4		
Sandoval County Transit Facility	7				4			1	7		1	3			1			

Table 23. Baseline Scenario: Annual Capital Expenditures (2022 Dollars, in Thousands)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Non-Revenue Fleet																		
NMRX Yard	$58		$52	$60	$27	$30		$57	$106		$52	$60	$27	$30		$57	$48	
Valencia County Transit Facility	$54	$22		$27	$44		$19		$54	$22		$27	$44		$19			
Sandoval County Transit Facility			$19	$19							$19	$19						
Total	**$112**	**$22**	**$71**	**$106**	**$71**	**$30**	**$19**	**$57**	**$160**	**$22**	**$71**	**$106**	**$71**	**$30**	**$19**	**$57**	**$48**	**$0**
Revenue Fleet																		
NMRX Yard																		
Valencia County Transit Facility	$413		$1,010	$276		$184		$671	$458		$920	$276				$626		
Sandoval County Transit Facility	$1,211				$368			$92	$1,211		$92	$276			$92			
Total	**$1,624**	**$0**	**$1,010**	**$276**	**$368**	**$184**	**$0**	**$763**	**$1,669**	**$0**	**$1,012**	**$552**	**$0**	**$0**	**$92**	**$626**	**$0**	**$0**
FLEET TOTAL	**$1,736**	**$22**	**$1,081**	**$382**	**$439**	**$214**	**$19**	**$820**	**$1,829**	**$22**	**$1,083**	**$658**	**$71**	**$30**	**$111**	**$683**	**$48**	**$0**

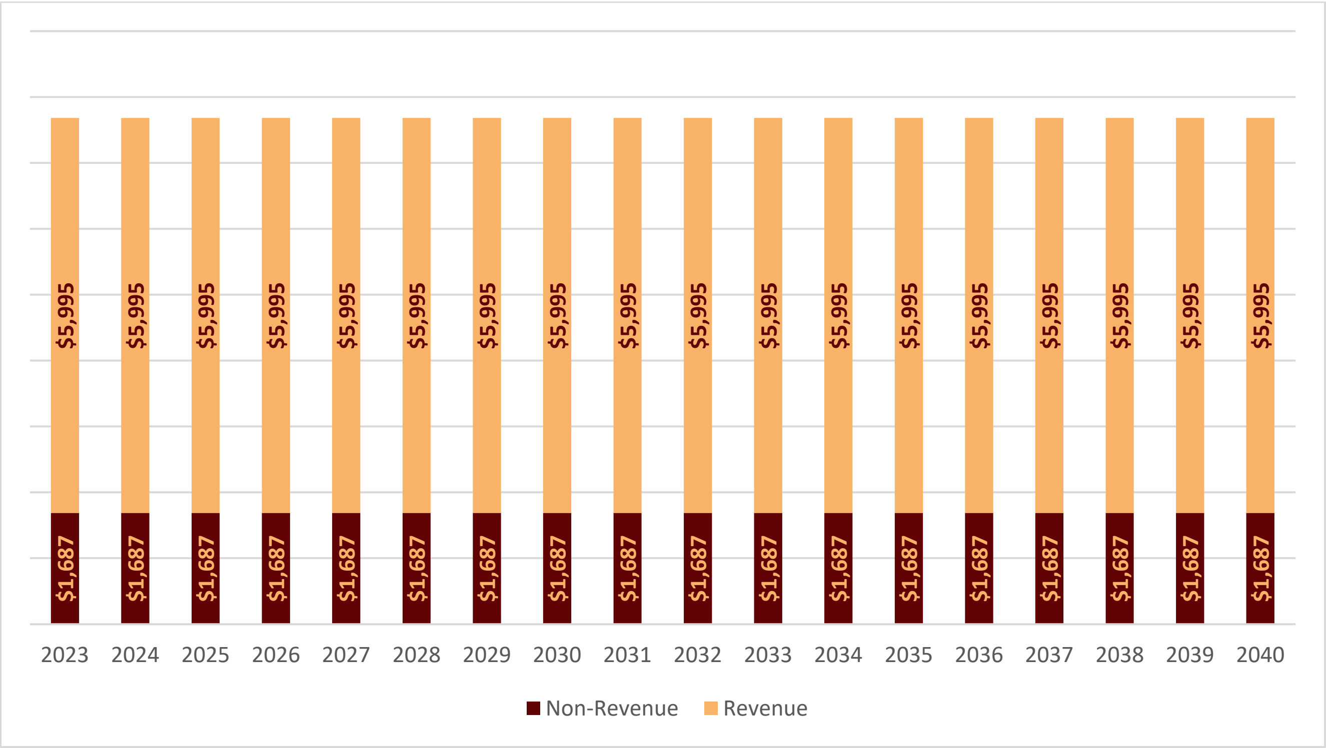

Figure 4. Baseline Scenario: Vehicle O&M Costs (2022 Dollars, in Thousands)

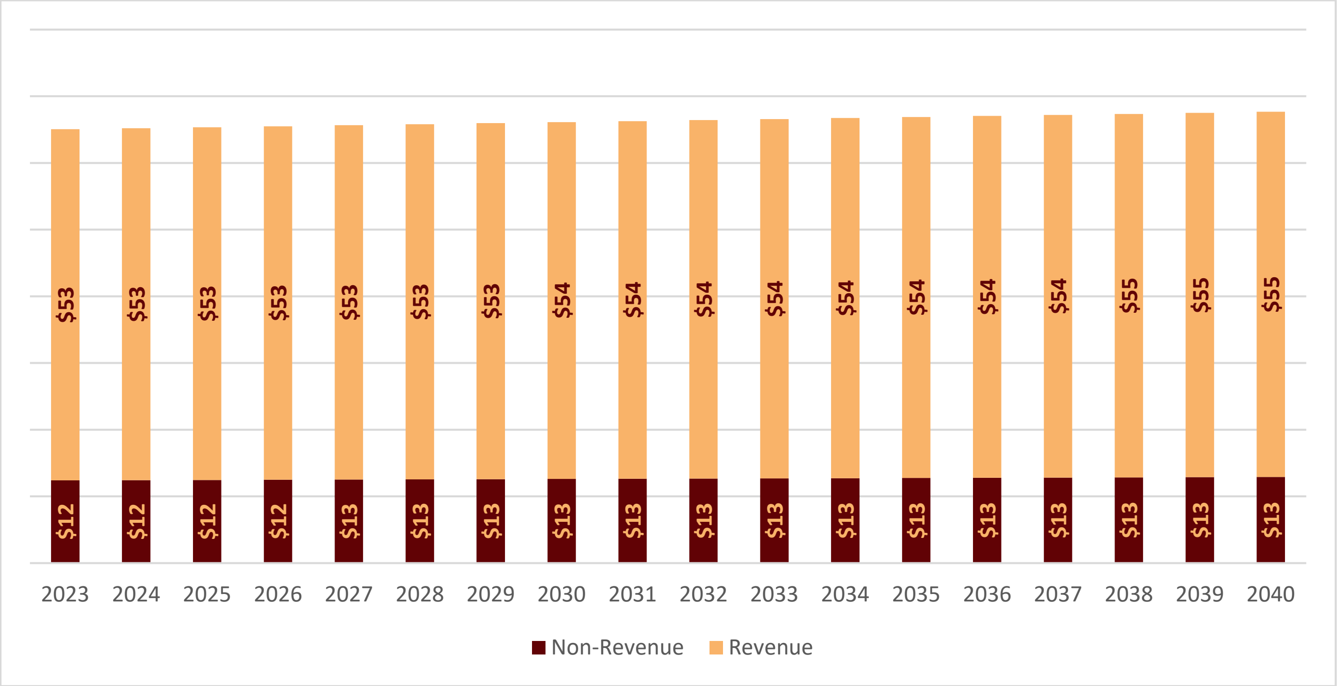

Figure 5. Baseline Scenario: Gasoline Fuel Costs (2022 Dollars, in Thousands)

Table 24. Baseline Scenario: Total O&M Costs (2022 Dollars)

Location	Vehicle O&M	Gasoline
Non-Revenue Fleet		
NMRX Yard	$20,392,623	$119,914
Valencia County Transit Facility	$8,837,650	$86,193
Sandoval County Transit Facility	$1,126,834	$21,690
Revenue Fleet		
NMRX Yard	$13,094,515	$160,398
Valencia County Transit Facility	$65,329,095	$535,225
Sandoval County Transit Facility	$29,488,599	$270,820

Table 25. Baseline Scenario: Total Annual Costs (2022 Dollars, in Millions)

	Total	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Non-Revenue	**$31.7**	**$1.8**	**$1.7**	**$1.8**	**$1.8**	**$1.8**	**$1.7**	**$1.7**	**$1.8**	**$1.9**	**$1.7**	**$1.8**	**$1.8**	**$1.8**	**$1.7**	**$1.7**	**$1.8**	**$1.7**	**$1.7**
Capital	$1.1	$0.1	$0.0	$0.1	$0.1	$0.1	$0.0	$0.0	$0.1	$0.2	$0.0	$0.1	$0.1	$0.1	$0.0	$0.0	$0.1	$0.0	$0.0
O&M	$30.6	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7
Revenue	**$117.1**	**$7.7**	**$6.0**	**$7.1**	**$6.3**	**$6.4**	**$6.2**	**$6.0**	**$6.8**	**$7.7**	**$6.0**	**$7.1**	**$6.6**	**$6.0**	**$6.0**	**$6.1**	**$6.7**	**$6.0**	**$6.0**
Capital	$8.2	$1.6	$0.0	$1.0	$0.3	$0.4	$0.2	$0.0	$0.8	$1.7	$0.0	$1.0	$0.6	$0.0	$0.0	$0.1	$0.6	$0.0	$0.0
O&M	$108.9	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0
Total	**$148.7**	**$9.5**	**$7.8**	**$8.8**	**$8.1**	**$8.2**	**$8.0**	**$7.8**	**$8.6**	**$9.6**	**$7.8**	**$8.8**	**$8.4**	**$7.8**	**$7.8**	**$7.9**	**$8.4**	**$7.8**	**$7.7**

Non-Revenue Fleet Transition

The non-revenue fleet transition acts as a necessary component of the overall zero emission transition strategy. The types of BEVs that the transit facilities use have existed in the market for far longer than electric and hydrogen vehicles which have had very little, if any, market testing. The annual cost breakdown of the total, undiscounted $36.7 million over the analysis period is shown in Table 31 at the end of this section.

Capital Costs

The capital costs associated with the non-revenue fleet transition scenario are represented by vehicle purchases, EV chargers, and infrastructure purchases. Annual vehicle purchase assumptions are provided in Table 26. Vehicle purchases in 2023 and 2024 reflect the current vehicle replacement plan and the final acquisitions of gasoline vehicles with the BEV transition will start in 2025. The non-revenue fleet composition dynamics are shown in Figure 6, which also shows the fleet will be fully transitioned to BEVs in 2031. Utility infrastructure at each transit facility is required to support new electric fleet. The timing of the infrastructure required for the non-revenue fleet is shown in Table 26.

Infrastructure supporting a revenue fleet at the Sandoval County Transit Facility will be implemented under the revenue vehicle transition plans after the viability of the Sandoval County Transit Facility BEV Pilot Program is assessed, which will be discussed further in the revenue fleet transition scenarios. The infrastructure implemented at the NMRX Yard and Valencia County Transit Facility will be able to support both the non-revenue and revenue fleets after the transition is finished.

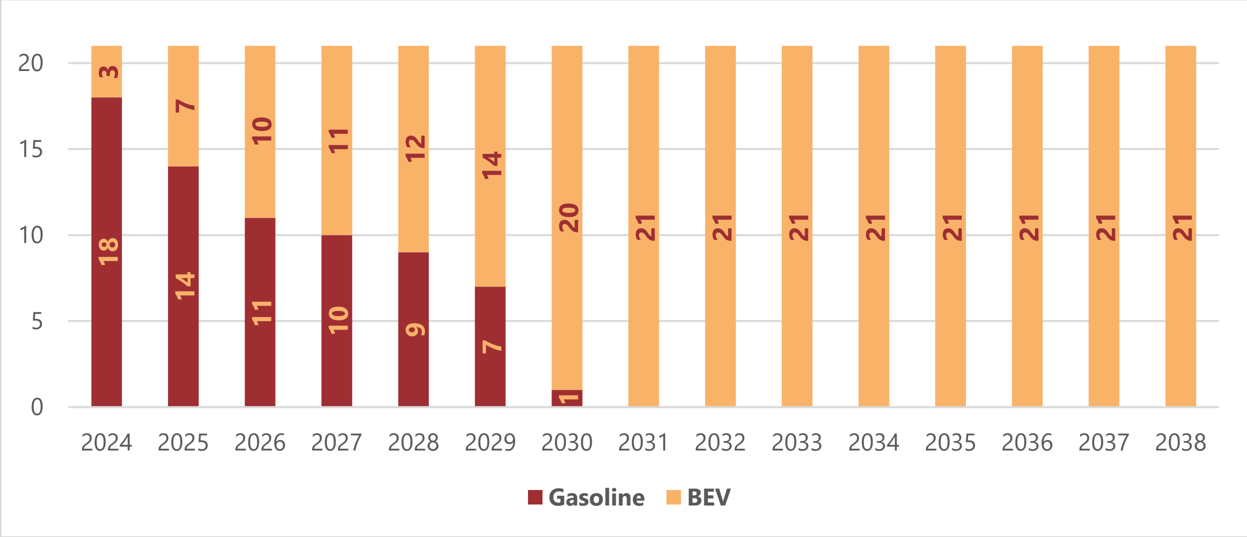

Figure 6. Non-Revenue Fleet Composition

Table 27 summarizes the projected annual capital and infrastructure investments that will be made through 2040. Over the analysis period, capital investments of $5.8 million (2022 dollars) will be made to transition the non-revenue fleet from all gasoline vehicles to all battery electric vehicles.

Table 26. Non-Revenue Purchase Schedule, 2023-2040

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gasoline Purchases																		
NMRX Yard	2																	
Valencia County Transit Facility	2	1																
Sandoval County Transit Facility																		
BEV Purchases**																		
NMRX Yard			2	2	1	1		2	3		2	2	1	1		2	1	
Valencia County Transit Facility				1	2		1		3	1		1	2		1		1	
Sandoval County Transit Facility			1	1							1	1						
Utility Infrastructure																		
NMRX Yard		1																
Valencia County Transit Facility			1															
Sandoval County Transit Facility		1																

**EV Charger Purchases match 1:1 with BEV Purchases at each location

Table 27. Non-Revenue Fleet Transition Annual Capital Costs (2022 Dollars, in Thousands)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gasoline Purchases																		
NMRX Yard	$58																	
Valencia County Transit Facility	$54	$22																
Sandoval County Transit Facility																		
Total	**$112**	**$22**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
BEV Purchases																		
NMRX Yard			$74	$84	$47	$42		$89	$216		$74	$84	$47	$42		$89	$125	
Valencia County Transit Facility				$47	$65		$32		$218	$32		$47	$65		$32		$125	
Sandoval County Transit Facility			$32	$32							$32	$32						
Total	**-**	**-**	**$107**	**$163**	**$111**	**$42**	**$32**	**$89**	**$434**	**$32**	**$107**	**$163**	**$111**	**$42**	**$32**	**$89**	**$249**	
FLEET TOTAL	**$112**	**$22**	**$107**	**$163**	**$111**	**$42**	**$32**	**$89**	**$434**	**$32**	**$107**	**$163**	**$111**	**$42**	**$32**	**$89**	**$249**	
Utility Infrastructure Purchase Schedule																		
NMRX Yard		$1,091																
Valencia County Transit Facility			$546															
Sandoval County Transit Facility		$1,999																
7.2 kW Level 2 Charger Purchase Schedule																		
NMRX Yard			$20	$20	$10	$10		$20	$30									
Valencia County Transit Facility				$10	$20		$10		$30	$10								
Sandoval County Transit Facility			$10	$10														
INFRA. TOTAL	**-**	**$3,090**	**$576**	**$40**	**$30**	**$10**	**$10**	**$20**	**$60**	**$10**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**

O&M Costs

Costs for O&M are driven primarily by the vehicle hours driven; this dictates the level of vehicle O&M required and the amount of gasoline and electricity needed as fuel inputs. As shown in Table 18, the total amount of non-revenue miles driven (transition or not) is assumed to stay constant at 240,744 miles. The fleet transition from gasoline vehicles to BEVs determines which miles are allocated to each vehicle type on an annual basis. The incremental transition drives vehicle O&M costs, summarized in Figure 7, due to BEV maintenance costs having a lower per-mile cost than gasoline vehicles. Over the 17-year analysis period, Rio Metro is projected to spend $29.2 million on vehicle O&M, with $8.0 million from gasoline vehicles, $21.2 million from BEVs.

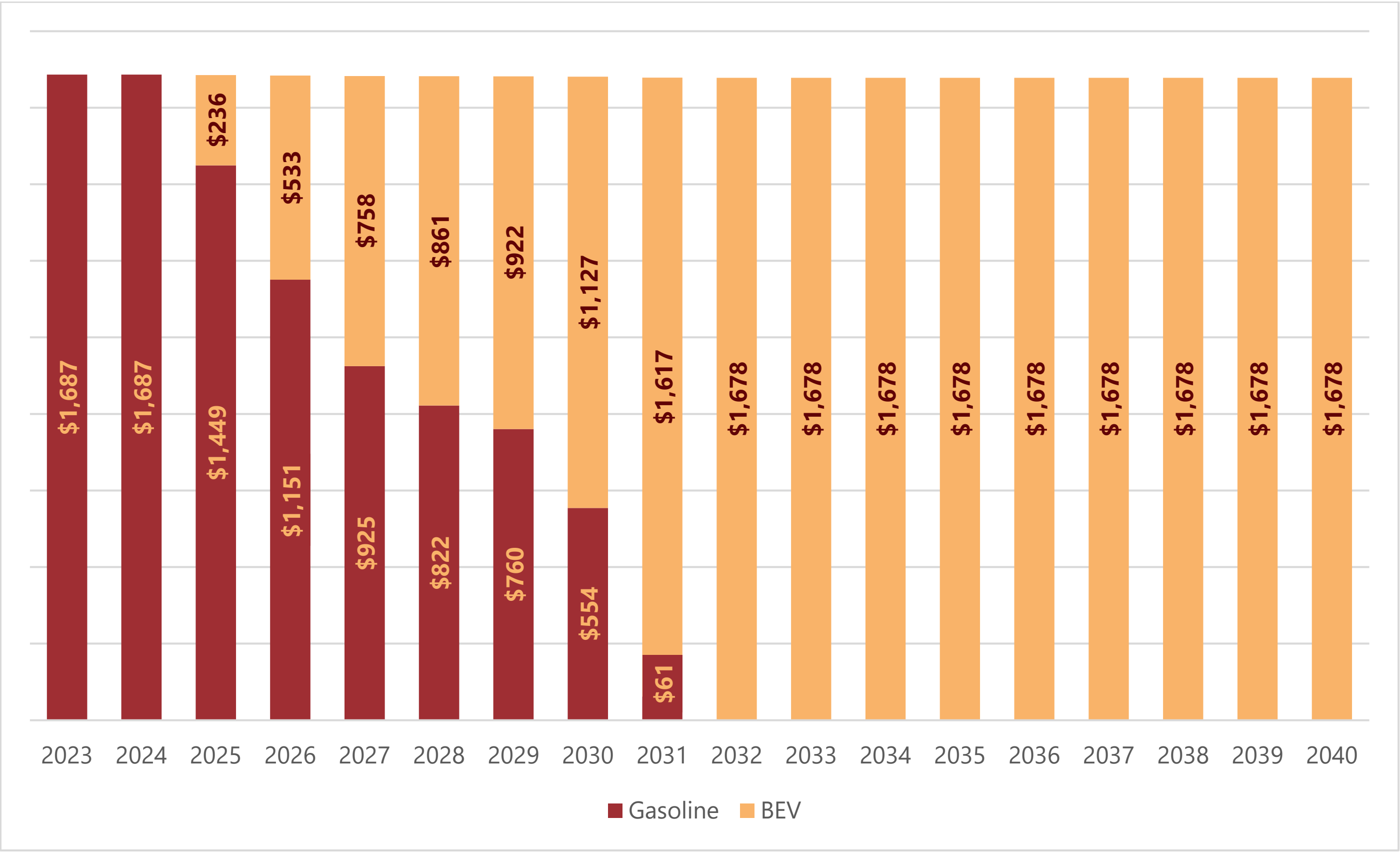

Figure 7. Non-Revenue Transition O&M Costs (2022 Dollars, in Thousands)

Included in O&M costs is the $1,000 monthly (annualized to a $12,000 yearly) charge for each charger that is implemented. Following the purchase schedule for vehicles, a total of 21 Level 2 Chargers are purchased (11 at NMRX Yard, 8 at Valencia County Transit Facility, and 2 at Sandoval County Transit Facility). These purchases correspond to total expenditures of $0.3 million in charger O&M expenses. As stated, the utility infrastructure will not have any associated maintenance costs, and no DC Fast Chargers will be purchased for the non-revenue fleets. Vehicle and charger O&M costs are shown in Table 29.

Table 28. Non-Revenue Vehicle and Charger O&M Costs, 2023-2040

Location	Gasoline	BEVs	Chargers
NMRX Yard	$5,870,603	$14,451,905	$132,000
Valencia County Transit Facility	$3,068,629	$5,741,168	$96,000
Sandoval County Transit Facility	$156,505	$965,644	$24,000

Table 29. Non-Revenue Fueling Costs, 2023-2040

Location	Total Gasoline Cost	Total Electricity Cost
NMRX Yard	$125,257	$135,309
Valencia County Transit Facility	$56,454	$55,677
Sandoval County Transit Facility	$6,158	$30,519
Total	**$187,868**	**$221,505**

Fueling and electricity costs make up the final component of O&M costs in the non-revenue vehicle transition. As with the vehicle O&M costs, fuel and electricity expenditures are based upon the number of miles driven by each vehicle type. The annual demand for gas and electricity is shown in Figure 8, and the subsequent change in annual fuel and electricity costs, shown in Figure 9 are a result of:

- Relatively lower initial electricity prices when adjusted to a gasoline equivalent (in 2022 dollars, a gasoline unit costs $5.55 versus $2.15 for an electricity unit); and
- A lower growth rate of electricity prices (0.03% annual growth of electricity verses 0.23% annual growth for gasoline).

In addition to the per-kWh charge, a monthly customer charge of $81.91 is accrued at each location, though this cost is vastly overshadowed by the cost of electricity. Over the 17 years of analysis, the non-revenue fleet will spend about $188,000 on gasoline and about $221,000 on electricity, leading to a total fuel cost of $409,373, displayed in Table 29.

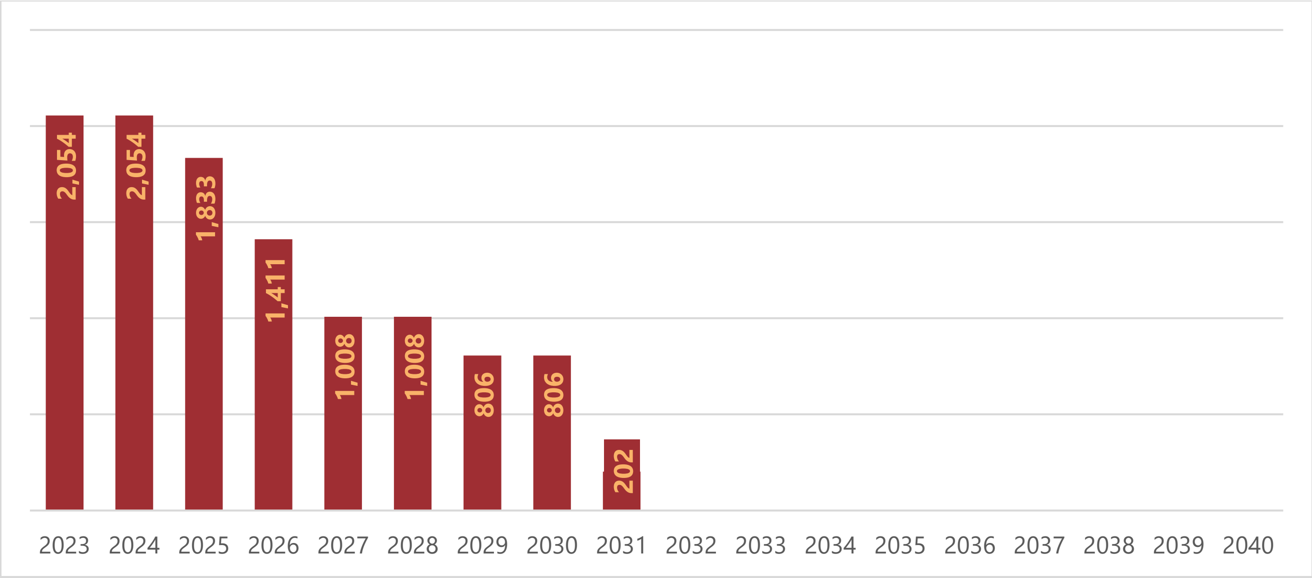

Figure 8. Non-Revenue Transition Annual Gasoline Demand (Gallons)

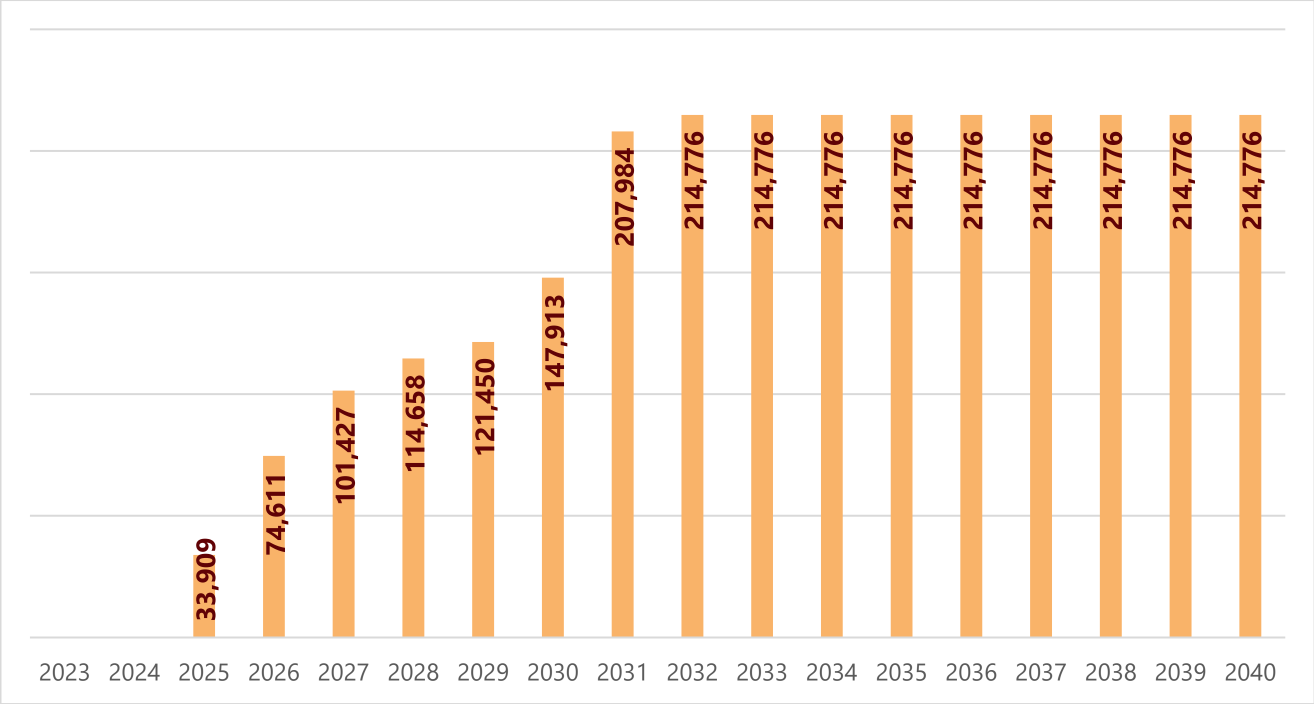

Figure 9. Non-Revenue Transition Annual Electricity Demand (kWh)

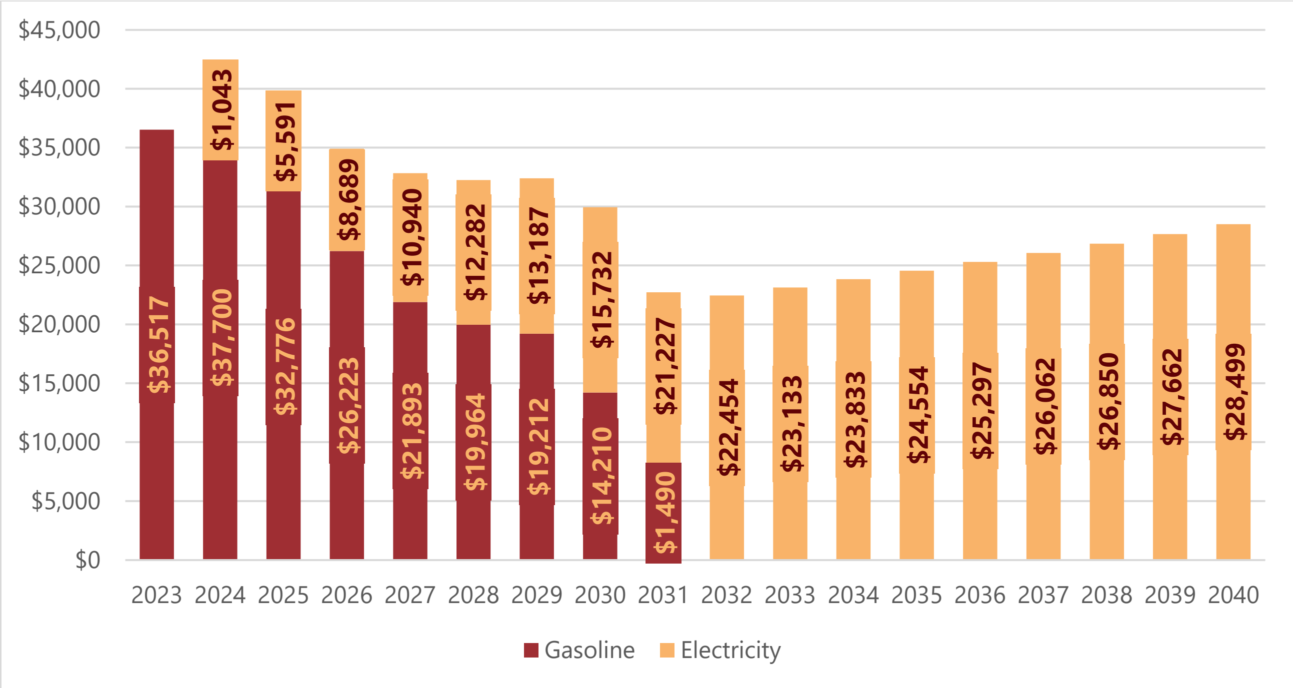

Figure 10. Non-Revenue Transition Annual Fueling Expenditures

Adding the three O&M components together leads to a total non-revenue transition O&M cost of $31.3 million, broken out by transit facility in Table 30.

Table 30. Total Non-Revenue O&M Costs

Location	Total Cost
NMRX Yard	$20,715,075
Valencia County Transit Facility	$9,017,927
Valencia County Transit Facility	$1,182,825
Total	**$30,915,827**

Transition Summary

The Non-Revenue fleet transition acts as a necessary component of the ZEB transition strategy, providing the bulk of the more costly capital infrastructure purchases. The types of BEVs that the transit facilities use have existed in the market for far longer than electric and hydrogen vehicles which have had very little, if any, market testing. The annual cost breakdown of the undiscounted total $36.7 million over the analysis period is shown in Table 31.

Table 31. Annual Non-Revenue Transition Costs

	Total	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Capital	**$5.8**	**$0.1**	**$3.1**	**$0.7**	**$0.2**	**$0.1**	**$0.1**	**$0.0**	**$0.1**	**$0.5**	**$0.0**	**$0.1**	**$0.2**	**$0.1**	**$0.0**	**$0.0**	**$0.1**	**$0.2**	**$0.0**
Vehicles	$1.9	$0.11	$0.02	$0.11	$0.16	$0.11	$0.04	$0.03	$0.09	$0.43	$0.03	$0.11	$0.16	$0.11	$0.04	$0.03	$0.09	$0.25	
Infra.	$3.8		$3.09	$0.58	$0.04	$0.03	$0.01	$0.01	$0.02	$0.06	$0.01								
O&M	**$29.8**	**$0.6**	**$1.7**	**$1.8**	**$1.8**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.8**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.7**	**$1.7**
O&M	$29.4	$0.6	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.8	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7	$1.7
Fueling	$0.4	$0.04	$0.04	$0.03	$0.03	$0.03	$0.03	$0.03	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02
Total	**$35.6**	**$0.7**	**$4.8**	**$2.4**	**$2.0**	**$1.9**	**$1.8**	**$1.8**	**$1.8**	**$2.3**	**$1.7**	**$1.8**	**$1.9**	**$1.8**	**$1.7**	**$1.7**	**$1.8**	**$1.9**	**$1.7**

BEV Revenue Fleet Scenario Transition

The annual cost breakdown over the analysis period is shown at the end of this section in Table 37 and is estimated to total $117.1 million (2022 Dollars).

Capital Costs

The BEV Revenue Fleet Scenario has capital costs in addition to the non-revenue vehicle transitions described in the prior section. Similar to the non-revenue transition plan, capital costs in the BEV Revenue Fleet Scenario are comprised of vehicle purchases, EV chargers, and utility infrastructure implementation.

BEV Pilot Program at Sandoval County Transit Facility

Rio Metro will begin the transition of their revenue fleet in 2027 with a Pilot Program of four BEVs at Sandoval County Transit Facility with additional vehicles being purchased in 2030 and 2031. Leading up to the Pilot Program, scheduled vehicle replacements will be gasoline; subsequent BEV purchases at Sandoval County Transit Facility through 2040 will be replacements of existing BEVs in the fleet.

BEV Full Revenue Fleet Transition

This rest of this section will consider a transition scenario in which all revenue vehicles will transition to BEVs beginning in 2030 at the conclusion of the 3-year BEV Pilot Program. The breakdown of the fleet composition over the course of the entire analysis period can be seen in Figure 11, with gasoline vehicles representative of the entire revenue fleet while BEVs are separated by location.

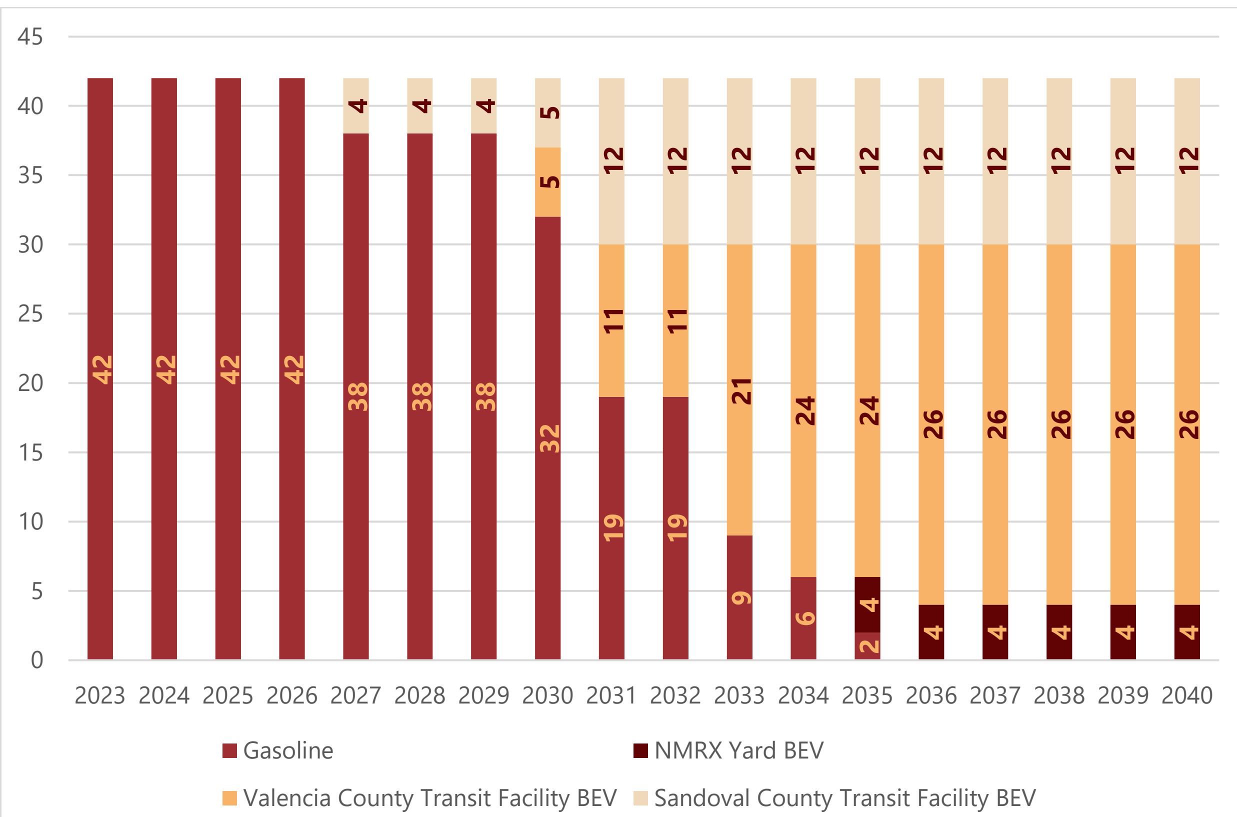

Figure 11. BEV Revenue Fleet Scenario Fleet Composition by Location

The vehicle purchase schedule described in Table 32 shows that no revenue vehicles will be purchased for deployment at the NMRX Yard over the course of the analysis. The current revenue fleet strategy at this facility is to replace vehicles at the end of their life with the "best of the worst" at other facilities. Specifically, vehicles that have been replaced at Sandoval County Transit Facility and Valencia County Transit Facility are moved to the NMRX Yard as these vehicles do not have as much use as the other facility vehicles. This strategy continues through the BEV transition at NMRX Yard; the four BEVs that make up the Sandoval County Transit Facility Pilot Program will replace the four NMRX Yard gasoline vehicles at the end of their useful life at Sandoval County Transit Facility in 2035.

As described in the non-revenue transition, utility infrastructure will have been purchased to accommodate the revenue BEVs at the NMRX Yard and Sandoval County Transit Facility. At the Valencia County Transit Facility, there will be an additional utility infrastructure cost incurred in 2029 to support the revenue fleet that will begin transitioning to BEVs in 2030. This cost (shown in 2022 dollars in Table 20) is the difference between the cost needed for the revenue vehicle utility infrastructure at Valencia County Transit Facility and the cost incurred for the non-revenue fleet.

EV Charger purchases follow the schedule laid out in Table 32. They consist of the Level 2 AC Chargers with a unit cost of $5,000 and installation costs of $5,000 each, and the DC Fast Chargers with a unit cost of $30,000 and installation costs of $42,500.

The costs associated with the purchase schedules described below are found in Table 33. Over the three locations, a total capital cost of $26.2 million will be incurred over the analysis period.

Table 32. BEV Revenue Fleet Scenario Transition: Capital Purchase Schedule

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gasoline Purchases																		
NMRX Yard																		
Valencia County Transit Facility	5		12	3		2												
Sandoval County Transit Facility	7																	
BEV Purchases																		
NMRX Yard																		
Valencia County Transit Facility								5	6		10	3		2		4		
Sandoval County Transit Facility					4			1	7		1	3			1			
Utility Infrastructure																		
NMRX Yard																		
Valencia County Transit Facility							EV Utility											
Sandoval County Transit Facility																		
7.2 kW Level 2 AC Chargers																		
NMRX Yard																		
Valencia County Transit Facility								1	5									
Sandoval County Transit Facility					4			1	2									
50 kW DCFCs																		
NMRX Yard																		
Valencia County Transit Facility								4	1		10	3		2				
Sandoval County Transit Facility									5									

Table 33. BEV Revenue Fleet Scenario Transition: Annual Capital Expenditures (2022 Dollars, in Thousands)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gasoline Purchases																		
NMRX Yard																		
Valencia County Transit Facility	$413		$1,010	$276		$184												
Sandoval County Transit Facility	$1,211																	
Total	**$1,624**	**-**	**$1,010**	**$276**	**-**	**$184**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
BEV Purchases																		
NMRX Yard																		
Valencia County Transit Facility								$3,331	$1,669		$2,900	$1,340		$580		$2,101		
Sandoval County Transit Facility					$1,160			$760	$3,840		$290	$870			$760			
Total	**-**	**-**	**-**	**-**	**$1,160**	**-**	**-**	**$4,092**	**$5,508**	**-**	**$3,190**	**$2,210**	**-**	**$580**	**$760**	**$2,101**	**-**	**-**
FLEET TOTAL	**$1,624**	**-**	**$1,010**	**$276**	**$1,160**	**$184**	**-**	**$4,092**	**$5,508**	**-**	**$3,190**	**$2,210**	**-**	**$580**	**$760**	**$2,101**	**-**	**-**
Utility Infrastructure Purchase Schedule																		
NMRX Yard																		
Valencia County Transit Facility							$1,579											
Sandoval County Transit Facility																		
7.2 kW Level 2 AC Charger Purchases																		
NMRX Yard																		
Valencia County Transit Facility								$10	$50									
Sandoval County Transit Facility					$40			$10	$20									
50 kW DCFC Purchases																		
NMRX Yard																		
Valencia County Transit Facility								$290	$73		$725	$218		$145				
Sandoval County Transit Facility									$363									
INFRASTRUCTURE TOTAL	**-**	**-**	**-**	**-**	**$40**	**-**	**$1,579**	**$310**	**$505**	**-**	**$725**	**$218**	**-**	**$145**	**-**	**-**	**-**	**-**

O&M Costs

As in the non-revenue vehicle transition, O&M costs are driven primarily by the distribution of vehicle miles across gasoline vehicles and BEVs following the fleet transition in Figure 11. Revenue and non-revenue vehicle O&M costs are accrued at different rates, per Table 34, as revenue vehicles have lower per-mile cost for operation and a higher per-mile cost for vehicle maintenance. Within these charges, BEVs have a lower per-mile maintenance rate relative to gasoline vehicles, while operating costs are the same for both vehicle types. Vehicle-based O&M expenses are combined for a total $107.6 million in expenditures, summarized in Figure 12.

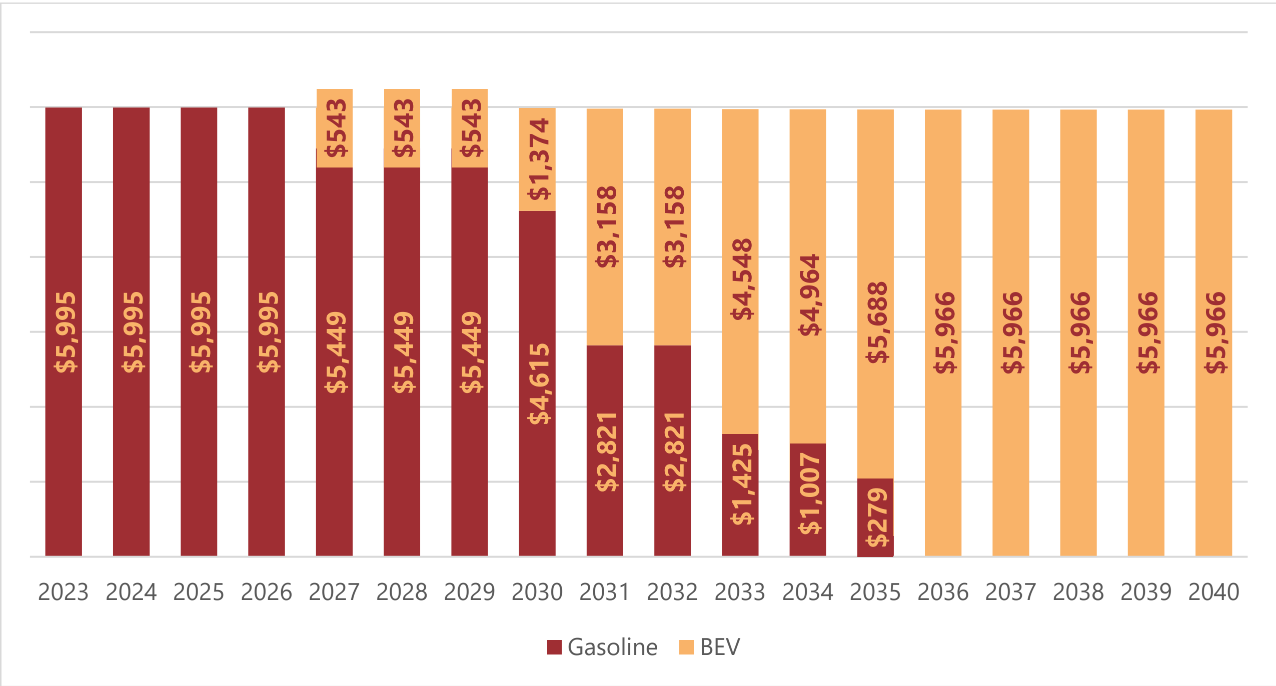

Figure 12. BEV Revenue Fleet Scenario Transition: Annual O&M Costs (2022 Dollars, in Thousands)

EV chargers have a separate monthly O&M charge, which accrues on a yearly per-charger basis after each charger is installed. This cost has no variation between Level 2 AC Chargers and DCFCs and totals to $4.4 million (2022 dollars). Stated previously, there are no O&M costs associated with EV utility infrastructure. Total vehicle and EV Charger O&M costs are broken out by transit facility in Table 34.

Table 34. BEV Revenue Fleet Scenario Transition: Total Vehicle and Charger O&M Costs (2022 Dollars)

Location	Gasoline	BEV	EV Chargers
NMRX Yard	$8,729,677	$4,343,764	$0
Valencia County Transit Facility	$33,781,284	$31,395,494	$2,712,000
Sandoval County Transit Facility	$10,785,182	$18,613,115	$1,644,000

The last factor in O&M costs for the BEV Revenue Fleet Scenario are fuel and electricity costs. Demand for fuel is driven by vehicles miles associated with each vehicle type and is shown in Figure 13. Demand for gasoline and electricity in the BEV Revenue Fleet Scenario corresponds to an estimated total gasoline cost of $219,000 and electricity cost of $113,000.

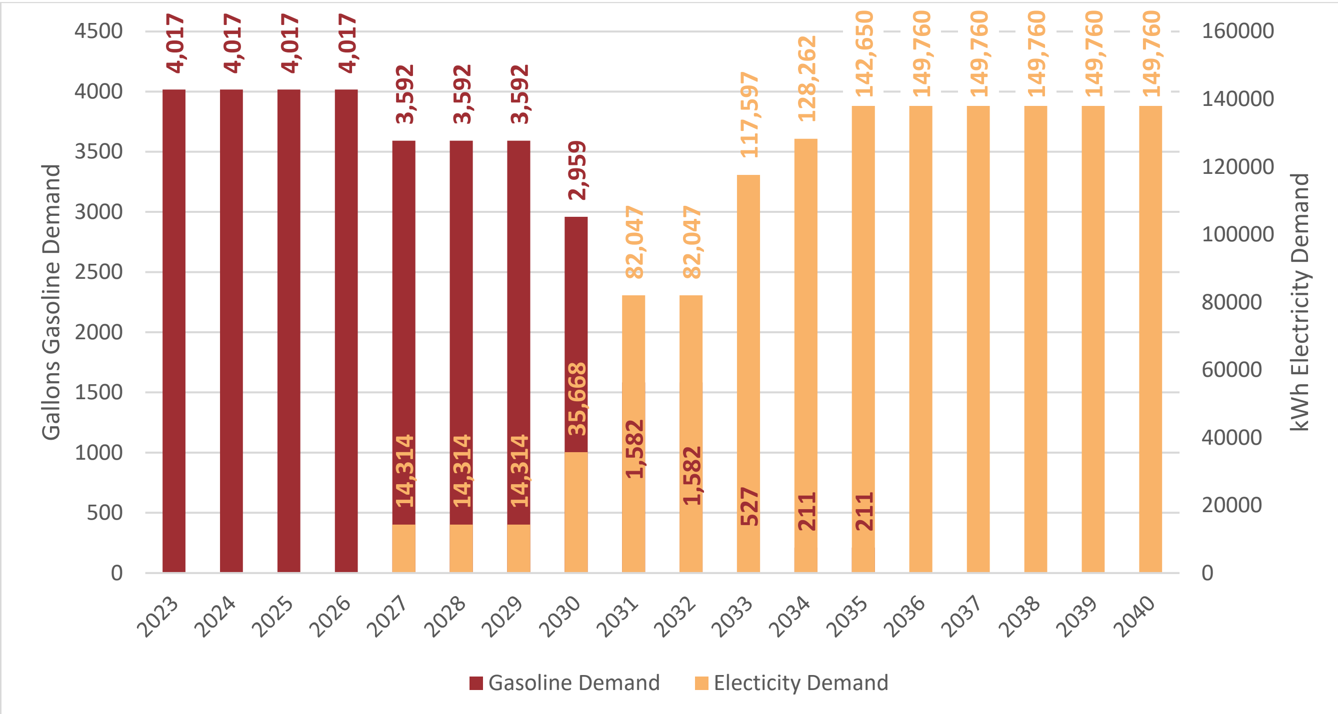

Figure 13. BEV Revenue Fleet Scenario Transition: Fuel and Electricity Demand

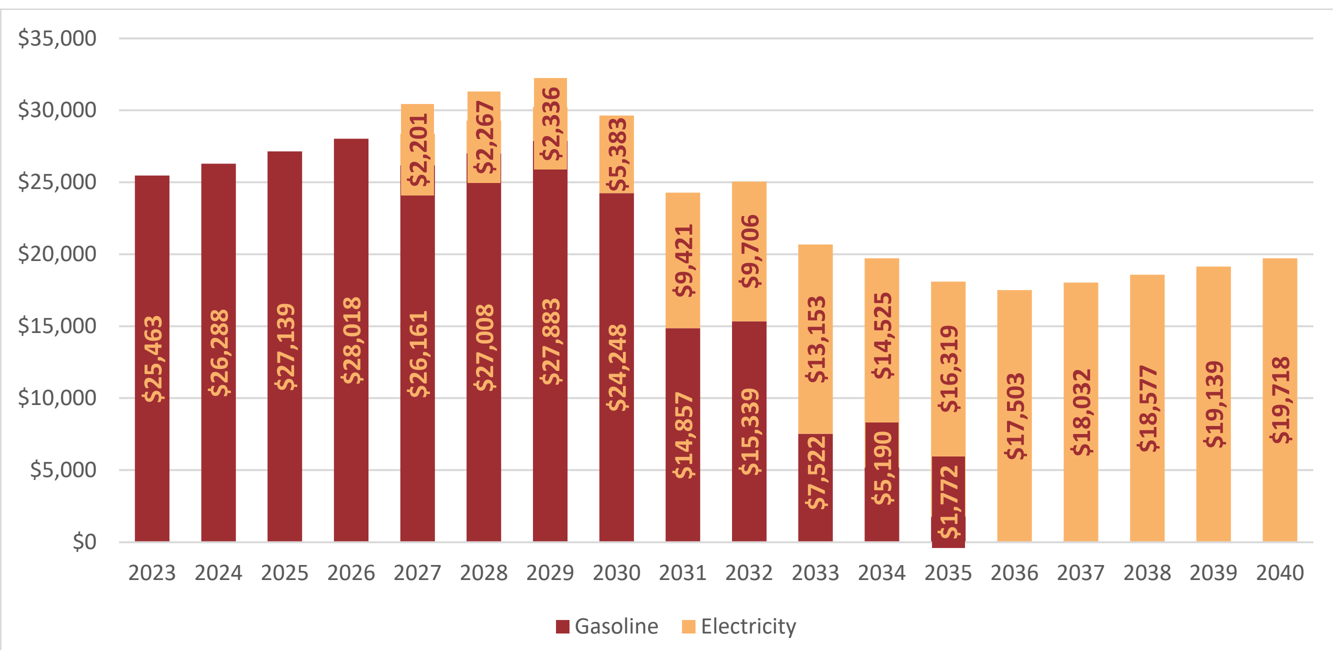

Figure 14. BEV Revenue Fleet Scenario Transition: Annual Fuel and Electricity Costs

Table 35. BEV Revenue Fleet Scenario Transition: Total Fuel Costs (2022 Dollars)

Location	Total Gasoline Cost	Total Electricity Cost
NMRX Yard	$28,867	$5,539
Valencia County Transit Facility	$143,376	$62,318
Sandoval County Transit Facility	$47,046	$45,225
Total	**$219,290**	**$113,082**

Table 36 presents the total O&M costs by location.

Table 36. BEV Revenue Fleet Scenario Transition: Total O&M Costs (2022 Dollars)

Location	Total Cost
NMRX Yard	$13,107,848
Valencia County Transit Facility	$68,094,473
Valencia County Transit Facility	$31,134,568
Total	**$112,336,889**

Table 37. BEV Revenue Fleet Scenario Transition: Total Costs (2022 Dollars, in Millions)

	Total	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Capital	**$24.3**	**$1.6**	**$0.0**	**$1.0**	**$0.3**	**$1.2**	**$0.2**	**$1.6**	**$4.4**	**$6.1**	**$0.0**	**$3.9**	**$2.0**	**$0.0**	**$0.7**	**$0.3**	**$1.0**	**$0.0**	**$0.0**
Vehicles	$20.7	$1.6		$1.0	$0.3	$1.2	$0.2		$4.1	$5.6		$3.2	$1.7		$0.6	$0.3	$1.0		
Infra.	$3.5					$0.0		$1.6	$0.3	$0.5		$0.7	$0.2		$0.1				
O&M	**$112.3**	**$6.0**	**$6.0**	**$6.0**	**$6.0**	**$6.1**	**$6.1**	**$6.1**	**$6.1**	**$6.3**	**$6.3**	**$6.4**	**$6.4**	**$6.4**	**$6.4**	**$6.4**	**$6.4**	**$6.4**	**$6.4**
O&M	$112.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.1	$6.3	$6.3	$6.4	$6.4	$6.4	$6.4	$6.4	$6.4	$6.4	$6.4
Fuel	$0.3	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Total	**$136.6**	**$7.6**	**$6.0**	**$7.0**	**$6.3**	**$7.3**	**$6.2**	**$7.6**	**$10.5**	**$12.4**	**$6.3**	**$10.3**	**$8.4**	**$6.4**	**$7.2**	**$6.7**	**$7.5**	**$6.4**	**$6.4**

FCEV Revenue Fleet Scenario Transition

The FCEV Revenue Fleet Scenario is second strategy being considered for Rio Metro's zero emission transition. The annual cost breakdown over the analysis period is shown in Table 43 and is estimated to be $134.2 million (2022 dollars) over the 2023 to 2040 period.

Capital Costs

The FCEV Revenue Fleet Scenario transition follows the same capital cost structure as the BEV Revenue Fleet Scenario transition. Identical to the BEV Revenue Fleet Scenario, the transition of Rio Metro's revenue fleet will begin in 2027 with a 4 vehicle BEV Pilot Program at Sandoval County Transit Facility.

The FCEV Revenue Fleet Scenario considers the case in which the decision is made in 2029 to transition the Valencia County Transit Facility's revenue fleet to FCEVs instead of BEVs. Capital costs will consist of vehicle purchases (gasoline vehicles, BEVs *and* FCEVs), EV chargers at the Sandoval County Transit Facility, and utility infrastructure at Valencia County Transit Facility designed to support the FCEV fleet that will be implemented.

Vehicle purchases at NMRX Yard follow the stated methodology, in which gasoline vehicles from Sandoval County Transit Facility and Valencia County Transit Facility are transitioned at the end of their eight-year life. The Sandoval County Transit Facility Pilot Program BEVs will replace the four gasoline revenue vehicles at the NMRX Yard in 2035. In 2030, Valencia County Transit Facility will begin replacing their gasoline-based revenue fleet with FCEVs. The long term fleet transition is displayed in Figure 15, with the associated vehicle purchase schedule in Table 38.[8]

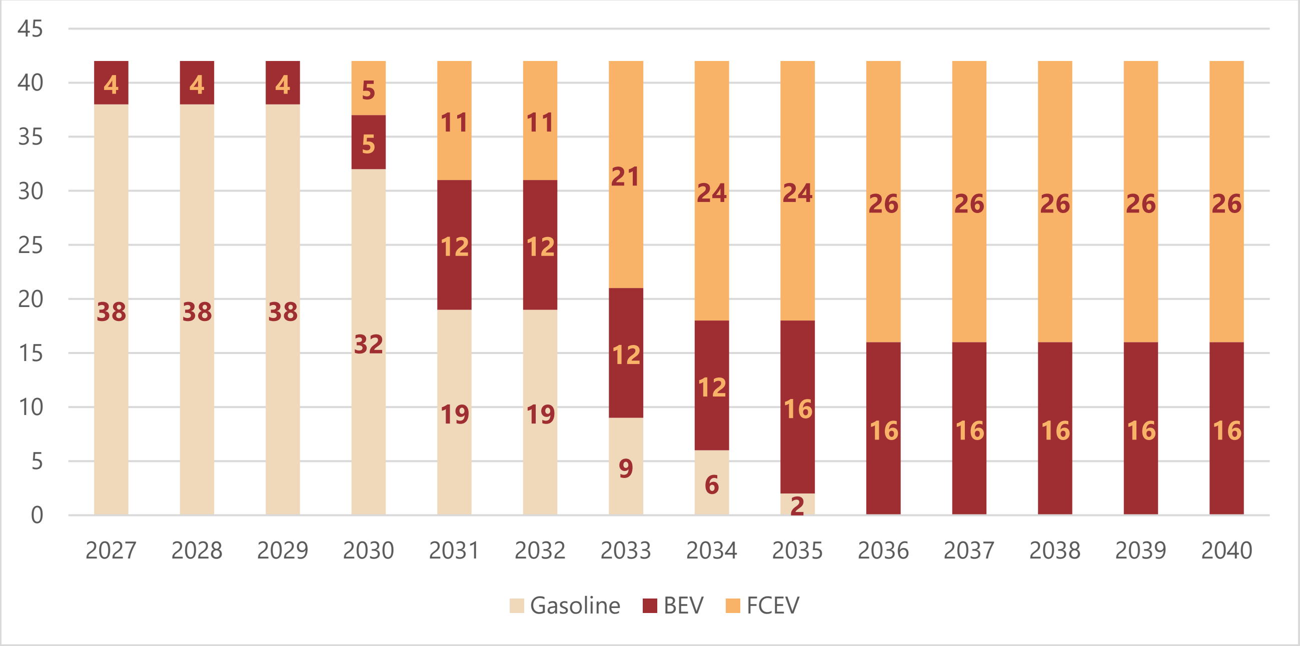

Figure 15. FCEV Revenue Fleet Scenario Fleet Composition

[8] The vehicle purchase schedule includes same-type replacements that do not affect the fleet makeup.

EV Charger purchases for revenue vehicles will only be made for the Sandoval County Transit Facility, as the NMRX Yard will utilize chargers purchased for their non-revenue fleet for their revenue vehicles as well, and the Valencia County Transit Facility will not have any revenue BEVs. The hydrogen utility infrastructure purchase at the Valencia County Transit Facility will be an addition to BEV utility infrastructure purchased in 2025 for the Valencia County Transit Facility non-revenue BEVs.

Table 38 summarizes the purchase schedule for the EV chargers and utility infrastructure, corresponding to the capital cost schedule shown in Table 39. Over the 2023 to 2040 period, a total of $21.6 million (2022 dollars) in capital investments will be made to transition the revenue fleets at all three transit facilities to zero emission vehicles.

Table 38. FCEV Revenue Fleet Scenario Transition: Capital Purchase Schedule

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
BEV Purchases												
NMRX Yard												
Valencia County Transit Facility												
Sandoval County Transit Facility		1	7		1	3			1			
FCEV Purchases												
NMRX Yard												
Valencia County Transit Facility		5	6		10	3		2		4		
Sandoval County Transit Facility												
H2 Utility Infrastructure (Valencia County Transit Facility												
NMRX Yard												
Valencia County Transit Facility	1											
Sandoval County Transit Facility												
EV Chargers (Sandoval County Transit Facility)												
Level 2 AC		1	2									
DCFC			5									

Table 39. FCEV Revenue Fleet Scenario Transition: Capital Expenditures (2022 Dollars, in Thousands)

	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
BEV Purchases												
NMRX Yard												
Valencia County Transit Facility												
Sandoval County Transit Facility		$760	$2,971		$290	$870			$290			
Total		**$760**	**$2,971**		**$290**	**$870**			**$290**			
FCEV Purchases												
NMRX Yard												
Valencia County Transit Facility		$1,248	$851		$1,710	$513		$342		$1,164		
Sandoval County Transit Facility												
Total		**$1,248**	**$851**		**$1,710**	**$513**		**$342**		**$1,164**		
FLEET TOTAL		***$2,008***	***$3,822***		***$2,000***	***$1,383***		***$342***	***$290***	***$1,164***		
Utility Infrastructure												
NMRX Yard												
Valencia County Transit Facility	$5,861											
Sandoval County Transit Facility												
EV Chargers												
NMRX Yard												
Valencia County Transit Facility												
Sandoval County Transit Facility		$10	$383									
INFRA. TOTAL	***$5,861***	***$10***	***$383***									

O&M Costs

O&M costs are identical to those described in the BEV Revenue Fleet Scenario until 2029. At this point, vehicle O&M costs will also accommodate a different revenue maintenance rate for FCEVs than BEVs and gasoline vehicles. As shown previously in Table 21, the per-mile cost to maintain vehicles is the lowest for FCEVs (followed by BEVs and gasoline vehicles). Vehicle operating costs remain constant for all three revenue vehicle types. Based on the transition plan, Figure 16 and Figure 17 summarize annual O&M expenses by vehicle type. Total O&M costs by location and vehicle type are $107.6 million as shown in Table 40.

Table 40. FCEV Revenue Fleet Scenario Transition: Total Vehicle O&M Costs (2022 Dollars)

Location	Gasoline	BEV	FCEV
NMRX Yard	$8,729,677	$4,343,764	$0
Valencia County Transit Facility	$33,781,284	$0	$31,345,687
Sandoval County Transit Facility	$10,785,182	$18,613,115	$0

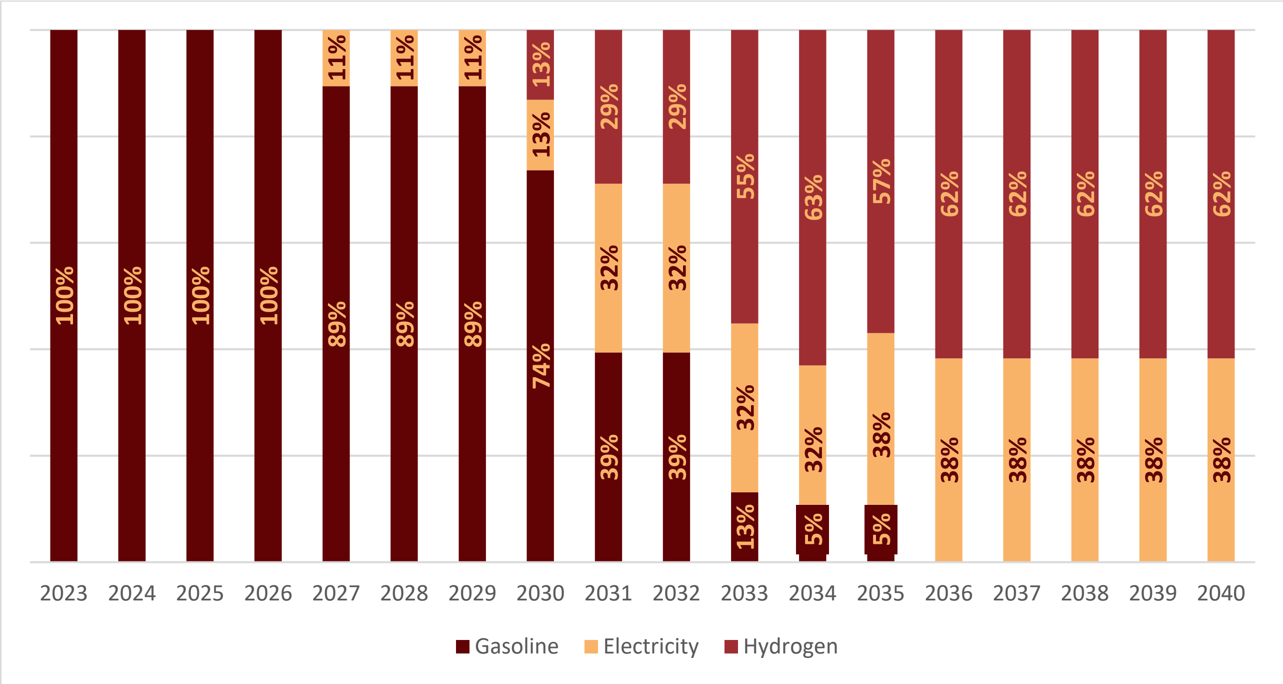

Figure 16. FCEV Revenue Fleet Scenario Transition: Fuel Demand, Percent of Total Gasoline-Gallon Units

EV chargers at Sandoval County Transit Facility will accrue the same per-charger cost that they do in the alternate revenue transition scenario. These costs total to $1.6 million over the lifecycle of the project. Departing from BEV utility infrastructure, hydrogen utility infrastructure will have an associated monthly rate, per facility.[9] Hydrogen utility infrastructure will make up $1.8 million in additional expenses over the analysis period.

Table 41. FCEV Revenue Fleet Scenario Transition: Total EV Charger and Hydrogen Infrastructure O&M Costs (2022 Dollars)

Location	EV Chargers	Hydrogen Infrastructure
NMRX Yard	$0	$0
Valencia County Transit Facility	$0	$1,807,056
Sandoval County Transit Facility	$1,644,000	$0

The demand for each type of fuel (gasoline, electricity, and hydrogen) are determined by miles driven by each vehicle type. The demand for each type of fuel, represented as a percent of total units that are gasoline-gallon-equivalent units, is shown in Figure 16. The fuel demand corresponds directly to fueling expenditures. As noted in the Key Assumptions section, the price of grey hydrogen is the lowest when compared on a gasoline-equivalent scale, at $1.23 per unit verses $2.15 and $5.55 per unit for electricity

[9] Estimates provided by the Option 2 within the Air Products Proposal and Technical Description for Hydrogen fueling infrastructure.

and gasoline, respectively. Hydrogen also benefits from the only fuel whose price is expected to decrease over time. Annual fueling expenditures are represented in Figure 17, and Table 42 shows total expenditures by location over the analysis period.

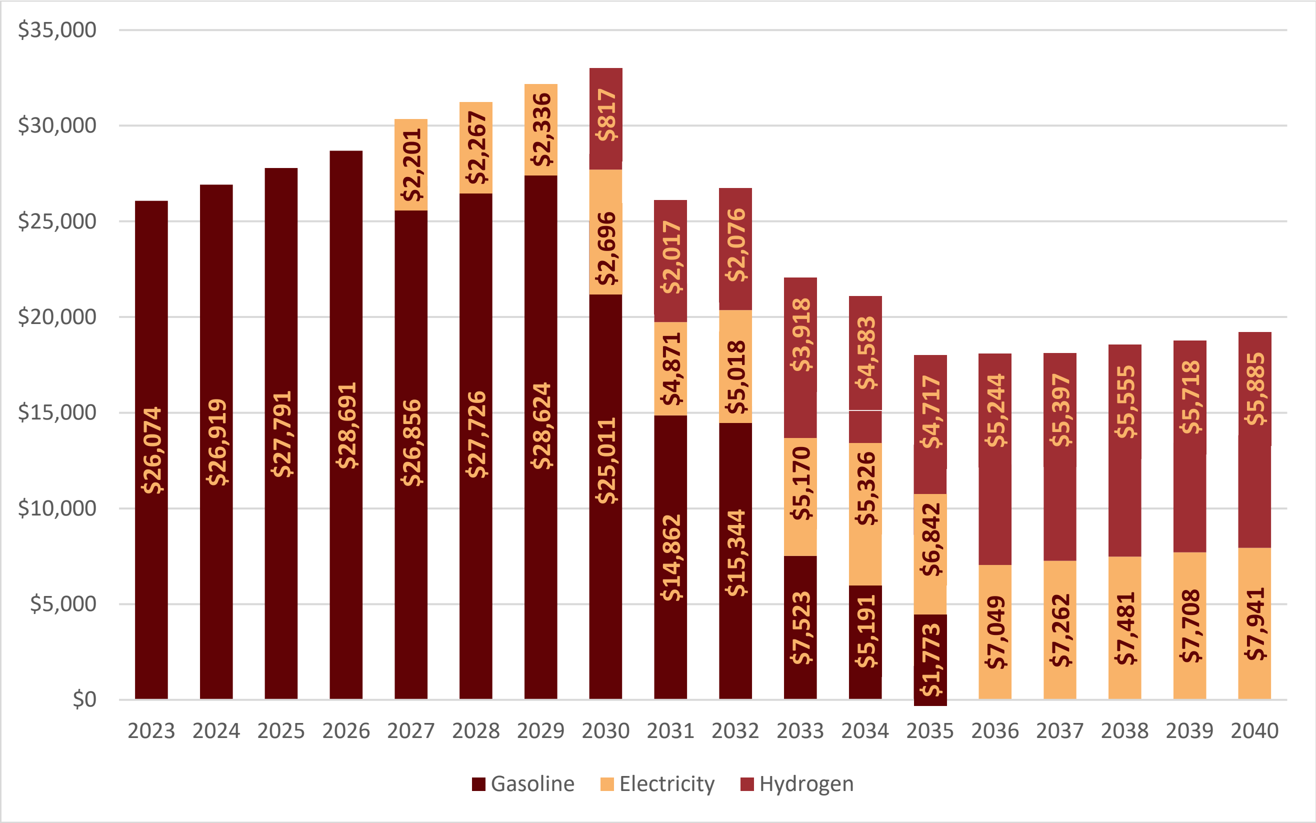

Figure 17. FCEV Revenue Fleet Scenario Transition: Fuel and Electricity Costs (2022 Dollars)

Table 42. FCEV Revenue Fleet Scenario Transition: Total Fuel Costs (2022 Dollars)

Location	Total Gasoline Cost	Total Electricity Cost	Total Hydrogen Cost
NMRX Yard	$28,867	$5,539	$0
Valencia County Transit Facility	$143,445	$0	$28,991
Sandoval County Transit Facility	$46,998	$45,193	$0
Total	**$219,310**	**$64,493**	**$28,991**

Table 43. FCEV Revenue Fleet Scenario Transition: Annual Costs (2022 Dollars, in Millions)

	Total	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Capital	**$21.6**	**$1.6**	**$0.0**	**$1.0**	**$0.3**	**$1.2**	**$0.2**	**$5.9**	**$2.0**	**$4.2**	**$0.0**	**$2.0**	**$1.4**	**$0.0**	**$0.3**	**$0.3**	**$1.2**	**$0.0**	**$0.0**
Vehicles	$15.3	$1.6		$1.0	$0.3	$1.2	$0.2		$2.0	$3.8		$2.0	$1.4		$0.3	$0.3	$1.2		
Infra.	$6.3					$0.04		$5.9	$0.01	$0.4									
O&M	**$111.3**	**$6.0**	**$6.0**	**$6.0**	**$6.0**	**$6.1**	**$6.1**	**$6.2**	**$6.2**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**	**$6.3**
O&M	$111.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.0	$6.2	$6.2	$6.3	$6.3	$6.3	$6.3	$6.3	$6.3	$6.3	$6.3	$6.3	$6.3
Fuel	$0.3	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.02	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01	$0.01
Total	***$132.9***	***$7.6***	***$6.0***	***$7.0***	***$6.3***	***$7.3***	***$6.2***	***$12.1***	***$8.2***	***$10.5***	***$6.3***	***$8.3***	***$7.7***	***$6.3***	***$6.6***	***$6.6***	***$7.4***	***$6.3***	***$6.3***

Lifecycle Cost Comparison

This section provides a comparison of the capital, O&M, and fueling cost estimates among the three scenarios considered. Since non-revenue vehicle purchases and the necessary utility infrastructure will begin to be purchased within the next two years, the full period between 2023 and 2040 is considered in the analysis.

Capital Cost Comparison

Table 44 provides a comparison of total capital costs among the three scenarios. As shown in the table, the BEV Revenue Fleet Scenario is less expensive than the FCEV Revenue Fleet Scenario by about $3 million. This arises from the cheaper EV infrastructure purchases offsetting the more-expensive BEVs. Due to the relative abundance of cheaper gasoline vehicles and not needing additional infrastructure, the baseline scenario has near $18 million less capital purchases compared to both transition scenarios.

Table 44. Capital Cost Comparison

	Baseline Scenario	BEV Revenue Scenario	FCEV Revenue Scenario
Vehicle Purchases	**$9,248,869**	**$22,680,465**	**$17,201,689**
Non-Revenue Vehicles	$1,072,399	$1,937,974	$1,937,974
Revenue Vehicles	$8,176,470	$20,742,492	$15,263,715
Infrastructure Purchases	**$0**	**$7,367,010**	**$10,139,358**
Total	**$9,248,869**	**$30,047,475**	**$27,341,047**

Operations and Maintenance Cost Comparison

Table 45 provides a comparison of vehicle and infrastructure operating and maintenance costs over the analysis period, based on assumptions described in the prior sections. As mentioned earlier, maintenance costs for BEVs and FCEVs are estimated based on differences that are provided by the US Department of Energy. These rates have little market testing and as such the approximations may not provide a wholly accurate representation of vehicle O&M costs. Between all three scenarios vehicle O&M costs all lie within about $4 million of each other over the analysis period, a gap characterized by O&M per-mile costs that are all within a $0.10 range. The Baseline Scenario O&M costs become less expensive once infrastructure-based O&M expenses (for EV chargers and the hydrogen utility infrastructure) are counted.

Table 45. Operations and Maintenance Cost Comparison

	Baseline Scenario	BEV Revenue Scenario	FCEV Revenue Scenario
Vehicle O&M	**$138,269,316**	**$137,902,971**	**$137,853,163**
Non-Revenue Vehicles	$30,357,107	$30,254,454	$30,254,454
Revenue Vehicles	$107,912,210	$107,648,517	$107,598,709
Infrastructure O&M	**$0**	**$4,608,000**	**$3,703,056**
Non-Revenue	-	$252,000	$252,000
Revenue	-	$4,356,000	$3,451,056
Total	**$138,269,316**	**$142,510,971**	**$141,556,219**

Fuel and Electricity Cost Comparison

Finally, Table 46 provides a comparison of total costs for gasoline, hydrogen, and electricity as vehicle fuel sources over the analysis period. Based on the per-unit assumptions and associated price growth rates, the FCEV Revenue Fleet Scenario is the most attractive, followed closely by the BEV Revenue Fleet Scenario. Both of these scenarios have accumulated costs savings of over $450,000 when compared to the Baseline Scenario.

Table 46. Fueling Cost Comparison

	Baseline Scenario	BEV Revenue Scenario	FCEV Revenue Scenario
Non-Revenue Fueling	**$227,797**	**$409,373**	**$409,373**
Gasoline	$227,797	$187,868	$187,868
Electricity	-	$221,505	$221,505
Hydrogen	-	-	-
Revenue Fueling	**$966,443**	**$332,385**	**$299,047**
Gasoline	$966,443	$219,310	$219,310
Electricity	-	$113,075	$50,732
Hydrogen	-	-	$29,005
Total	**$1,194,240**	**$741,758**	**$708,420**

Net Present Value and Payback Period Analysis

A net present value (NPV) and payback period analysis was conducted to compare the two alternative-fuel based transition scenarios to the Baseline Scenario. The analysis included capital costs (vehicles, charging equipment, and infrastructure needs) and O&M costs (operations, maintenance, and fuel) for the transition scenarios relative to the Baseline Scenario. In other words, only the incremental cost savings and increases on an annual basis were included. All cost savings and increases over the 2024 to 2040 period were presented in 2022 dollars and discounted at 5 percent.

The purpose of this analysis is to determine if the upfront capital expenditures can be overcome by annual vehicle maintenance and propulsion savings. The analysis does not attempt to quantify external benefits, such as emissions reduction, and assumes no changes to ridership or service levels. The only benefit, or in this case disbenefit, is the change in cost to the agency. In other words, the analysis looks at direct cost impacts to Rio Metro and does not attempt to quantify costs and benefits on a larger scale.

Additionally, the analysis does not assume capital costs will be offset by potential grant funding, and these savings do not remove any costs from the NPV calculations. Possible infrastructure-related grant funding is discussed in the main report.

The systemwide discounted NPV for the BEV Revenue Fleet Scenario is negative $15.8 million and the NPV for the FCEV Revenue Fleet Scenario is negative $14.1 million. The negative NPVs reflects that the two transition scenarios cannot offset the higher capital, O&M, and propulsion expenditures in the Baseline Scenario. Therefore, there is no payback period for either scenario within the analysis period.