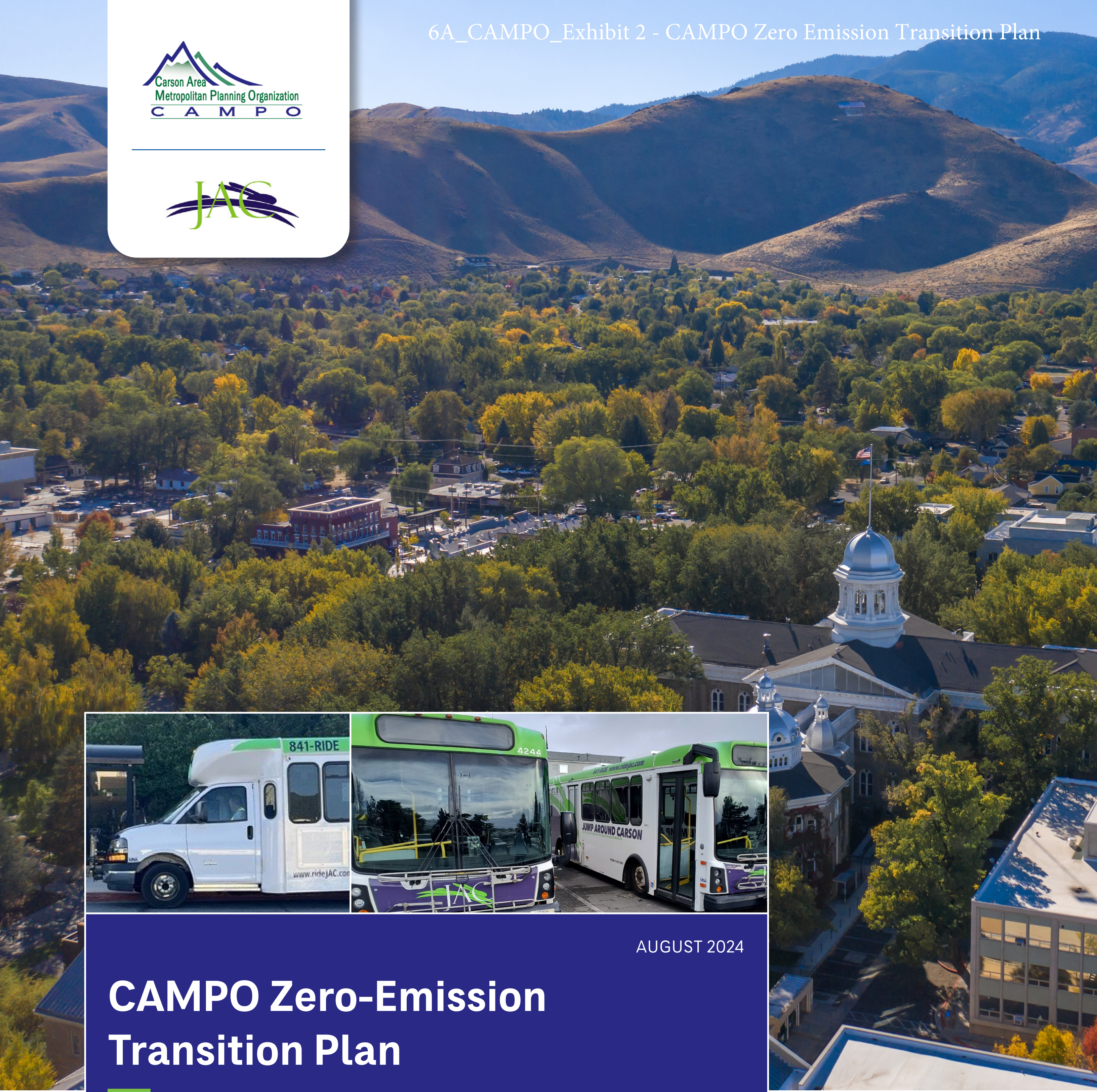
Carson Area Metropolitan Planning Organization
C A M P O

JAC



AUGUST 2024

CAMPO Zero-Emission Transition Plan

Carson Area Metropolitan Planning Organization

CDM Smith

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Acronyms and Abbreviations

%	percent
°F	degrees Fahrenheit
A	ampere
AC	alternating current
BEB	battery electric bus
CAMPO	Carson Area Metropolitan Planning Organization
CDL	commercial driver's license
CEJEST	Climate & Economic Justice Screening Tool
CFRP	carbon fiber reinforced polymer
CNG	compressed natural gas
CO_2	carbon dioxide
Cutaway	cutaway chassis bus
DART	Douglas Area Rural Transportation
dBA	A-weighted decibel
DCFC	direct current fast charger
DOT	U.S. Department of Transportation
EPA	U.S. Environmental Protection Agency
ERTEP	NV Energy's Economic Recovery Transportation Electrification Plan
FCEB	hydrogen fuel cell electric bus
FTA	Federal Transit Authority
FY	fiscal year
GFRP	glass fiber reinforced polymer
GHG	greenhouse gas
GVWR	gross vehicle weight ratings
JAC	Jump Around Carson
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour

lbs	pounds
LMI	low and moderate income
Low-No Emission Bus Program	Federal Transit Authority's FTA's Low or No Emission Grant Program (49 United States Code U.S.C. 5339[(C]))
MPG	miles per gallon
MT	metric tons
N/A	not applicable
NDEP	Nevada Division of Environmental Protection
NDOT	Nevada Department of Transportation
NEMA	National Electrical Manufacturers Association
NEVI	National Electric Vehicle Infrastructure Formula Program
NFPA	National Fire Protection Association
NOFO	Notice of Funding Opportunity
OEM	original equipment manufacturer
PCDPW	Placer County Department of Public Works
Pusher	pusher chassis bus
QR code	quick-response code
RTC Washoe	Regional Transportation Commission of Washoe County
RTP	Regional Transportation Plan
RTSC	Carson City Regional Transportation Stakeholder Coalition
TAM Plan	Transit Asset Management Plan
TART	Tahoe-Truckee Area Regional Transit
TCO	total cost of ownership
TDCHSP	Jump Around Carson's Transit Development and Coordinated Human Services Plan
TTD	Tahoe Transportation District
U.S.C.	United States Code
V	volt
VMT	vehicle miles traveled
VRM	vehicle revenue mile
ZETP	Zero-Emission Transition Plan

Executive Summary

Jump Around Carson (JAC) is the public transit system in Carson City, Nevada. JAC is interested in pursuing funds from the Federal Transit Authority's Low or No Emission Grant Program (49 United States Code 5339[c]) for the purchase of low or no emission buses and bus-related infrastructure. One of the requirements for qualification for the grant program is the development of this Zero-Emission Transition Plan (ZETP) (DOT 2022).

The JAC ZETP addresses the following statutory requirements:

	ZETP Requirement	Discussion in JAC ZETP
	Demonstrate a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions.	Section 4.0 of the JAC ZETP describes vehicles, infrastructure, and a deployment timeline recommended for JAC's transition to low or no emission transit.
	Address the availability of current and future resources to meet costs for the transition and implementation.	Section 5.3 of the JAC ZETP focuses on JAC's most prominent funding challenge and options for addressing it.
	Consider policy and legislation impacting relevant technologies.	The transit agency is influenced by policies adopted by JAC, the Carson Area Metropolitan Planning Organization (CAMPO), and regional entities. Section 2.8, Section 3.0, Section 5.3, and Appendix A of the JAC ZETP summarize these policies and any related impacts.
	Include an evaluation of existing and future facilities and their relationship to the technology transition.	Section 2.5, Section 2.6, and Section 4.4 of the JAC ZETP describes the current state and necessary future state of the JAC Yard, Carson City Public Works campus, and the Downtown Transfer Plaza.
	Describe the partnership of the applicant with the utility or alternative fuel provider.	NV Energy, the local utility, was interviewed in the development of the JAC ZETP. Appendix A.2.2 provides the interview summary. Considerations of that conversation informed the development of Section 4.4 and Section 4.5.4 of the JAC ZETP.
	Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers of the applicant to operate and maintain zero-emission vehicles and related infrastructure and avoid displacement of the existing workforce.	Section 2.5.3, Section 2.6.3, Section 2.7.1, and Section 4.6of the JAC ZETP summarize the existing state of the workforce and the new skills that are needed for JAC's transition to low or no emission transit, including drivers, fleet maintenance workers, and facility maintenance workers.

The following is a high-level summary of major plan elements.

Long Term Fleet Management Plan

JAC has 17 fleet vehicles: five diesel pusher buses, 11 gasoline cutaway buses, and one gasoline minivan. These vehicles are used to service the agency's four fixed routes as well as on demand paratransit services.

Both battery electric buses (BEBs) and hydrogen fuel cell electric buses (FCEBs) were analyzed for feasibility. FCEBs were eventually ruled out, primarily because of the lack of existing hydrogen fuel infrastructure in the region and the lack of cost-effectiveness of FCEBs at the small scale of JAC's fleet.

Different pusher BEB battery capacities were also analyzed. JAC should purchase standard-range pusher buses and build a mid-route charger for topping up the battery throughout the day. If the agency faces challenges with building a mid-route charger, while it works towards that solution it can purchase extended-range pusher buses and rely solely on depot charging. Standard-range models and extended range options both have benefits and downsides.

The proposed roadmap is a two-phased approach, with Phase 1 as the initial deployment and Phase 2 as the large-scale deployment. Phase 1 will deploy enough vehicles to allow JAC to collect real-life performance metrics, while gradually acclimatizing drivers and maintenance staff to the requirements of low and no emission buses. The data gathered in Phase 1 will then enable JAC to customize equipment specifications or, if needed, revise and refine their strategy for Phase 2.

Based on JAC's current services, during Phase 1, the agency should procure two pusher BEBs and perform electrical service upgrades at the JAC Yard to install two 150 kilowatt (kW) depot chargers. In Phase 2, it is recommended that the agency procure a total of 5 pusher BEBs (including those purchased in Phase 1), but size electrical service upgrades at the JAC Yard to accommodate up to 12 pusher BEBs. The actual number of pusher BEBs that should be purchased depends on the prospective CAMPO route to Mound House and the cutaway BEB market, which is currently in its infancy. Depot chargers in Phase 2 should be installed at a ratio of approximately one charger for one BEB. The chargers should be 150 kW DCFCs for the pusher BEBs and 50 kW DCFCs for cutaway BEBs.

Costs of Transition and Implementation

One of the transit agency's major challenges in vehicle procurement is obtaining the local match component of grants, so the funding section of this ZETP recommends strategies for meeting the local match requirement, and offers ideas for possible federal, state, and regional funding sources that should be considered.

A total cost of ownership analysis was also performed. This analysis showed that legislation in the form of federal grant funding (both for the existing diesel pushers and the low/no emission buses) has a big impact on how each of the vehicle choices financially compare. By the end of the anticipated 12-year lifespan of the buses, the hybrid diesel-electric buses and the BEBs both have a lower cumulative total cost of ownership compared to the diesel pushers.

Policy and Legislation

Internal and regional policies were analyzed for this report. An understanding of internal policies shaped recommendations including the optimal location for depot charging at the JAC Yard, and changes needed for fleet maintenance. The recommendations of this ZETP were influenced by the policies and plans of neighboring transit agencies, including the Regional Transportation Coalition of Washoe County, the Tahoe Transportation District, and Douglas Area Rural Transit. Legislation related to no/low emission buses has a strong impact on costs, which is seen in the total cost of ownership analysis.

Existing and Future Facilities

The transition to BEBs will require extensive infrastructure changes to the JAC Yard for depot charging. The electrical upgrades and recommended charging equipment are detailed in this report. Changes to the fleet maintenance bay will also be needed, including installing a small charger for as-needed charging in the facility, obtaining tools to enable repairs on rooftop equipment, and fire suppression equipment for battery technology-related incidents.

Partnership with Utility Provider

JAC's utility, NV Energy, provided information on timelines and costs of the electrical infrastructure upgrades included in this recommendation. NV Energy also confirmed that the electrical demand of the proposed BEBs can be supported in the region.

Workforce Impacts

The operations and fleet maintenance workforce will need training to accommodate the new vehicles. Bus drivers may need different classes of commercial driver's licenses to operate heavier vehicles and will need to be brought up to speed on managing buses with high and low voltage components. Driver training on utilizing the regenerative braking of the buses is also important to optimize energy recapture. Fleet maintenance staff will need training on the new powertrain types. Manufacturer-provided training and in-house vehicle manufacturer support are highly recommended methods for training staff on new skills.

Other

To highlight the benefits of the zero-emission transition, as well as dispel misconceptions, JAC should perform community outreach to connect with governing bodies, community groups, transit ridership, and the non-ridership population. The outreach goals, type of detail shared, information gathered, and method and frequency of outreach should be tailored to best suit these different audiences.

The transition roadmap outlines the next steps for JAC to proceed with its zero-emission transition. After project funding is secured, JAC can proceed with Phase 1.

Executive Summary Reference

DOT. 2022. "Zero-Emission Fleet Transition Plan." Accessed June 22, 2024, https://www.transit.dot.gov/funding/grants/zero-emission-fleet-transition-plan.

– End of Executive Summary –

1.0 Introduction

Jump Around Carson (JAC) is the public transit system in Carson City, Nevada. JAC is interested in pursuing funds from the Federal Transit Authority's (FTA's) Low or No Emission Grant Program (49 United States Code [U.S.C.] 5339[c]) (hereby called FTA's Low-No Emission Bus Program) for the purchase of low or no emission buses and bus-related infrastructure. One of the requirements for qualification for the grant program is the development of this Zero-Emission Transition Plan (ZETP) (U.S. Department of Transportation [DOT] 2022).

The following are statutory requirements of a ZETP:

	ZETP Requirement	Discussion in JAC ZETP
	Demonstrate a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions.	This document describes vehicles, infrastructure, and a deployment timeline recommended for JAC's transition to low or no emission transit. Section 4 provides additional details.
	Address the availability of current and future resources to meet costs for the transition and implementation.	This document focuses on JAC's most prominent funding challenge and options for addressing it. Section 5.3 provides additional details.
	Consider policy and legislation impacting relevant technologies.	The transit agency is influenced by policies adopted by JAC, the Carson Area Metropolitan Planning Organization (CAMPO), and regional entities. Section 2.8, Section 3.0, Section 5.3, and Appendix A summarize these policies and any related impacts.
	Include an evaluation of existing and future facilities and their relationship to the technology transition.	This document describes the current state and necessary future state of the JAC Yard, Carson City Public Works campus, and the Downtown Transfer Plaza. Section 2.5, Section 2.6, and Section 4.4 provide additional details.
	Describe the partnership of the applicant with the utility or alternative fuel provider.	NV Energy, the local utility, was interviewed in the development of this plan. Appendix A.2.2 provides the interview summary. Considerations of that conversation informed the development of Section 4.4 and Section 4.5.4.

	ZETP Requirement	Discussion in JAC ZETP
	Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers of the applicant to operate and maintain zero-emission vehicles and related infrastructure and avoid displacement of the existing workforce.	This document summarizes the existing state of the workforce and the new skills that are needed for JAC’s transition to low or no emission transit, including drivers, fleet maintenance workers, and facility maintenance workers. Section 2.5.3, Section 2.6.3, Section 2.7.1, and Section 4.6 provide additional details.

To develop content to meet these requirements, JAC started with data gathering. Interviews were conducted with internal stakeholders, stakeholders from the transit agency’s governing body, neighboring transit agencies, regional entities, and community members.

The recommended transition to zero-emission vehicles was then designed by analyzing specifications of existing vehicles currently available on the market.

The following sections of this report document this recommended deployment of zero- or no-emission vehicles for JAC and the rationale.

2.0 Existing Conditions

2.1 Entities

JAC began operations in 2005. JAC is operated by the Carson City Regional Transportation Commission and is governed by the Carson Area Metropolitan Planning Organization (CAMPO), which is responsible for the metropolitan planning in the Carson City urbanized area, consisting of Carson City, northern Douglas County, and western Lyon County. Other regional transportation agencies and non-transportation entities identified operating in the vicinity of the Carson City urbanized area are detailed in Appendix A.

2.2 Existing Service

2.2.1 Routes and Schedules

JAC operates four fixed routes, designated as Route 1, Route 2A, Route 2B, and Route 3, as shown in Figure 1. After the buses are picked up from the JAC Yard, all routes start and end at the Downtown Transfer Plaza on North Plaza Street in front of the Carson City Federal Building (705 North Plaza Street). Each route has a scheduled run time of approximately 45 minutes. There is a scheduled 10- to 15-minute recovery time at the Downtown Transfer Plaza between the end of a run and the start of the next. Fixed-route transit services operate between 6:30 a.m. and 7:30 p.m. Monday through Friday and operate between 8:30 a.m. and 4:30 p.m. on Saturday. Fixed-route services do not operate on Sunday. The following list describes JAC fixed-route routing and destinations.

- Route 1 serves the northwest portion of Carson City and connects riders to the Carson City Senior Center, North Carson Crossing retail center, Carson City Library, Carson City Community Center, and Carson Tahoe Regional Medical Center.
- Routes 2A and 2B serve the central portion of Carson City following virtually identical routes but running in opposite directions. These routes connect riders to the Western Nevada College, the Sierra Nevada Health Center, the Boys & Girls Clubs of Western Nevada, and the Nevada Department of Health and Human Services (including the Division of Child and Family Services, the Division of Welfare and Supportive Services, and other services related to mental health and support of children and families).
- Route 3 serves the southern portion of Carson City and connects riders to Carson City Hall, the Department of Motor Vehicles, the Nevada Department of Transportation (NDOT), Fuji Park, and a Costco retail center.

In addition to the fixed routes, CAMPO's JAC Assist program provides paratransit services. Paratransit services use smaller cutaway buses and operating hours are the same as the fixed routes. JAC's paratransit services include subscription services (i.e., ongoing services) as well as on demand services, which are scheduled 2 weeks to 1 day in advance.

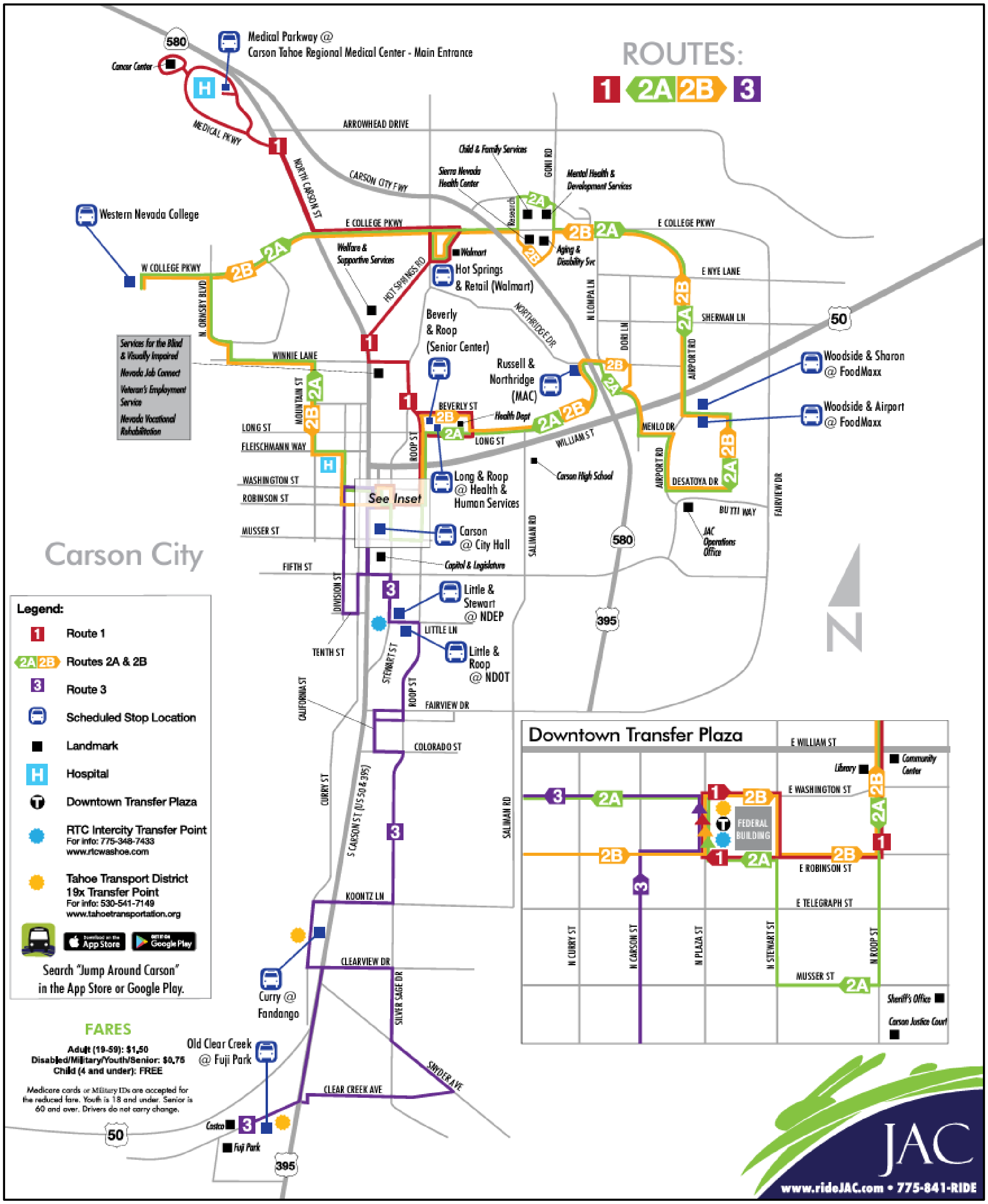

Figure 1: Map of Jump Around Carson Fixed Routes

Source: Carson City 2022

2.3 Population

The State of Nevada Department of Taxation (State of Nevada 2023) estimates that as of July 2023, Carson City had a population of 58,923 people. The population projections estimate a population increase to 61,674 people in 2041.

JAC has identified (Carson City 2023-b) that the following population subsets are considered transit-dependent populations—people who rely more heavily on public transportation in the region.

- Youth (5 to 17 years old)
- Seniors (65+ years old)
- Low-income households
- Disabled
- Zero-vehicle households

JAC operations and procurement are influenced by the specific needs of these populations. Examples include the free senior bus pass program (made available by a grant by the State Aging and Disability Services Division) and a vehicle procurement preference for buses with ramps over buses with lifts to improve the onboarding experience of wheelchair riders.

JAC's purpose is to increase the mobility and independence of the community through serving its riders, but the transit agency also impacts non-rider members of the community. JAC buses provide the benefits of reducing traffic congestion, though this comes with noise and air pollutants from running the fossil fuel–powered vehicles.

Communities living near JAC routes experience both the benefits and drawbacks of proximity to public transit. Parts of the CAMPO region are identified as Areas of Persistent Poverty (as defined by the Bipartisan Infrastructure Law) and Historically Disadvantaged Communities (as defined by Justice40). These areas are shown in the Figure 2: (DOT n.d.-a). The orange regions are Areas of Persistent Poverty, and the pink and blue regions are Historically Disadvantaged Communities (pink areas are disadvantaged communities from the Climate & Economic Justice Screening Tool [CEJEST]; blue areas are a federally recognized tribe or tribal entity). Figure 2 contains some regions that are linked to multiple communities. DOT's Grant Project Location Verification interactive webpage provides additional details. The numbers in the regions are census track identifiers. Figure 2 is a general snapshot of Carson City—it does not match CAMPO's jurisdiction exactly.

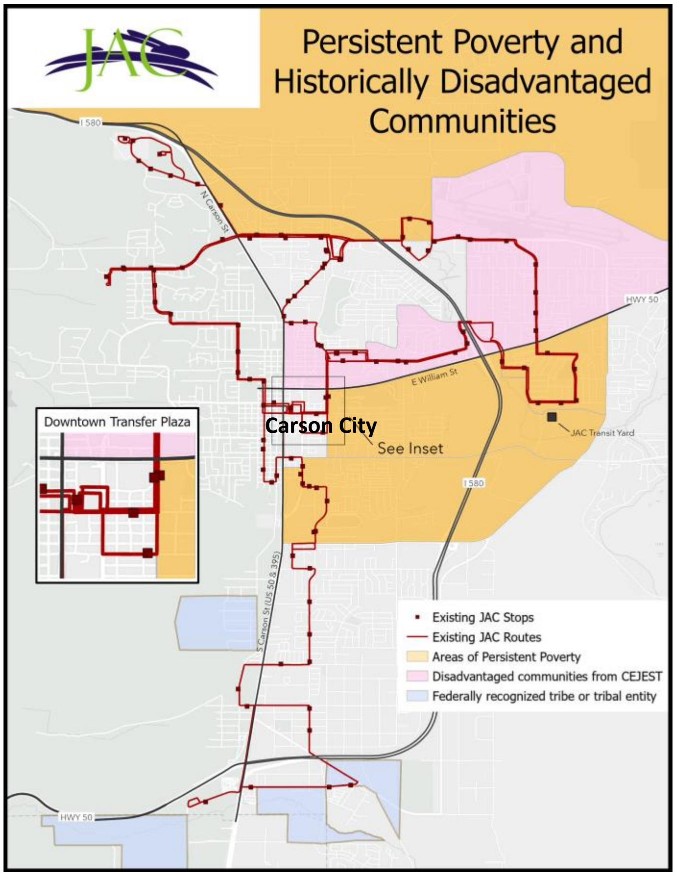

Figure 2: U.S. Department of Transportation Map of Areas of Persistent Poverty and Historically Disadvantaged Communities

2.3.1 Ridership

Ridership of JAC's fixed routes has risen from 183,700 passenger trips in fiscal year (FY) 2011 to 2012 up to 195,200 passenger trips in FY 2017 to 2018. In 2019, the average maximum hourly ridership on Routes 1, 2A, 2B, and 3 was 31, 14, 25, and 19 passengers, respectively. Ridership of JAC's paratransit services has steadily risen from 13,800 passenger trips in FY 2011 to 2012 to 28,000 passenger trips in FY 2017 to 2018. The effects of the pandemic caused by the emergence of the COVID-19 virus caused significant upset to the ridership of JAC's transit services in 2020 and 2021. Ridership in FY 2023 was reported to be 145,233 passenger trips.

2.4 Existing Fleet

JAC operates a fleet of 17 rolling stock transit bus service vehicles. The fleet comprises vehicles primarily used for fixed-route services, vehicles primarily used for paratransit services, and vehicles used for both. The vehicles primarily serving fixed routes are three pusher chassis (called pusher[s]) 35-foot diesel buses and two pusher 34-foot diesel buses. The vehicles primarily used for paratransit services are two cutaway chassis (called cutaway[s]) 24-foot gasoline buses, two cutaway 21-foot gasoline buses, and one minivan chassis 19-foot gasoline bus. The vehicles used for both fixed routes and paratransit are five cutaway 28-foot gasoline buses and two cutaway 24-foot gasoline buses.

For fixed routes, pusher buses were typically used on Routes 1 and 3, while Routes 2A and 2B used a mix of pusher buses and cutaway buses depending on ridership demand. On Saturdays, all routes generally use the pusher buses. On a typical day, a bus leaves the JAC Yard (discussed further in Section 2.5) in the morning and is used to serve its assigned route until the end of the day, with drivers changing out mid-day at the Downtown Transfer Plaza.

For the fixed routes, one cycle of the route can be completed over approximately 45 minutes, with a 15-minute scheduled stop at the Downtown Transfer Plaza between the end of one route cycle and the beginning of the next. Because of this consistent route design, daily bus service miles are largely consistent between the four routes. Performance data from February 2024 indicates that revenue miles for each fixed route was 135 to 155 miles/day. Including nonrevenue miles increases the service miles for each fixed-route service to 145 to 165 service miles/day.

For paratransit routes, smaller cutaway chassis buses are typically used. Since paratransit vehicles do not follow fixed routes, the daily bus miles vary. Paratransit vehicles typically return to the JAC Yard between trips to wait for the next dispatch. Performance data from February 2024 indicates that paratransit service miles (including nonrevenue miles) across all vehicles used for this service, was 50 to 90 service miles/day.

2.4.1 Vehicle Efficiencies

Based on 2023 annual performance data, JAC's pusher buses achieved a weighted average fuel efficiency of 6.95 miles/gallon of diesel fuel and an average maintenance metric of 871 miles between workorders. The cost of maintenance per service mile, accounting for both parts and labor, ranged from $0.78/mile to $2.62/mile across JAC's pusher buses, with an average cost of $1.34/mile.

Based on 2023 annual performance data, JAC's cutaway buses and minivan bus achieved an average fuel efficiency of 10.29 miles/gallon of gasoline fuel and an average maintenance metric of 1,774 miles between workorders. The cost of maintenance per service mile, accounting for both parts and labor, ranged from $0.09/mile to $0.46/mile across JAC's cutaway buses, with an average cost of $0.22/mile.

2.4.2 Vehicle Phase Out Criteria

Funding is a major limitation for the phase out and replacement of JAC vehicles. Vehicles are phased out when local share funding is available and based on the investment rankings of the JAC fleet. These investment rankings are calculated, as detailed in JAC's current Transit Asset Management Plan (TAM Plan), based on a number of criteria including whether the vehicle's age exceeds the FTA's useful life benchmark and minimum useful life age, whether the vehicle's mileage exceeds the FTA's minimum useful life mileage, and a calculated condition score which encompasses bus performance, maintenance costs, condition of vehicle components, and other factors.

Table 1, from the TAM Plan, presents the anticipated replacement year for CAMPO's existing rolling stock transit vehicles, identified by fleet vehicle number and vehicle body type.

Table 1: Jump Around Carson Transit Asset Replacement Schedule

Anticipated Replacement Year	Pusher Chassis Buses	Cutaway or Minivan Chassis Buses
FY 2023	—	4238, 4239
FY 2024	4243, 4244	—
FY 2025	—	4241, 4242
FY 2026	4245, 4249, 4250	—
FY 2027+[1]	—	4251, 4252, 4253, 4254, 4255, 4256, 4257, 4258

Note(s):
1. FY 2027 and beyond are not covered under the current TAM Plan.

2.5 Jump Around Carson Yard

2.5.1 Operations

The JAC fleet is stored in a gated lot at the JAC Yard at 3770 Butti Way, as shown in Figure 3. Gate access is limited to the JAC employees and the bus drivers (who are employed by the contract operator), who park their personal vehicles on the perimeter of the lot.

Figure 3: Jump Around Carson Yard

The drivers start their day at the JAC Yard, where they drive the transit vehicles to the Downtown Transfer Plaza for their first route. After their last route of the day ends at the Downtown Transfer Plaza, the drivers take the transit vehicles back to the JAC Yard.

The JAC Yard is uncovered. In the center of the parking lot, where the pusher buses and cutaways are stored, there are bollards with electric receptacles where the vehicles are plugged in to power their engine block heaters. In snowy conditions, the JAC Yard is not plowed. Staff outfit the buses with chains that allow the vehicles to maneuver the short distance from the lot to the road. Power outages in the region are rare, but if they occur, the service to the JAC Yard and the Carson City Public Works facility get power reestablished quickly. These facilities are prioritized by the utility since they provide critical services for the region.

2.5.2 Physical Infrastructure

The JAC Yard has an existing overhead electrical service from NV Energy (three phase, 208 volt [V], 200 ampere [A]) that feeds a 200 A panelboard mounted on the JAC office building. The panelboard provides power both to the building and another panelboard in the parking lot that feeds the engine block heaters.

The existing 208 V system is too low to power the 480 V input direct current fast chargers (DCFCs) recommended for charging pusher buses. Additionally, no emergency generation or redundancy currently exists in the JAC Yard power feeds.

2.5.3 Workforce (Bus Drivers and Dispatchers)

The drivers for the JAC fleet are employees of the contract operator, which generally employs one driver per JAC rolling stock vehicle. Most of the drivers have a commercial driver's license (CDL). Drivers without CDLs operate only the vans used for paratransit. The JAC dispatchers are also employees of the contract operator.

The contract operator manages the training of its employees.

2.6 Carson City Public Works Facility – Fleet Maintenance Bay and Vehicle Wash Bay

2.6.1 Operations

The fleet maintenance building is at the Carson City Public Works campus at 3303 Butti Way (Figure 4), which is across the street from the JAC Yard. Figure 5 shows the proximity of these facilities. The Carson City Public Works campus is gated and access is restricted. The JAC fleet drivers have access to the main gate and wash bay during normal business hours, but do not have full access to the facility or to the vehicle maintenance bays.


Figure 4: Carson City Public Works Campus Outside of Maintenance Bays 1 through 5

Figure 5: Carson City Public Works Campus Location Relative to JAC Yard

The fleet maintenance team is responsible for the vehicle maintenance of all JAC and Carson City vehicles. Current capacity allows for 65 percent (%) of the maintenance to be performed in-house, with the rest sent out to third parties. The goal is to increase the fleet maintenance performed in-house to 90%. The fleet vehicle team services all city vehicles in addition to JAC vehicles, which impacts the maintenance repair schedule for transit vehicles. Lead times for parts are a bottleneck for vehicle maintenance, sometimes leaving a vehicle out of service for months at a time.

The wash bay is also in the Carson City Public Works campus and can be used by any Carson City Public Works employee.

2.6.2 Physical Infrastructure

The Carson City Public Works campus has multiple electrical services at 480 V throughout the site. These are suitably sized to provide additional infrastructure for fast charging of electric vehicles. The maintenance bays which service JAC buses are outfitted with 240 V systems which would be suitably sized to provide additional infrastructure for limited slower, Level 2 charging of electric vehicles. The fleet maintenance team uses modular column lifts for their vehicles, which have a capacity of 18,500 pounds (lbs) per column.

2.6.3 Workforce

The fleet maintenance team is staffed by Carson City Public Works and consists of eight staff: six technicians, one foreman, and one parts coordinator. The technicians have varying levels of abilities and experiences, but the goal is to have all team members trained and comfortable with performing work on all vehicles.

Training for this team consists of a combination of hands-on training, on-site training, off-site training, YouTube videos, calling into hotlines, and mentorship. Off-site training is seen as a particularly effective incentive. Staff that meet certain goals (e.g., achieving certifications) qualify to attend training courses during which they learn about certain equipment while enjoying a change in their normal routine. These off-site training opportunities increase buy-in and interest in the equipment that team members work on.

2.7 Facility Maintenance

2.7.1 Workforce

The facility maintenance team is also based out of the Carson City Public Works campus. It is staffed by Carson City Public Works and consists of seven people that service 96 buildings across the city. Approximately half of the staff is trained for technical electrical work.

2.8 Related Policies, Plans, and Legislation

The primary policies and legislation impacting the technologies evaluated in this plan include JAC and CAMPO planning documents that provide context into elements of the vision for transportation in Carson City, NDOT’s transportation electrification goals and strategies, plans for the broader adoption of zero-emission technologies by other transit agencies which overlap or abut the service area of JAC, and federal legislation relating to transportation funding. The following plans provide key context for the development of the ZETP:

- TAM Plan, JAC Transit System, Federal Fiscal Year 2023 – 2026
- Jump Around Carson Transit Development and Coordinated Human Services Plan (TDCHSP)
- Carson Area Transportation System Management Plan
- CAMPO 2050 Regional Transportation Plan (RTP)
- Carson City Comprehensive Master Plan
- Carson City Public Works Maintenance Plan, rev. June 2024

Stakeholder interviews were coordinated to provide context on the current status of zero-emission adoption by neighboring transit agencies and on NDOT zero-emission strategies, discussed in Section 3.0 and Appendix A. Federal legislation applicable to transportation funding is discussed detail in Section 5.3.

3.0 Stakeholder Interviews

Throughout the plan preparation process, meetings were coordinated with key stakeholders to assess the potential for partnerships in the zero-emission transition and to build on the successes and learn from the challenges that other entities have experienced.

The regional transit agencies that JAC spoke with are:

- The Regional Transportation Commission of Washoe County (RTC Washoe) primarily services Reno, Nevada, with one fixed route that services Carson City's Downtown Transfer Plaza.
- The Tahoe Transportation District (TTD) primarily services south Lake Tahoe, with one fixed route that services Carson City's Downtown Transfer Plaza.
- Douglas Area Rural Transit (DART) facilitates access to Minden, Gardnerville, and the Gardnerville Ranchos. Although DART does not have a fixed route into Carson City, DART riders can travel to Carson City via a transfer to a TTD line.

These agencies are at various points in their zero-emission transitions, with some having been early adopters and others just beginning their transitions.

The other regional entities that JAC spoke with are:

- NDOT
- NV Energy, Carson City's local electricity utility
- Carson City Regional Transportation Stakeholder Coalition (RTSC)

In addition to these interviews, numerous planning documents for these stakeholders were reviewed to gain further insight into regional activities and goals. A separate memorandum as developed, summarizing the applicable plans and policies (CDM Smith, 2024). Appendix A summarizes the results of stakeholder interviews.

4.0 Transition Strategy

4.1 Benefits of a Zero-Emission Transition

The availability of -federal funds to purchase new public fleet vehicles from the FTA's Low-No Emission Bus Program is a major motivator for the zero-emission transition of the JAC fleet. Although sustainability and climate action are not the primary drivers for this transition, an alternative fuel fleet will still provide important sustainability and climate action benefits.

Low or no emission buses improve air quality by reducing local and regional levels of criteria air pollutants, particulate matter, and other pollutants such as mobile source air toxins or air pollutants that cause odors. This betters the quality of life for both the JAC ridership as well as those populations who live, work, learn, and play near areas that the buses operate. Another benefit of low or no emission buses is the reduction in operating noise. Numerous studies have linked daily noise exposure to even relatively common noise levels with negative health effects, most notably hypertension and heart disease, and with annoyance and disruption of focus in humans. (Babish and Umweltbundesamt 2006; World Health Organization 1999). Noise levels typical of heavy diesel trucks and buses approach 85 A-weighted decibels (dBA), 15 dBA above the commonly accepted safe daily average noise exposure level of 70 dBA[1] (EPA 1974; California Department of Transportation 2013). Reduced noise pollution is known to have health benefits and improves quality of life for those in noise-sensitive areas, like residences, schools, religious institutions, childcare services, and medical facilities.

The State of Nevada's 2019 Senate Bill 254 established ambitious climate goals. These include a 45% reduction of statewide greenhouse gases (GHGs) relative to 2005 levels by 2030, and net zero GHGs by 2050. A low or no emission JAC bus fleet would contribute to this goal by reducing GHGs from the fleet's tailpipe emissions.

4.1.1 Localized Impacts

The populations in closest proximity to JAC's existing fixed routes will experience the greatest benefits from the zero-emission transition. Figure 6 shows that a number of the regions with a high population concentration, particularly those on the north and west sides of the city, will experience benefits. Figure 7 visualizes the distribution of people identified as low income—there is a denser population on the east and south sides of the city who will experience the benefits from a zero-emission transition. Appendix B provides maps of the JAC routes in relation to the senior population, minority population, limited English population, and people with disabilities population.

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[1] On the dBA scale, a 15 dBA increase in noise level equates to a 32 times increase in noise energy because of the logarithmic nature of noise levels. Every 3 dBA increase equates approximately to a doubling in noise energy.

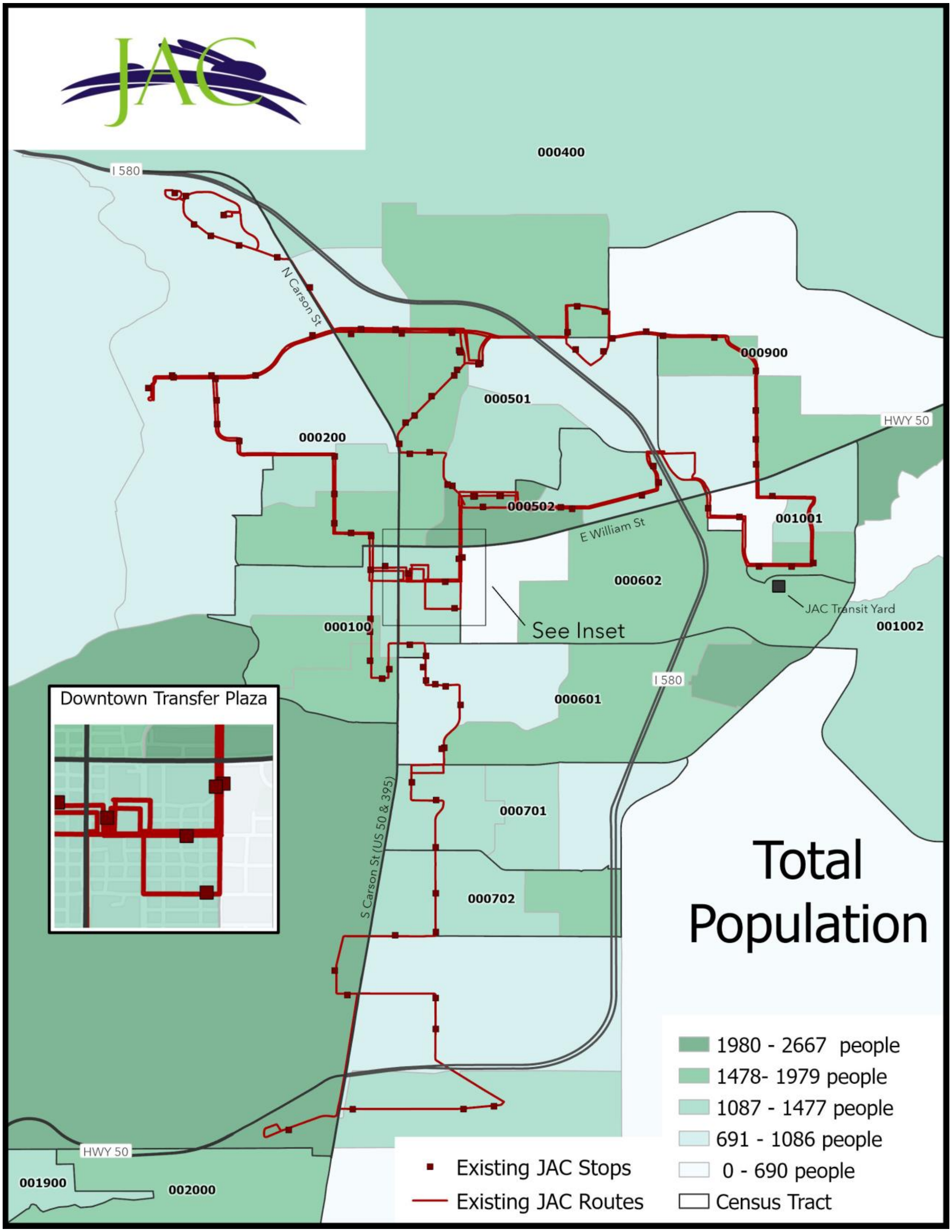

Figure 6: Jump Around Carson Fixed Routes in Relation to the Concentration of the Carson City Population

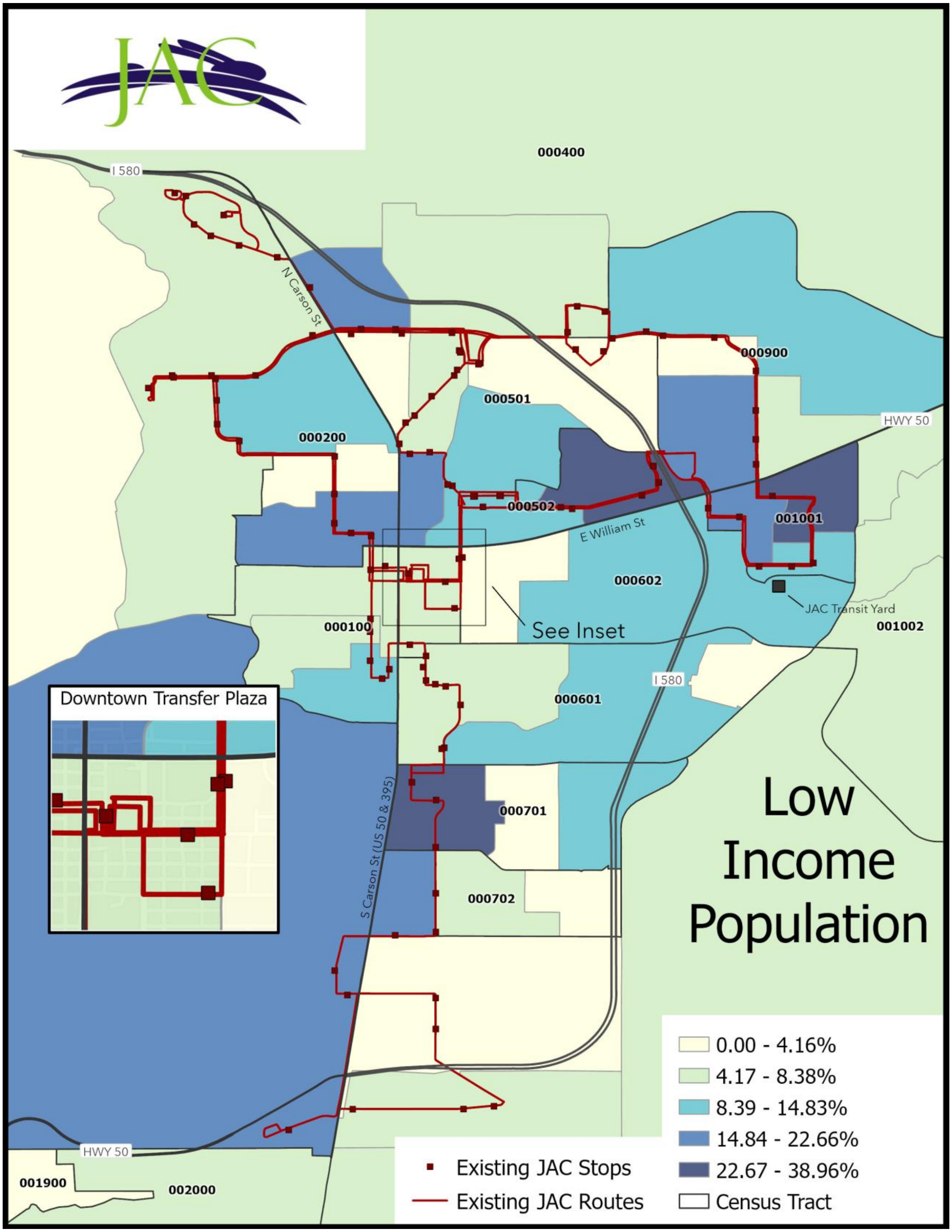

Figure 7: Jump Around Carson Fixed Routes in Relation to Carson City's Low-Income Population

4.2 Roadmap

JAC would benefit from a two-phased approach to its zero-emission transition: Phase 1 as the initial deployment and Phase 2 as the large-scale deployment. Figure 8 shows the roadmap for this transition.

The following subsections include detailed information on the vehicle (Section 4.3), infrastructure (Section 4.4), operation (Section 4.5), and workforce (Section 4.6) considerations of this transition strategy. Based on these analyses considering logistics, vehicle capabilities, total costs of ownership, and other JAC-specific vehicle and operational requirements, it is recommended that CAMPO pursue a zero-emission transition to battery electric bus (BEB) vehicles.

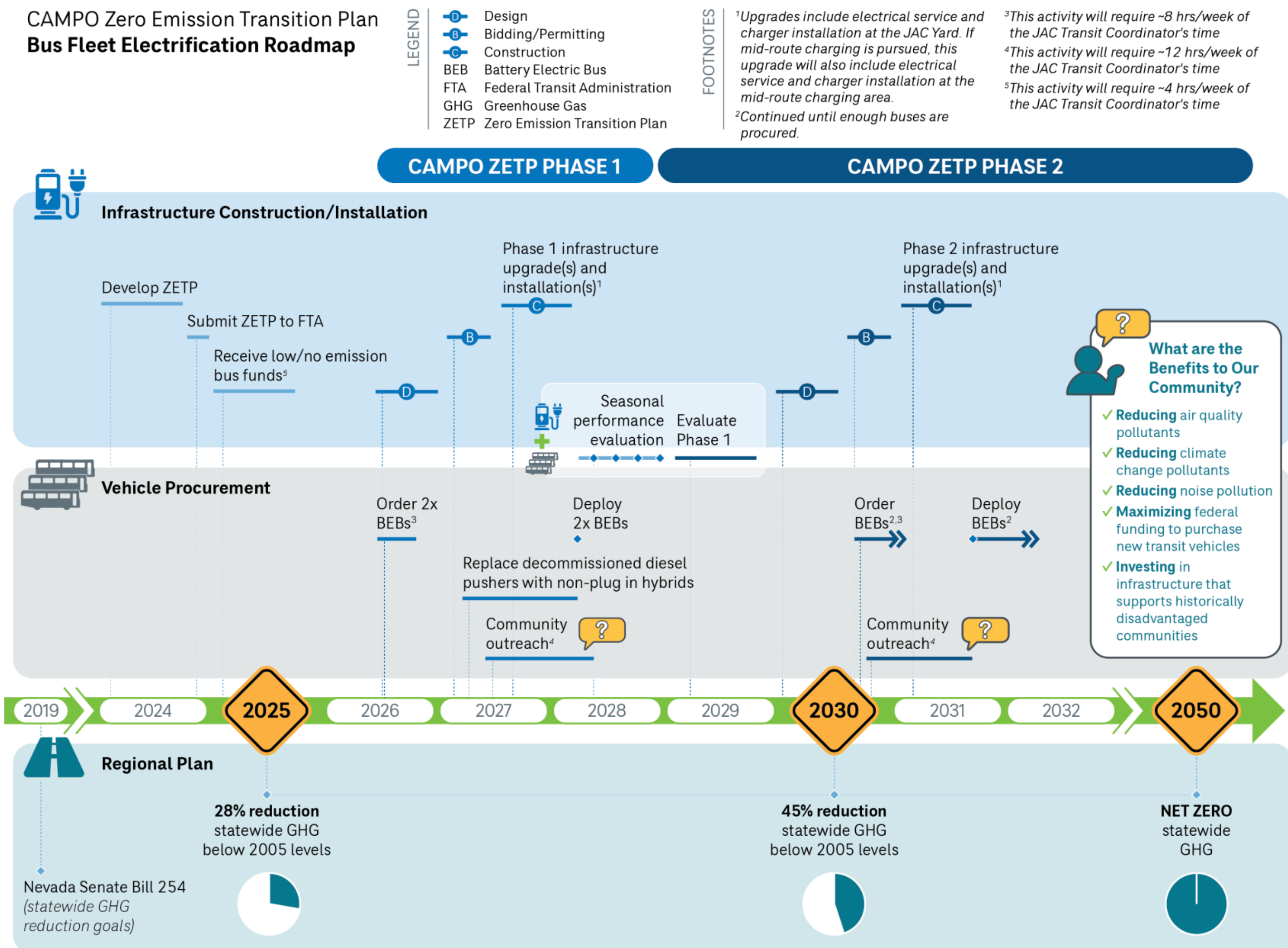

Figure 8: Zero-Emission Transition Roadmap

4.2.1 Phase 1: Initial Deployment

Phase 1 deploys the appropriate counts of battery electric bus (BEB) vehicles to allow JAC to collect valuable performance information, while gradually acclimating drivers and maintenance staff to the differing requirements of low and no emission buses.

Investing in a small-scale ramp-up phase allows JAC to distribute the local share of capital infrastructure investments across multiple fiscal years. It also provides flexibility for JAC to refine the implementation approach prior to large-scale deployment (e.g., consider alternative BEB or charger manufacturers, adjust the battery sizes, install larger/smaller capacities or counts of chargers). This flexibility could be particularly beneficial if vehicles or equipment behave differently during use than anticipated during this plan's development, and any changes should be informed by performance data obtained during Phase 1.

Even with the significant federal share of costs associated with funding through the FTA's Low-No Emission Bus Program (discussed further in Section 5.3.1), a significant local share is still anticipated. Therefore, the recommended bus procurement strategy for both Phase 1 and Phase 2 has existing rolling stock fleet vehicles replaced with low or no emission vehicles as the existing vehicles meet JAC's TAM Plan criteria for replacement.

In Phase 1, JAC would procure two standard-range pusher BEBs to replace conventional diesel pusher buses. Any additional procurements of pusher buses during Phase 1 should be hybrid diesel-electric buses. It is anticipated that Phase 1 could initiate as early as 2026. As discussed in Section 2.4.2, three pusher buses are anticipated for replacement in FY 2026. Under this ZETP, two of these buses could be replaced with standard-range BEBs and one could be replaced with a hybrid diesel-electric bus. Since commercial availability of low and no emission cutaways are currently limited, replacements for decommissioned cutaways should be conventionally fueled vehicles throughout Phase 1.

Phase 1 infrastructure upgrades would be needed to support two 150 kilowatt (kW) DCFCs at the JAC Yard for depot charging of the new BEBs. Additional infrastructure upgrades would be needed to support one 350 kW DCFC at the JAC Downtown Transfer Plaza for mid-route charging of the new BEBs.

4.2.1.1 Mid-Route Charging

Use of a mid-route charger will allow JAC to fulfill its daily fixed-route mileage requirements with 30-foot or longer standard-range pusher BEB models. It is expected that, at the low end of warrantied battery health and in suboptimal weather conditions, standard-range pusher BEBs would require at least two ten-minute mid-route charging sessions per day per bus.

Currently, the anticipated optimal location for the transit agency to implement mid-route charging would be JAC's Downtown Transfer Plaza, on North Plaza Street in front of the Carson City Federal Building (705 North Plaza Street). Each of JAC's fixed routes overlaps at this location, and the existing buffer period of 10 to 15 minutes between the end of one route cycle and the start of the next could be used for charging. If CAMPO builds a new transfer area in the future or makes adjustments to fixed routes, the optimal location for mid-route charging should be reevaluated.

The following are the key benefits and risks of this mid-route charging strategy:

- **Benefits:** Establishing mid-route charging would provide the benefit of reducing range anxiety of the drivers, as well as eliminating the need for extended-range buses, which are more expensive (see Section 5.0). Additional benefits include supporting public transit in the greater region. Neighboring transit agencies—RTC Washoe and TTD—expressed that they would take advantage of the opportunity to charge at the Downtown Transfer Plaza, where they each have one stop. Enabling these agencies to use electric buses for their routes that service this area would expand the benefits of RTC Washoe and TTD's zero-emission transitions to the residents of Carson City.
- **Risks:** If the mid-route charger is not in operation because of a maintenance need, JAC may need to swap out the standard-range BEB midday during weekday routes because a standard-range model's battery capacity may not meet the daily mileage demand, depending upon battery health and weather conditions.

4.2.1.2 Timeline

Phase 1 could start as early as 2026 and would last approximately 3 years.

The lead time for vehicle procurement of BEBs is 1 to 2 years. Placing an order for two BEBs by mid-2026 would allow for the vehicles to be deployed in early 2028. Starting in early 2027, any additional decommissioned diesel pushers should be replaced with hybrids. These new hybrid buses should arrive in time to be deployed alongside the BEBs. Training for vehicle maintenance on the hybrids and BEBs can then be conducted in the same time frame. This is beneficial since the electrical components of these vehicles have similarities.

On the electrical infrastructure side, the design of upgrades to the JAC Yard should start in mid-2026, followed by a short period of bidding, with permitting starting in early 2027. Construction in the JAC Yard would then commence in mid-2027. A common limiting factor for service upgrades is the availability of transformers, which recently have had lead times of more than 1 year. However, NV Energy retains a safety stock of transformers, which allows for an approximately 8-month time frame for the acquisition and installation of the transformer and other equipment needed for utility-side upgrades. Improvements to the JAC Yard and Downtown Transfer Plaza should occur in parallel to the utility-side upgrades.

One year before deployment of the BEBs (starting early 2027), JAC should begin community outreach. This two-way dialogue with the community will help JAC leadership gain input, as well as educate the community on project goals and benefits. This can help support future CAMPO Board decisions.

Activities related to the zero emission transition will require bandwidth from CAMPO staff (e.g., JAC Transit Coordinator, CAMPO Transportation Manager) to execute. For example, within the 10 month timeframe estimated for coordination with the FTA to receive the low/no emission bus funds, this activity is anticipated to require ~4 hours/week of the JAC Transit Coordinator's time. Within the 5 month timeframe estimated for procurement of new vehicles, this activity is anticipated to require ~8 hours/week of staff time. In the year that community outreach should be performed, engaging in or facilitating this activity is anticipated to require ~12 hours/week of staff time, though periodically. The bandwidth required for these activities may change between Phase 1 and Phase 2 depending on how different or similar the approaches are between the Phases (e.g., If the Phase 1 strategy for community outreach was effective, resources developed for Phase 1 can be leveraged for Phase 2, reducing the requirement of staff bandwidth).

4.2.1.3 Phase 1 Performance Evaluation

When the BEBs are deployed in early 2028, performance information should be collected at least seasonally to evaluate Phase 1 fleet and infrastructure performance. It is critical to monitor performance under extreme weather conditions, which might influence the power characteristics of the BEBs, such as reducing charging or regenerative braking energy recapture efficiencies. Throughout Phase 1, it is recommended to collect daily performance information for the BEBs during heat wave or extreme cold conditions and in heavy precipitation or icy roadway conditions. Extreme heat and cold conditions are those periods that fall outside of the average climatological range expected for Carson City (e.g., average daytime temperatures above 88 degrees Fahrenheit [°F] or below 25°F) (Weather Spark 2024). The following performance metrics should be collected:

- Mileage achieved on battery percentage (expecting 80% battery to fulfill 150 miles)
- Depot charging time (expecting 5 to 7 hours with a 150 kW DCFC to replenish 80% to 90% of the battery)
- Vehicle maintenance (expecting reductions in downtime[2] relative to the performance of existing diesel pushers)
- Staff training (expecting drivers to experience minimal range anxiety and expecting vehicle maintenance staff to feel supported in their training on the new vehicles/feel like they know which resources to leverage to address new maintenance tasks)
- Community and ridership perception (community members and ridership relative understanding of zero-emission transition benefits and participation in the outreach process)
- If applicable, mid-route charging time (expecting 10-minute charging period between routes to enable standard-range BEBs to fulfill daily mileage without needing to return to the JAC Yard for depot charging)

4.2.1.4 Alternative Phase 1 Implementation Approaches

A variety of challenges, including but not limited to supply chain and components availabilities, fiscal or implementation time constraints, or changes to local, state, or federal priorities, could result in the recommended Phase 1 implementation approach not meeting the needs of the JAC transit system. To expand the flexibility and robustness of this ZETP to adapt to these potential challenges, the following high-level alternative implementation approaches have been considered.

Standard-Range Fleet, No Initial Mid-Route Charger

This approach would involve the installation of a mid-route charger being delayed until the start of Phase 2. This could occur due to fiscal constraints, construction or decision-making timeframes for a new transfer area, or other reasons. Under this approach, JAC would procure two 30-foot or larger

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[2] CAMPO's TAM Plan calculates downtime percentage as the count of maintenance workorders divided by the count of operating days per year. Reduction in downtime directly correlates to a reduction in maintenance workorders over any given time period.

standard-range pusher BEBs and make the supporting Phase 1 infrastructure upgrades at the JAC Yard with no upgrades at the Downtown Transfer Plaza.

Operationally, JAC would charge the BEB pushers on depot charging alone, limiting their daily range, particularly in extreme weather. JAC would operate the BEBs fully for Saturday routes, which require reduced daily range relative to weekday routes. For weekday routes, JAC may be able to operate the BEB's fully, however base battery range, battery degradation, or extreme weather effects may prevent this full operation of standard-range BEBs without mid-route charging; in such a case, JAC could operate the BEBs in an alternating bus configuration wherein one BEB operates in the morning, then returns to the depot mid-day to charge for the remainder of the day, being replaced by the other BEB for the remainder of the service.

Extended-Range Fleet, No Mid-Route Charger

This approach would involve no installation of a mid-route charger. Under this approach, JAC would procure two 35- to 40-foot extended-range pusher BEBs and make the supporting Phase 1 infrastructure upgrades at the JAC Yard with no upgrades at the Downtown Transfer Plaza. As discussed in Section 4.3.1.2 and Section 5.1, this approach require larger BEBs—potentially up to 40 feet in length to meet necessary range requirements—and would have the highest total cost of ownership (TCO) of all evaluated Phase 1 approaches. Operationally, JAC would charge the BEB pushers on depot charging alone. JAC would operate the BEBs fully for all fixed routes.

Hybrid Diesel-Electric Fleet

This approach would involve no installation of any charging infrastructure. Under this approach, JAC would procure hybrid diesel-electric pusher buses and no upgrades would be completed at the JAC Yard or Downtown Transfer Plaza. As discussed in Section 5.1 and Section 5.2, this approach would have the lowest TCO when considering only Phase 1. However, this approach would not benefit from noise reductions and would benefit less from air pollutant and greenhouse gas emission reductions relative to implementation approaches using BEB pushers. Operationally, JAC would operate the hybrid diesel-electric fleet fully for all fixed routes.

4.2.2 Phase 2: Large-Scale Deployment

Phase 2 is the large-scale deployment of zero-emission vehicles and the related support infrastructure. In Phase 2, JAC would procure at least three additional pusher BEBs (bringing the total count of pusher BEBs to five) to replace JAC's five existing diesel pushers. In this Phase, JAC would also consider procuring two additional pusher BEBs to accommodate a possible future fixed route serving the Mound House community. This Phase would also have JAC consider the procurement of an additional five pusher or cutaway BEBs to replace the five gasoline cutaways sometimes used for fixed routes.[3] This would bring the potential total count of pusher BEBs to 12.

The Phase 2 infrastructure upgrade recommendations for the JAC Yard (Section 4.4.1.2) are sized to accommodate the power needed for chargers for a full fleet BEB fleet, including an expanded fleet to

[3] At the time or writing, pusher BEBs are recommended to replace five of the 12 current gasoline cutaways because there is currently a lack of commercially available cutaway BEBs. If cutaway hybrid diesel-electric buses or BEBs become commercially available in the future, either cutaway hybrid diesel-electric buses or BEBs could be used to replace the gasoline cutaways.

serve a potential future Mound House route. These upgrades would be needed to support up to ten 150 kW DCFCs and up to twelve 50 kW DCFCs or 19 kW Level 2 alternating current (AC) chargers at the JAC Yard for depot charging of the BEB fleet. For redundancy and availability of mid-route charging, it is recommended that a second 350 kW DCFC be installed at the JAC Downtown Transfer Plaza.

Phase 2 starts with an evaluation period, analyzing the data from Phase 1 with the goal of rightsizing the fleet and infrastructure to JAC's operating conditions. The following list provides illustrative examples of how JAC should refine its strategy based on data gathered in Phase 1.

- If the mileage achieved during cold weather is less than 100 miles/day on 85% of a pusher BEB's battery capacity, JAC should consider shifting the Phase 2 fleet composition from entirely BEBs to a mix of BEBs and hybrid diesel-electric buses.
- If JAC's 150 kW Phase 1 depot DCFCs can replenish 80% to 90% of a BEB's battery faster than 5 hours, JAC can reduce the power output needed for its Phase 2 chargers.
- If the mid-route charger was not built in Phase 1 and the vehicles are struggling to fulfill the daily fixed-route mileage, a mid-route charger should be reevaluated for Phase 2.
- If the mid-route charger was built in Phase 1 but the logistics of mid-route charging or charging session durations are not sufficient for BEBs to fulfill the daily fixed-route mileage, diesel-electric hybrid buses or extended-range BEBs should be reevaluated for Phase 2.
- If vehicles are experiencing frequent service incidents, different models should be considered, or the number of diesel vehicles kept on hand for redundancy should be increased.
- If bus drivers are experiencing excessive range anxiety, a mid-route charger should be reevaluated.
- If vehicle maintenance staff do not feel they are efficiently learning the skills needed to repair the new vehicles, different training methods should be considered.
- If community and ridership interest and support of the zero-emission transition is deemed low, outreach strategy should be reevaluated.

4.2.2.1 Timeline

Phase 2 starts with the evaluation period for rightsizing the vehicles and infrastructure. This activity should begin after a full year of performance metrics have been collected for the BEBs, as early as 2029.

On the vehicle procurement side, all decommissioned pushers should be replaced with BEBs, unless Phase 1 performance indicates that hybrid diesel-electric buses should remain a notable component of the fleet. Vehicles should be ordered far enough in advance to accommodate a 1- to 2-year lead time. The earliest orders should occur in mid-2030 to arrive by late 2031. JAC should plan to keep one to two diesel or hybrid diesel-electric pushers in the fleet for use in the instance of a prolonged power outage in the region.

On the electrical infrastructure side, designing the upgrades to the JAC Yard should start in early 2030, followed by a short period of bidding and permitting starting in mid-2030. Construction in the JAC Yard would then commence in early 2031. The upgrades should consist of upgrading the electrical capacity and installation of sufficient conduit and wire ducting to support the future installation of up to ten 150 kW DCFCs and up to twelve 50 kW DCFCs or 19 kW Level 2 AC chargers. As JAC procures vehicles, it should procure and install the vehicle's corresponding depot charger. When the charger arrives, JAC would just need to install it on the pad, then pull the wires from the duct banks to connect the equipment.

Starting in early 2031, in the year before the deployment of the BEBs, JAC should perform another round of community outreach. Insight gathered during community outreach performed during Phase 1 should be used to better tailor Phase 2 outreach activities to inform community members about the benefits of the zero-emission transition.

4.2.2.2 Phase 2 Performance Evaluation

When the Phase 2 vehicles are deployed in late 2031, it is recommended to continue evaluation of Phase 1 performance metrics (Section 4.2.1.3) on a regular cadence, though the frequency recommended can be modified based on Phase 1 findings.

4.3 Recommended Fleet Vehicles for Zero-Emission Transition

JAC's fixed-route transit services are currently met by five dedicated diesel pusher buses and six transit/paratransit shared-use gasoline cutaway buses. The following sections discuss the zero-emission vehicle options considered in this plan development. For the purposes of cost considerations, all dollar amounts presented in this section are 2022 dollars and present a reasonable estimate of anticipated costs but should not considered a quote for actual total costs. Market considerations at the time of procurement may result in actual costs that differ from the presented cost estimates.

4.3.1 Fixed-Route Transit Fleet

4.3.1.1 Hybrid Diesel-Electric Buses

Hybrid diesel-electric pusher buses are widely used in today's transit market and are generally considered to be a proven, cost-effective steppingstone for an agency's zero-emission transition. They are broadly available from a wide range of manufacturers and the service capabilities and useful life of current-generation hybrid buses are the same as conventional diesel buses.

Capital Costs

The average capital cost of a 30- to 40-foot hybrid diesel-electric pusher bus is approximately $675,000 excluding the federal share from any applicable grants (Argonne National Laboratory 2023). Hybrid diesel-electric pusher buses are eligible as low emission vehicles under the Low-No Emission Bus Program. While hybrid diesel-electric buses are more fuel efficient and less polluting than conventional diesel buses, this class of vehicle still has significant tailpipe emissions relative to zero-emission alternatives, such as BEBs and FCEBs. As the BEB and FCEB bus markets continue to mature and grow, it is possible that future federal policy or legislation changes may reduce or eliminate grant support for the purchase of hybrid diesel-electric buses in favor of BEB, FCEB, or other future zero-emission technologies.

The batteries in hybrid diesel-electric pusher chassis buses are fully regenerative and do not require chargers or other infrastructure beyond that needed to operate and maintain conventional diesel buses.

Vehicle Efficiency and Maintenance

Hybrid diesel-electric transit buses are generally more fuel efficient than conventional diesel buses, with fuel economies generally 20% higher than their non-hybrid diesel counterparts. The average maintenance costs for hybrid diesel-electric transit buses ($0.87/mile) additionally tend to be lower than non-hybrid diesels because of reductions in brake wear from regenerative braking and reduced strain on the vehicle engines (Argonne National Laboratory 2023; National Renewable Energy Laboratory 2006). For the purposes of the cost estimates discussed in Section 5.1, a fuel economy of 8.34 miles/gallon, a 20% improvement over JAC's existing fleet, is assumed for hybrid diesel-electric buses.

4.3.1.2 Battery Electric Buses

BEBs are widely used in today's transit market and are generally considered the gold standard in zero-emission transit. The BEB transit market has matured significantly over the past decade but has recently experienced significant upheavals among major manufacturers, including the major U.S. manufacturer Proterra Inc. (Proterra) experiencing a period of insolvency, and both Canadian manufacturer Nova Bus Corporation and U.S. manufacturer ElDorado National-California each changing their business models and exiting the U.S. transit BEB market. Nevertheless, multiple major BEB manufacturers remain in the U.S. market, including BYD Auto (BYD), Gillig, GreenPower Motor Company Inc. (GreenPower), New Flyer, and Phoenix Motorcars (Phoenix).[4]

Service Considerations

The useful life of BEBs is the same as conventional diesel buses; however, service capabilities differ between BEBs and conventionally fueled buses, primarily in the achievable service range between refueling or charging and the amount of time needed to refuel or recharge.

Depot and Mid-Route Charging Strategies

Transit agencies deploying BEBs either rely entirely on depot charging or use depot charging with supplemental mid-route charging. Under the depot charging strategy, BEBs operate the entire service on a single charge, returning to the depot at the end of service to charge overnight.

With supplemental mid-route charging, fast chargers are installed at a transfer area or other location where buses can stop to charge for 10 to 15 minutes periodically throughout the service. Agencies utilizing mid-route charging typically also use depot charging, as relying exclusively on the high-power mid-route charging may result in long-term degradation of battery health. The benefits and drawbacks of depot and mid-route charging strategies are discussed in Section 4.2.1.1.

Battery Electric Bus Range

Although the batteries in BEBs are generally warrantied by manufacturers, a certain level of acceptable degradation in the battery capacity is always included, resulting in reductions to a BEB's maximum range on a single charge as the vehicle ages and battery degrades. Additionally, to prevent excessive heating of a BEB's battery pack and extend battery health, charging of BEBs is generally artificially limited to 90% of the battery's maximum capacity.

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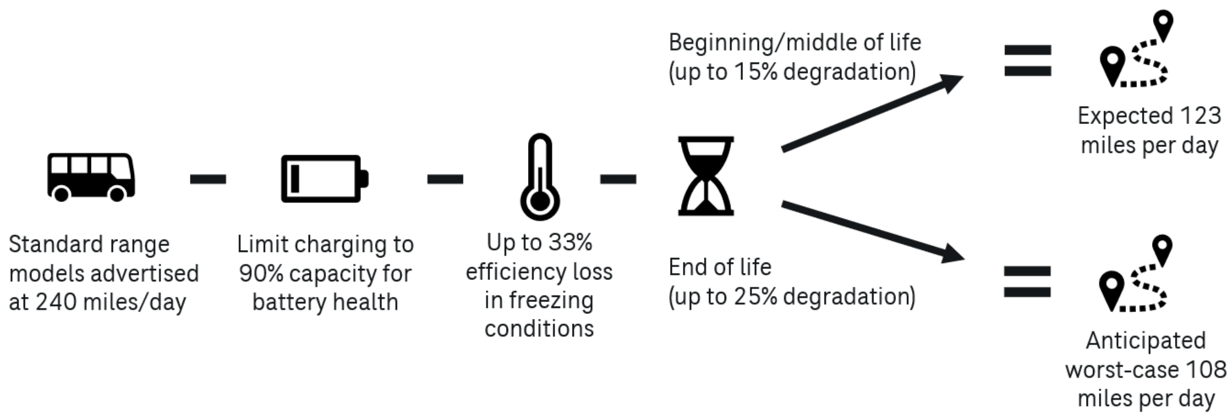
[4] Phoenix completed its purchase of Proterra's BEB transit bus manufacturing and sales operations in January of 2024.

A case study on the Duluth Transit Authority BEB fleet found that in temperature conditions of 25°F (severe freezing conditions), BEB range can decrease by an additional 33% because of increased heating demands and reductions to the effectiveness of regenerative braking because of road conditions (National Renewable Energy Laboratory 2022). Further case studies have indicated that between 37% to 40% of en-route energy use is reclaimed by regenerative braking, making this technology a key factor in real-world BEB range capabilities (Yu et al. 2023). Generally, BEBs operating in cold climates are outfitted with manufacturer-supplied auxiliary diesel-fueled heating systems to remove heating loads from BEB batteries and prevent substantial additional efficiency loss in freezing conditions.

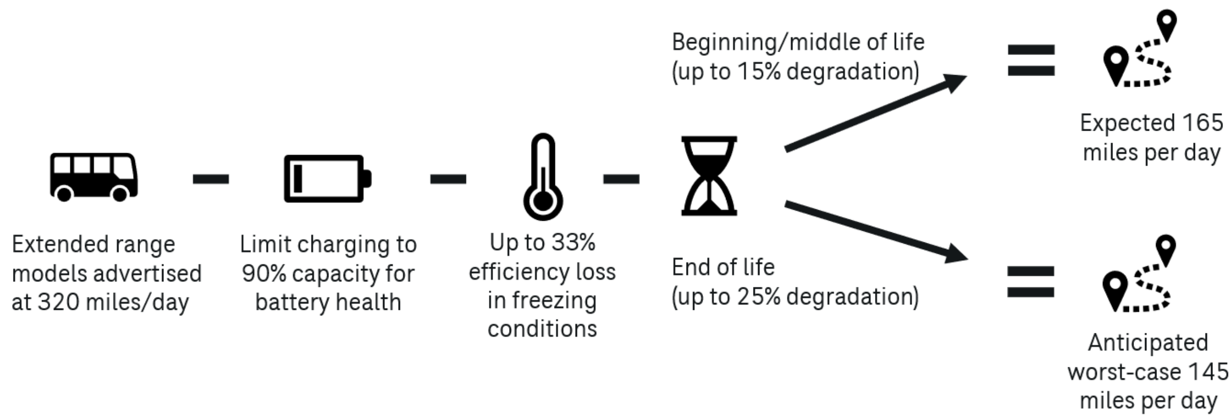
Current-generation standard-range pusher BEBs advertise vehicle ranges of 240 miles per charge. As illustrated in Figure 9, with mild battery degradation and efficiency losses from severe freezing conditions, it can be expected that standard-range BEBs may fail to meet the 145 to 165 miles/day requirements of JAC's fixed routes on a single charge. This would make mid-route charging a requirement under these conditions.



Source: CDM Smith

Figure 9: Standard-Range Battery Electric Bus Anticipated Service Conditions

Current-generation extended-range configuration BEBs advertise vehicle ranges of up to 320 miles/charge. Figure 10 shows that extended-range configurations could be expected to achieve the 145 to 165 mile/day requirements of JAC's fixed routes on a single charge under mild battery degradation and efficiency losses from severe freezing condition. Mid-route charging would therefore not be required under these conditions. However, with the most severe battery degradation allowable under typical battery warranty conditions and severe range reductions because of freezing conditions, an extended-range BEB would struggle to achieve the ranges required by JAC's longest routes on a single charge when the vehicle nears its end of life. In this case, without mid-route charging, it would only be able to service JAC's shortest trips.



Source: CDM Smith

Figure 10: Extended-Range Battery Electric Bus Anticipated Service Conditions

Sizing Limitations

When operating a fixed-route service, rightsizing of the bus to meet the ridership demand of the service population can be a key issue. It is understood that, for the purposes of bus sizing, 30-foot pusher chassis buses are optimally sized for navigation of JAC routes, ridership capacity, and ease of maintenance. While 35-foot pusher chassis buses may be considered acceptable for future bus purchases, and some of JAC's existing buses are 35 feet, the preferred length is 30 feet or less.

In current-generation BEBs, standard-range configurations suitable for the mid-route charging approach are available in lengths of 30 feet and larger. Extended-range configurations are generally only available for 35-foot buses. Some manufacturers may only offer extended-range configurations meeting JAC's needs on 40-foot or larger buses. Of the major U.S. BEB manufacturers, only BYD, GreenPower, and Arboc Specialty Vehicles[5] (Arboc), a subsidiary of NFI Group Inc. which also owns New Flyer, currently offer BEBs in the 30-foot size category most appropriately sized for JAC's current ridership demands. Discussions with a representative from Gillig have indicated that a 30-foot pusher chassis BEB from Gillig may enter the market in the coming years that may also be considered at the time of procurement.

Capital Costs

The capital cost of a standard-range 30- to 40-foot pusher BEB is between $900,000 and $1,100,000, excluding the federal share from any applicable grants. These vehicles are eligible zero-emission vehicles under the Low-No Emission Bus Program (Argonne National Laboratory 2023). Conversations with BEB manufacturer representatives indicate that extended-range configurations could cost between $1,075,000 and $1,275,000. The BEB market is rapidly evolving and market forces and technological changes may cause fluctuations in the ultimate capital costs of procuring a BEB. The actual manufacturer-quoted capital costs of a BEB should be evaluated and considered at the time of purchase.

Vehicle Efficiency and Maintenance

The efficiency of BEBs, generally characterized in kilowatt-hour (kWh)/mile, varies significantly based on the climatological and geographical conditions of an area and on an individual driver's experience using

[5] Arboc was the manufacturer of JAC's current fleet of diesel pusher buses.

regenerative braking. Altoona test data and case studies have shown efficiencies between 1.82 to 2.32 kWh/mile on previous-generation 40-foot pusher BEBs (National Renewable Energy Laboratory 2020, 2022). Smaller 30-foot buses are typically lighter and more efficient than larger 35- or 40-foot extended-range buses. Current-generation BEB efficiencies of 1.82 kWh/mile and 2.05 kWh/mile for standard- and extended-range BEBs, respectively, is assumed for the purposes of cost estimates discussed in Section 5.1.

Maintenance costs of BEBs are generally lower than conventional diesel or hybrid diesel-electric buses. Case studies on previous-generation 40-foot pusher chassis BEBs have average maintenance costs ranging from $0.60/mile to $0.64/mile (Argonne National Laboratory 2023; National Renewable Energy Laboratory 2020).

4.3.1.3 Hydrogen Fuel Cell Electric Buses

Hydrogen fuel cell electric pusher buses are relatively new in today's transit market but have been adopted by larger transit agencies. They are available from a very limited number of U.S. manufacturers. The service capabilities and useful life of current-generation fuel cell electric buses (FCEB) are the same as conventional diesel buses. While considered to be a proven technology, FCEBs are held back by high capital infrastructure costs and unique maintenance requirements.

Hydrogen fueling infrastructure is currently prohibitively expensive for small transit agencies. Hydrogen fueling station equipment and installation is estimated to cost upwards of $5,000,000, and hydrogen buses require additional safety upgrades and redundancies to maintenance facilities, which costs upwards of $1,000,000. For large-scale deployments, these high capital facility costs become effectively distributed across dozens of bus purchases, but at the scale of JAC's small fleet, a high-level review of costs indicates that construction of hydrogen fueling infrastructure would not be economical.

Market research and discussions with RTC Washoe, which recently acquired two FCEBs and are constructing their own hydrogen fueling station, have indicated that in the western Nevada region, commercial hydrogen supplies are limited. While a public passenger vehicle hydrogen fueling station is in the City of Truckee, California, hydrogen for passenger vehicles is pressurized to a different level than that needed for FCEBs. Therefore, this source cannot be used to supply hydrogen fuel to Carson City. While RTC Washoe has stated a willingness to share their future hydrogen fueling infrastructure with JAC, a high-level assessment of the logistics of driving FCEBs from Carson City to Reno for refueling shows that this approach would not be economical or logically reasonable.

Additionally, based on local hydrogen costs communicated by RTC Washoe, it is anticipated that FCEBs would have similar per mile fuel costs as compared to hybrid diesel-electric buses, demonstrating limited benefits of this technology at JAC's scale. Moreover, the capital purchase costs of FCEBs tend to be comparable to or greater than that of current-generation BEBs, rendering FCEB's neither more efficient than hybrid options nor more cost-effective than BEBs.

For these reasons, hydrogen FCEBs were determined not to be suitable for JAC's needs and were eliminated from further consideration in this plan.

4.3.2 Paratransit Fleet

The market for BEB, FCEB or hybrid gasoline-electric or diesel-electric cutaway buses is only beginning to emerge. Although a variety of manufacturers, including Green Power Motors, Endera, and Phoenix currently offer electric cutaway buses, these vehicles are relatively new to the market and there has not been significant research or case studies demonstrating the efficacy of these vehicles for paratransit services, particularly in climates similar to that of Carson City.

It is anticipated that, as the zero-emission cutaway bus market matures, cutaway BEBs will become more widely available. While zero-emission cutaway vehicles were omitted from detailed planning and the economic analysis in Section 5.1, for the purposes of infrastructure deployment planning, the anticipated future electrical demands of BEB cutaway vehicles is included in the Phase 2 infrastructure recommendations, as described in Section 4.4.1.2.

4.3.3 Transit Fleet Costs Summary

For pusher buses suitable to meet the demands of JAC's fixed-routes, hybrid diesel-electric buses, standard-range BEBs, extended-range BEBs, and hydrogen FCEBs were evaluated. While hydrogen FCEBs were screened out of further consideration due to excessive capital costs, each other fixed-route fleet option was carried forward for further benefit and cost analysis. Table 2 summarizes the capital costs of these options relative to conventional diesel pusher buses which were used in the TCO analysis. Table 3 summarizes the base Phase 1 maintenance and operation costs

Table 2: Phase 1 Capital Costs of Diesel, Hybrid, and Electric Bus Options

Cost Category	34- or 35-Foot Diesel Pusher	Hybrid Diesel-Electric Pusher	30-Foot BEB with Mid-Route Charging	35-Foot Extended-Range BEB
Rolling Stock				
Rolling Stock Unit Cost **(Phase 1 Cost)**	$500,000 **($1,000,000)**	$675,000 **($1,350,000)**	$900,000 **($1,800,000)**	$1,100,000 **($2,200,000)**
Additional Battery Pack Unit Cost **(Phase 1 Cost)** [two per bus]	N/A	N/A	N/A	$90,000 **($360,000)**
Rolling Stock Unit Cost **(Phase 1 Cost)** as Specified	$500,000 **($1,000,000)**	$675,000 **($1,350,000)**	$900,000 **($1,800,000)**	$1,280,000 **($2,560,000)**
FTA Match	85%	85%	85%	85%
Rolling Stock Unit Cost **(Phase 1 Cost)** as Specified with FTA Match	$75,000 **($150,000)**	$101,250 **($202,500)**	$135,000 **($270,000)**	$192,000 **($384,000)**

Sources: Argonne National Laboratory 2023; Bissell, R. 2 April 2024; FTA 2024; FTA 2021

Note: BEB = battery electric bus; N/A = not applicable

Table 3: Phase 1 Base Operating Costs of Diesel, Hybrid, and Electric Bus Options

Cost Category	34- or 35-Foot Diesel Pusher	Hybrid Diesel-Electric Pusher	30-Foot BEB with Mid-Route Charging	35-Foot Extended-Range BEB
Fuel Costs				
Fuel Economy	6.95 MPG	8.34 MPG	1.82 kWh/mile	2.05 kWh/mile
$ per Gallon (diesel) or $ per kWh (electric)	$3.92		$0.09122	
Charger Efficiency	N/A		91.4%	
Base Per-Mile Operating Cost	$0.56	$0.47	$0.18	$0.20
FTA Match	50%	50%	50%	50%
Base Per-Mile Operating Cost with FTA Match	$0.28	$0.24	$0.09	$0.10
Maintenance Costs				
Base Per-Mile Maintenance Cost ($)	$1.36	$0.87	$0.64	$0.64
FTA Match	80%	80%	80%	80%
Base Per-Mile Maintenance Cost ($) with FTA Match	$0.27	$0.17	$0.13	$0.13

Sources: AAA 2024; EIA 2024; FTA 2021; National Renewable Energy Laboratory 2022; National Renewable Energy Laboratory 2020; National Renewable Energy Laboratory 2006; NV Energy 2024

Note: BEB = battery electric bus; kWh = kilowatt hour; MPG = miles per gallon; N/A = not applicable

4.4 Recommended Infrastructure for Zero-Emission Transition

As discussed in Section 4.3, only hybrid diesel-electric pusher buses and pusher BEBs were carried forward for further assessment. This zero-emission transition requires upgrades to infrastructure at the JAC Yard and potentially the Downtown Transfer Plaza. Electrical demand should be considered in the design of any future JAC facilities (i.e., a new transfer area) to support the charging of BEBs. For the purposes of cost considerations, all dollar amounts presented in this section are 2022 dollars.

4.4.1 Jump Around Carson Yard

Multiple locations were evaluated for potential depot charging, with the conclusion of installing charging infrastructure at the JAC Yard. The Carson City Public Works campus was evaluated as a potential depot charging area, as it is already outfitted with an electrical system capable of supporting pusher BEBs. However, the lack of accessibility to the contracted drivers resulted in elimination of this site from further consideration. Carson City's emergency services facility, which is currently under construction, was also considered for depot charging. However, a review of the design drawings showed that the electrical service was designed for up to 208 V and was insufficient to support the 480 V chargers needed for depot charging of pusher BEBs.

The present electrical transformer and auxiliary infrastructure at the JAC Yard is rated at 208 V, 200 A. This voltage and current are insufficient to support the anticipated electrical infrastructure needed for the BEB fleet. To meet the needs of the zero-emission transition, upgrades are required at the JAC Yard.

Sections 4.4.1.1 and 4.4.1.2 describe the recommended infrastructure upgrades for Phase 1 and Phase 2, respectively.

As indicated previously, no infrastructure upgrades are required at the JAC Yard for the deployment of hybrid diesel-electric buses.

4.4.1.1 Phase 1 Infrastructure

Chargers

To support depot charging of the pusher BEBs at the JAC Yard under Phase 1, it is anticipated that two 150 kW DCFCs, such as the ChargePoint Express Plus, ABB HVC-C150, ABB Terra, or Heliox Flex180, should be installed.

The recommended chargers typically consist of a 150 kW power block and one or more charge dispenser pedestals each equipped with one or two charging cables. In the initial configuration, each power block should be connected to one pedestal equipped with two charging cables. The installation of two cables would allow for the simultaneous half-speed charging of up to two BEBs from a single charger.

It is generally advised under Phase 1 to charge each BEB at a separate charger, leaving the second cable at each pedestal unused. The installation of two chargers with two cables each provides redundancy and allows for both BEBs to be charged from a single charger in the event of charger damage or failure. Data collected from the effectiveness of simultaneous charging of two BEBs from a single pedestal can be used to inform charger counts needed to support Phase 2.

Electrical Service Upgrades

An electrical service upgrade is necessary to provide adequate power. The JAC Yard should be upgraded from its current 208 V system to a 480 V system. Under Phase 1, a new electric feed from NV Energy would need to be supplied to a 500 kilovolt-ampere (kVA) pad-mounted transformer with 480 V secondary. This transformer will feed a 480 V, 800 A National Electrical Manufacturers Association (NEMA) 3R switchboard that will distribute power to each of the chargers and throughout the existing site. An additional 75 kVA, 480 V to 208 V/120 V transformer would be needed to supply the existing JAC building with power. During installation of these services, an underground duct bank, conduit, and wire to feed the chargers and other electrical distribution equipment would need to be installed. Discussions with engineers at NV Energy at the time of report preparation indicated that there is no concern with the utility’s ability to provide the necessary power to support an electrified JAC fleet once these capacity upgrades are completed.

It is also recommended that the system include provisions for a portable generator to provide backup power to the site in case of an outage. For Phase 1, a cost-effective approach would be to install a portable generator connection cabinet that can be interlocked with the main switchboard to provide backup power to the site. A portable generator can be rented, as needed, or purchased and stored at the Carson City Public Works campus for deployment at JAC, as needed. During Phase 1, this is optional because the primary backup during a prolonged electrical outage would be the diesel or hybrid buses. In Phase 2, it is more critical to establish a permanent backup power option if most of the fleet is electric; in Phase 1, the backup would be the diesel buses that are on-site.

Capital Costs

The capital costs for procuring and installing chargers and upgrading the electrical services were cross-referenced from market research and case studies with additional input from BEB manufacturers and NV Energy. The costs for electrical upgrades are highly variable, in part because of the costs of the transformer units, which can change significantly from month to month based on supplies and demands. A snapshot cost estimate from NV Energy in May 2024 estimated the cost to be approximately $105,000 for a 2,500 kVA transformer (Gillig 2022; Jenkins 2024). Overall construction and installation costs can be as low as $50,000 or upwards of $400,000 (Paladino 2024; Transportation Research Board 2018). NV Energy estimated the utility-side costs to upgrade service at the JAC Yard to be approximately $75,000 (Jenkins 2024). JAC would procure a contractor to complete JAC-side upgrades including construction, purchase, and installation of the switchboard, conduit, generator connection cabinet, concrete-reinforced pads, and underground duct bank. This would likely total at least $200,000 (Bissell 2024)[6]. The average costs to purchase and install a 150 kW DCFC pedestal is approximately $50,000 (Transportation Research Board 2018).

The overall cost of Phase 1 infrastructure upgrades at the JAC Yard could be expected to total upwards of $515,000, assuming $70,000 for the 500 kVA transformer, anticipated construction costs, two 150 kW DCFCs, and a 30% contingency on transformer costs. This estimate excludes the federal share from any applicable grants such as the Low-No Emission Bus Program.

4.4.1.2 Phase 2 Infrastructure

Phase 2 is intended to support large-scale deployment of both pusher BEBs and cutaway BEBs. The anticipated Phase 2 infrastructure needs are based on current-generation equipment and power requirements. While these needs are based on the best available information currently available, it is anticipated that data collected under Phase 1 will be used to inform decision-making on the precise infrastructure ultimately procured for Phase 2.

These infrastructure upgrades are designed to assume the highest likely demand. For highest demand estimates, it is assumed that each of CAMPO's five fixed-route diesel pusher buses are converted to pusher BEBs, and five of the seven cutaway gasoline buses (which currently service both paratransit and fixed routes) are also converted to pusher BEBs requiring 150 kW DCFCs. Additionally, for the highest demand estimates, it is assumed that the remaining five cutaway gasoline buses and minivan chassis bus used for paratransit are converted to cutaway BEBs requiring 50 kW DCFCs. This demand sizing may or may not reflect the actual composition of JAC's future transit fleet; however, the cost differences between reduced-sized service upgrades and high-demand-sized service upgrades are marginal, and these assumptions ensure that the Phase 2 upgrades will be sufficient to support JAC's future fleet needs.

Chargers

To support depot charging of the pusher BEBs at the JAC Yard under Phase 2, multiple 150 kW DCFCs, such as the ChargePoint Express Plus, ABB HVC-C150, ABB Terra, or Heliox Flex180, would need to be

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[6] Engineer judgment

installed. Power service should be sized sufficiently to support chargers at a minimum ratio of one charger for every pusher BEB[7].

As mentioned previously, it is possible to charge two BEBs at half speed from a single charger using multiple cables. While service infrastructure should be sized to assume one charger per bus, during design and implementation of Phase 2, charging data from Phase 1 can be used to determine the actual number of chargers to be installed. It is recommended that regardless of the effectiveness of half-speed charging, at least one 150 kW DCFC should be installed for every one-and-a-half pusher BEBs in service to ensure appropriate redundancy. Since power service upgrades and JAC Yard upgrades will be made assuming a highest demand, chargers can be purchased and installed under Phase 2 with relative ease as new BEBs are purchased, reducing the up-front capital costs of Phase 2 upgrades.

To support depot charging of future cutaway BEBs used for paratransit services, it is expected that 50 kW DCFCs or smaller 19 kW Level 2 AC chargers would be sufficient for overnight depot charging. This should be confirmed at the time of purchase in a discussion with the vendor. It is expected that paratransit BEBs would top up their charge throughout the day when returning to the JAC Yard between service calls. They should use their own 50 kW DCFCs or the 150 kW DCFCs installed for the pusher BEBs.

Service Upgrades

Service upgrades beyond those completed under Phase 1 would be necessary to provide adequate power under Phase 2. The recommended service upgrade is sized to support up to ten 150 kW DCFCs, allowing for redundancy in charging equipment and ensuring adequate capacity for future fleet composition changes or route expansions. The recommended Phase 2 service upgrades would also provide adequate power for the operation of the 12 or more 50 kW DCFCs or 19 kW Level 2 AC chargers used for a future paratransit cutaway BEB fleet.

Under Phase 2, a new electric feed from NV Energy would need to be supplied to a 2,500 kVA pad-mounted transformer with 480 V secondary, and a 4000 A, 480 V NEMA 3R switchboard would be used. NV Energy noted that they keep this size of transformer in stock, and that 2,500 kVA is the largest size transformer available. They state that there are no concerns about the power available on the local utility grid to accommodate the new energy demand. In this phase, it is most important to install a permanent generator or procure a larger portable generator to charge buses in a loss of power.

Capital Costs

As with Phase 1 capital costs, Phase 2 infrastructure capital costs were based on cross-referenced data from market research and case studies with additional input from BEB manufacturers and NV Energy. While the estimated costs below represent the best cost estimate information at the time of writing, market factors (including changes to the supply chain), demand or availability of components, or inflation could result in the actual costs at the time of Phase 2 implementation differing from the values presented below.

[7] A charger consists of one power block of the indicated kW rating connected to one pedestal equipped with two charging cables.

The overall cost of Phase 2 infrastructure upgrades at the JAC Yard could be expected to total upwards of $625,000. This value excludes chargers and assumes $105,000 for the 2,500 kVA transformer, anticipated construction costs, and a 30% contingency on transformer costs. This estimate excludes the federal share from any applicable grants such as the Low-No Emission Bus Program.

It is assumed that 150 kW DCFCs would be installed as pusher chassis BEBs are procured, and charger counts would be maintained at a ratio of at least one charger for every one or one-and-a-half pusher BEBs in service (depending on the charging data collected during Phase 1), at a cost of approximately $50,000 per charger. It is assumed that 50 kW DCFCs or 19 kW Level 2 AC chargers would be installed as cutaway chassis BEBs are procured, and charger counts would be maintained at a ratio of one charger for every one cutaway BEB in service at a cost of approximately $25,000 per 50 kW DCFC or $3,000 per 19 kW Level 2 AC charger. These estimates exclude the federal share from any applicable grants such as the Low-No Emission Bus Program.

4.4.2 Transfer Area

Upgrades to the transfer area, currently the Downtown Transfer Plaza, would be required under the mid-route charging strategy. In 2019, the JAC Transit Development and Coordinated Human Services Plan noted that, as a long-term capital investment, upgrades to the JAC transfer area should be considered, which could require a future relocation of the existing transfer area.

4.4.2.1 Location Assessment

Prior to the procurement of a mid-route charger or installation of supporting infrastructure, it is critical that the status of future capital plans related to a new transfer area be assessed. As discussed in Section 4.2, the design of Phase 1 upgrades is anticipated to commence as early as 2026. At or prior to this time, JAC leadership should coordinate with applicable stakeholders to determine the direction for capital investment into a new or expanded transfer area. Capital investment into a new or expanded transfer area including mid-route charging infrastructure would be eligible for funding under the Low-No Emission Bus Program, discussed further in Section 5.3.1.

It is important to note that the 2023 Carson City JAC Transit Center Study (Carson City 2023-a) was conducted to evaluate the possible relocation of the transfer area. The study found that the nearby alternative locations analyzed were not anticipated to reduce transit operating costs or reduce passenger travel times by improving connections between buses. When comparing performance on 7 metrics (construction cost, parking impact, downtown area goals, transit efficiency & access, passenger safety & convenience, adjacent land use compatibility, expandability/flexibility), the existing site performed better overall by a small margin. Therefore, substantial relocation of the transfer area is not anticipated.

4.4.2.2 Chargers

To support mid-route charging of the pusher BEBs under Phase 1, it is recommended to install one 350 kW or greater capacity DCFC, such as the ChargePoint Express Plus, ABB Terra HP, or similar equipment. It is recommended that the mid-route charger be a newer plug-in format charger rather than an overhead inverted pantograph format charger for ease of serviceability and cross compatibility across bus models. This is a more affordable approach to install initially and has less maintenance requirements, as there are fewer moving parts that can break and cause downtime. Additionally, mid-route chargers will need to have the ability to securely lock away the mid-route charging cable to avoid the general public's use of or accidental damage to the charging infrastructure.

Under Phase 2, installation of a second 350 kW or greater capacity DCFC is recommended for redundancy and to support the mid-route charging needs of a more heavily electrified fleet. Phase 2 should also consider a portable generator connection to back up these mid route chargers in emergency situations. A portable generator could be procured and kept on standby and plugged into a connection cabinet near the charging infrastructure.

4.4.2.3 Service Upgrades

It is recommended that the electrical service at the transfer area be sized to support two 350 kW mid-route DCFCs. A new electric feed from NV Energy would need to be supplied to a 1,000 kVA pad-mounted transformer with 480 V secondary, and a 1,600 A, 480 V NEMA 3R switchboard would be used. If higher output and faster chargers are found to be needed, this will require a larger transformer and switchboard.

4.4.2.4 Capital Costs

The capital costs of procuring and installing chargers and upgrading electrical services were cross-referenced from market research and case studies with additional input from BEB manufacturers and NV Energy. The cost of electrical upgrades is highly variable, in part because of the costs of the transformer units, which can change significantly from month to month based on supplies and demands. NV Energy estimated the costs for utility-side upgrades at the JAC Yard to be around $75,000, and costs at the transfer area should be similar (Jenkins 2024). JAC would procure a contractor to complete JAC-side upgrades such as installation of the switchboard, conduit, and electrical cabling, which would likely also total around $75,000[8]. The costs to purchase and install a 350 kW DCFC can range from $250,000 to $500,000 and newer plug-in format chargers average around $300,000[9] (Transportation Research Board 2018).

The overall cost of infrastructure upgrades at the transfer area under Phase 1 could be expected to total upwards of $685,000. This is assuming $85,000 for the 1,000 kVA transformer, anticipated construction costs, one 350 kW mid-route DCFC, and a 30% contingency on transformer costs. The addition of a second 350 kW DCFC under Phase 2 would be expected to cost approximately $300,000. These estimates exclude the federal share from any applicable grants such as the Low-No Emission Bus Program.

4.4.3 Code Requirements, Permitting Considerations

The project's installation will need to conform to National Fire Protection Association (NFPA) 70, *National Electric Code*. Also, electrical service entrance equipment and metering installation will need to conform to NV Energy standards. This will allow local building officials to approve any required electrical

[8] Engineer judgment

[9] Engineer judgment

work permits for the infrastructure upgrades at the site. Professional engineer stamped drawings must be sent to authority with jurisdiction at the Carson City Building Division for approval.

It is recommended that chargers and electrical equipment has an Underwriters Laboratory (UL) listing to ensure that quality tested equipment is being used.

4.4.4 Infrastructure Costs Summary

The infrastructure upgrades and support equipment necessary to support the needs of a transitioned JAC hybrid diesel-electric bus, standard-range BEB, or extended-range BEB Phase 1 fixed-route fleet were evaluated. Table 4 summarizes the capital costs of these options relative to conventional diesel pusher buses which were used in the TCO analysis.

Table 4: Phase 1 Capital Costs of Diesel, Hybrid, and Electric Bus Infrastructure and Equipment

Cost Category	34- or 35-Foot Diesel Pusher	Hybrid Diesel-Electric Pusher	30-Foot BEB with Mid-Route Charging	35-Foot Extended-Range BEB
Depot Infrastructure				
Chargers (two at $50,000 each)	N/A	N/A	$100,000	$100,000
Infrastructure and Installation	N/A	N/A	$416,000	$416,000
Depot Charger, Infrastructure, and Installation Cost	N/A	N/A	$516,000	$516,000
FTA Match	N/A	N/A	90%	90%
Depot Charger, Infrastructure, and Installation Cost with FTA Match	N/A	N/A	**$51,600**	**$51,600**
Transfer Area Infrastructure				
Mid-Route Charger	N/A	N/A	$300,000	N/A
Infrastructure and Installation	N/A	N/A	$385,500	N/A
Mid-Route Charger, Infrastructure, and Installation	N/A	N/A	$685,500	N/A
FTA Match	N/A	N/A	90%	N/A
Cost with FTA Match	N/A	N/A	**$68,550**	N/A

Sources: Bissell, R. 2 April 2024; FTA 2024; Jenkins, B. 3 June 2024; Paladino, L. 17 April 2024; Transportation Research Board 2018

Note: BEB = battery electric bus; N/A = not applicable

4.5 Operational Changes for Zero-Emission Transition

4.5.1 Recommended Fleet Operation

4.5.1.1 Length and Frequency of Charging

Existing diesel-fueled pusher buses are capable of refueling at standard diesel fuel dispensers with relative ease and swiftness and can be expected to reliably operate throughout a service day without needing to refuel.

Hybrid Diesel-Electric Buses

Recommended hybrid diesel-electric pusher chassis buses purchased under Phase 1 would be able to refuel with similar ease and swiftness as their diesel-fueled counterparts and complete a full day of service without needing to refuel.

Battery Electric Buses

Recommended pusher BEBs purchased under Phases 1 and 2 are not capable of recharging as swiftly as diesel vehicles can refuel. They are limited to recharging at designated areas outfitted with specific high voltage charging systems.

At their maximum charging rate of 150 kW, depot DCFCs would be capable of charging a current-generation BEB, such as the standard-range 435 kWh New Flyer 35-foot Xcelsior CHARGE NG, from 0% to 80% in approximately 3 hours, or 100% in approximately 6 hours. When charging two BEBs simultaneously from the same charger, charging rates of 60 kW to 75 kW can be achieved and batteries can be charged from 0% to 80% in approximately 6 hours, or 9 hours for BEBs in extended-range configurations. Charging of extended-range configurations of BEBs would be expected to take roughly 50% longer than their standard-range counterparts. To preserve battery health, it would be expected that BEBs would not typically charge above 90% capacity.

At 350 kW, a mid-route DCFC would be expected to add 58 kW over 10 minutes of opportunity charging, which equates to approximately 28 miles of range.

4.5.1.2 Regenerative Braking

As discussed in Section 4.3.1.2, a significant portion of a BEB's efficiency and achievable range per charge is related to effective use of regenerative braking. Vehicles equipped with regenerative brakes require a different style of driving than conventional vehicles. With vehicles equipped with regenerative braking, most vehicle deceleration is achieved by using passive resistance from the electric motors without need to engage the vehicles brakes, recovering significant power to the batteries in the process. When coming to a complete stop or decelerating rapidly, use of the vehicle's brakes is still required. Vehicle operators should receive specific operation training on the nuances of regenerative vehicle operation, discussed in Section 4.6.

4.5.2 Recommended Fleet Maintenance

As discussed previously, both hybrid diesel-electric pusher buses and pusher BEBs have lower per-mile maintenance costs on average than conventional diesel pusher buses. This is due, in part, to the regenerative braking reducing wear on the braking systems of low and no emission buses. There is also a reduced need (eliminated need for BEBs) for oil changes, air filter changes, and other typical maintenance activities because of reduced load on the vehicle engines. However, there are other maintenance considerations that should be identified during the procurement of a hybrid diesel-electric bus or BEB.

4.5.2.1 Preventative Maintenance and Testing

Most BEB original equipment manufacturer (OEM) warranties guarantee the battery capacities of BEBs to not degrade below 70% or 80% over the 12-year useful life of a BEB. Batteries will degrade over time and degradation is not always easy to consistently measure, which can present a challenge in determining if or when a warranty claim should be submitted. OEMs generally provide testing procedures that can be used to measure the battery capacity of a BEB. This may require training in the operation of specialized testing equipment. Upon the procurements of BEBs, the *Carson City Public Works Maintenance Plan* should be updated to include periodic battery testing, which should be conducted every 6 to 12 months to identify capacity degradation or other anomalies in battery performance.

Additional tests and preventative maintenance activities vary from vehicle to vehicle depending on the OEM. It is recommended that upon procurement of a BEB, the OEM provide a checklist of activities, recommended minimum and maximum intervals, training or other skills needed, tools needed, and required parts needed to complete each activity. It is recommended that *Carson City Public Works Maintenance Plan* be updated to include this checklist. It is possible that certain activities may require specific expertise from licensed electricians or OEM technicians.

Maintenance Bay, Vehicle Lifts, and Overhead Maintenance

It is recommended that one of the maintenance bays be specifically equipped for work on electrical buses to help organize BEB-specific equipment. Currently, there is sufficient electrical capacity in the maintenance bay to power a Level 2 AC charger for as-needed charges for BEBs.

It is often necessary to access to the underside of BEBs for preventative maintenance or testing; therefore, it is generally recommended that mobile hydraulic lifts be used in maintenance bays. Carson City Public Works currently uses modular mobile hydraulic lifts for maintenance of the existing diesel pusher bus fleet, fire trucks, and other large vehicles. The weight ratings of these lifts (maximum 18,500 lbs per column) make them sufficient for the maintenance of BEBs.

An additional consideration is the need to access the top side of BEBs for similar maintenance or testing procedures. While exact access requirements may differ depending on the BEB model procured, it is expected that top side access equipment used by Carson City Public Works for maintenance of fire vehicles should be sufficient for the preventative maintenance needed for BEBs.

For atypical maintenance activities, such as the replacement of roof-mounted batteries on some BEB models, it is important to identify the weight of the batteries and appropriate equipment to safety move a battery to and from the roof of a bus. Possible options include a securely braced rough terrain forklift, small crane, or other OEM-recommend pieces of equipment.

Vehicle Washing

There are no specific provisions for the washing of BEBs, which can be washed in the same vehicle bays and in a comparable manner to conventional diesel buses.

Fire Suppression Systems

When performing maintenance on high-voltage equipment and lithium-ion batteries, there is a potential for fires to occur from punctures, short circuits, or software failures resulting in thermal runaways. It is necessary that fire suppression systems in the maintenance bay be verified to meet or exceed the minimum requirements for lithium or other battery technology-related fires as specified by the vehicle OEM. OEM first responder guides, including recommended fire suppression techniques, are available on the NFPA website (NFPA 2024). The primary goal in electric bus fire response is to prevent fire from spreading to nearby electric buses. The general approach for handling these fires includes not using class ABC extinguishers or small quantities of water. Instead, high volume water sources should be used, such as those available through a reliable water supply and an enhanced density water-based fire protection system. This is because lithium battery fires can take significant time and thousands of gallons of water to fully control (Gillig 2022). Other control measures such as spaced parking of BEBs from other BEBs and structures, the use of fire-retardant blankets, or the use of specialized extinguishers may also be needed to meet the safety recommendations of a vehicle OEM. Upon the procurements of BEBs, the *Carson City Public Works Maintenance Plan* should be updated to include these fire control measures and procedures and copies of the appropriate NFPA documents and OEM first responder guides should be maintained on-site.

4.5.2.2 Curative Maintenance

Unplanned malfunction or failure of components in fleet vehicles may prevent the safe or reliable operation of those vehicles, effectively immobilizing portions of the fleet. Similar to diesel-fueled vehicles, spare parts inventories should be maintained for critical components. For BEBs, some components that are not necessarily critical may have significant lead times when ordered from a vendor and should be maintained in inventory on-site. A list of critical and recommended components, and the general quantities of components on a per vehicle basis, should be provided by the OEM during the bus procurement process. These components should be maintained on-site in the recommended quantities. For components not maintained on-site, a general list of the components, pricing, and lead times should also be provided by the OEM.

It is recommended to source components directly from the OEM, when possible, as components available only through distributors are sometimes only available as bundled kits, presenting an issue of added cost for unnecessary parts.

Out of Service Bus Towing

For service of BEBs, it is important to plan for the need to tow an out of service BEB to the maintenance facility. The towing needs of these vehicles differ from diesel buses both because of their greater weight and the added resistance of the regenerative electric motor system. It is expected that existing Carson City Public Works resources for towing large out of service vehicles (e.g., fire trucks), which are considerably heavier than the recommended 30-foot BEBs, would be sufficient for towing out of service BEBs.

4.5.2.3 Battery Storage

Expended batteries from BEBs that have been replaced under warranty will need to be stored on-site until disposed of appropriately. Establishing standard operating procedures are particularly important for damaged batteries where the stability of chemicals is compromised. Battery storage should be a cool, humidity-controlled environment out of direct sunlight and in a room with fire rated walls. If feasible, designating an entirely separate structure for battery storage would be preferred. It is recommended that, upon the procurements of BEBs, the *Carson City Public Works Maintenance Plan* be updated to include battery storage procedures consistent with OEM recommendations. OEM battery recycling, reselling of degraded batteries, reuse of degraded batteries for on-site battery power backups, or other disposal strategies can be considered to manage expended batteries when replaced under warranty or at a vehicle's end of life.

4.5.2.4 Fleet Storage

Covered fleet storage is not required for operation of hybrid diesel-electric buses or BEBs in Carson City's climatological conditions. That said, covered storage areas, which shield buses from the elements, are likely to contribute to preserving the longevity of paint or other bus coatings and reduce the weathering of exposed bus components. A covering would also make morning deployment of the buses more efficient by reducing the need for deicing in the colder months.

4.5.3 Recommended Charger Maintenance

Charging systems for BEBs also typically require a degree of preventative maintenance and may require the occasional curative maintenance. It is recommended that at the time of charger procurement, the charger OEM provide a maintenance manual that outlines the necessary preventative maintenance activities, recommended minimum and maximum intervals, training or other skills needed, tools needed, and required parts needed to complete each activity. Upon the installation of BEB chargers, the *Carson City Public Works Maintenance Plan* should be updated to include these maintenance needs.

Similarly to bus OEMs, charger OEMs should provide a list of critical and recommended parts to keep in stock on-site and a list of other components and their anticipated lead times. It is expected that certain charger maintenance activities would need to be completed by a licensed electrician or OEM technician because of the large amounts of power in these systems.

The recommended depot chargers are 150 kW DCFCs and 50 kW DCFCs for pusher BEBs and cutaway BEBs, respectively. Typically, depot chargers require minimal maintenance and are designed in a modular fashion, which allows replacement of damaged parts without disruption to the depot charging network.

The recommended mid-route chargers are 350 kW or greater DCFCs which generate considerable heat during operation. Mid-route charging systems are typically equipped with cooling systems, air filters, fans, or other cooling components that require periodic cleaning or other preventative maintenance. Some mid-route chargers have more complex drop-down pantograph components that require additional preventative maintenance as well. These complexities can be avoided by using a plug-in charger with a lockable charging cable.

4.5.4 Solar, Bidirectional Power

4.5.4.1 Solar

Installing solar at the JAC Yard should be considered to reduce the amount of electricity demanded from the utility, with the co-benefit of providing the vehicles with overhead shelter from the weather. Since most of the charging will be performed at night, JAC could potentially offset the cost of that electricity by selling power back to the utility during the day.

During the stakeholder conversation, NV Energy expressed that the utility does have net metering procedures. Requirements for nonresidential net metering has specific requirements (e.g., when a project exceeds 1,000 kVA, there are different engineering standards). NV Energy expressed an openness to help JAC understand these standards better if the transit agency would like to pursue on-site solar. The Carson City Public Works campus is on a separate electrical service from the JAC Yard, so increasing solar capacity at the Carson City Public Works campus will not directly reduce the grid electricity demand from JAC's BEBs. However, if solar capacity was increased at the Carson City Public Works campus, the additional electricity could be sold back to NV Energy under net metering procedures to help CAMPO offset the costs and utility-side GHG emissions of charging the JAC BEBs.

4.5.4.2 Bidirectional power

The direct current chargers recommended in this plan can have vehicle-to-grid technology enabled, which allows vehicles to send power back into the grid—this is valuable during times of high demand. NV Energy is looking into this program but has not implemented it currently. If it is implemented in the future, this technology would be the source of additional co-benefits. Extra BEBs that are not being used for routes would support the region's resilience with additional power during times of grid stress, and JAC would get some revenue from selling electricity back to the utility.

4.6 Workforce Transition

4.6.1 Operations Staff

Operations staff (i.e., drivers) will need to use their skills operating conventional diesel buses as well as other skills and knowledge to operate BEB and hybrid diesel-electric buses. BEBs and hybrid diesel-electric buses have different components and controls than conventional diesel-fueled buses, including different gauges or displays. Additionally, as discussed in Section 4.5.1.2, to operate efficiently, these vehicles require different driving styles when decelerating as compared to conventional diesel buses.

4.6.1.1 Licensure

Under Nevada state law, CDLs are classed based on the gross vehicle weight ratings (GVWRs) and towing weights of vehicles. JAC's current diesel buses are less than 26,000 lbs GVWR; therefore, the requirement for JAC's current drivers is likely Class C CDLs. Standard-range BEBs that are 30 feet long would likely remain at or below the 26,000 lbs GVWR limit; therefore, they would not require a higher class of licensure. Extended-range BEBs that are 35 or 40 feet long would be likely meet or exceed 26,001 GVWR, which would require the drivers to hold Class B CDLs.

Additionally, many current-generation BEBs are equipped with air brake systems. Under Nevada state law, if drivers did not take or failed the air brake component of the CDL test, the CDL is issued with an

L restriction or potentially a Z restriction (Nevada Department of Motor Vehicles 2022). At the time of BEB procurement, it is essential that JAC coordinate with the contract operator (the provider of bus drivers) and the BEB OEM to evaluate the licensure requirements of the specified BEBs in Nevada.

4.6.1.2 Components and Electronic Systems

Drivers must be trained on the basic components and electronic systems present in the BEBs and hybrid diesel-electric buses that they will be operating. This includes how to turn the bus on and off, and how to read the gauges, meters, and screens that indicate the battery state of charge, remaining operating time, estimated range, and other key system notifications that may come up during bus operation. For safety reasons, drivers should also be informed of the locations of emergency cutoff switches throughout the BEBs.

Typically, BEBs have separate power switches for low and high voltage components. In some case studies, a lack of driver training resulted in low voltage systems never being turned off in BEBs, resulting in drainage of the low voltage auxiliary batteries to the point of requiring replacement (California Air Resources Board 2020).

4.6.1.3 Physical Systems and Concepts

Drivers will also require training on the physical systems and conceptual operation of those systems for the BEB of hybrid diesel-electric bus. Hands-on bus OEM-provided training can be highly effective at teaching concepts and familiarizing drivers with the physical systems of the buses. This training can include, but is not limited to, how to drive with regenerative braking, the BEB's mechanical braking systems, and any hill holding and roll back behaviors of the bus.

Additionally, BEBs present new, unique hazards that drivers must be prepared for. BEBs are generally dramatically quieter than conventional diesel buses, presenting risks to pedestrians who might not see or hear the vehicle coming. Although newer generation BEBs include noise-generation systems to prevent completely silent operation, drivers will need training on how best to mitigate the risks that might stem from more quiet bus operation. Other BEB and hybrid diesel-electric bus hazards include voltage-related hazards. Drivers should be trained in the procedures and actions to be taken during an emergency (e.g., contact first responders, evacuate passengers, power off vehicle, emergency cutoff of power systems, if applicable).

The plug-in nature of charging a BEB can also present challenges in the misuse of chargers, such as driving away with the bus still plugged in or charging cables not being correctly stored. While most current-generation BEBs include systems that prevent the driving of the vehicle while plugged in, it is still important for drivers to be trained on the procedures for charging and completing charge of the buses, typically available from charger OEM manuals or through hand-on training with bus OEM staff.

Driver Recognition Program

Because of the significant operating and energy efficiency benefits that can be achieved through effective operation of BEBs, such as maximizing regenerative braking, it is suggested to implement a driver recognition program. Under such a program, which is recommended by the Transportation Research Board, daily kWh per operating mile energy statistics can be collected for drivers and aggregated over each month or season's operations, offering incentives—such as gift cards or driver of the month recognition—to those drivers that rank highest (Transportation Research Board 2018). A program of this nature has the dual utility of both encouraging drivers to operate the buses at highest efficiency and identifying those staff best suited to training new BEB drivers.

4.6.2 Maintenance Staff

Both BEB and hybrid diesel-electric buses require additional, specific training on maintenance procedures. The American Public Transportation Association publishes curricula for both powertrain types, providing an outline of key skills and learning objectives for any training program (American Public Transportation Association 2023, 2016). They include topic areas such as safety elements, maintenance procedures, troubleshooting, and other relevant considerations for operation and repairs. Key areas of focus include safely working with high voltage electric powertrains, maintenance of battery components, and any inspection or other procedures that may be different from conventionally powered diesel buses. Additionally, new bus models of any powertrain type may include data, control, and other computer systems that differ from those found on vehicles currently used in the fleet. Rather than being a training program itself, each of these publications should be viewed as a guide to determine which skills and methods are necessary for staff.

In terms of resources available for providing training to maintenance staff, there are two main options: vehicle-specific training provided by the OEM or third-party training programs (e.g., the Transit Workforce Center's series of webinars) (Transit Workforce Center n.d.-a). Typically, OEM-provided training will be most effective for the needs of maintenance staff, as it focuses on the actual bus models in operation, rather than general concepts and knowledge. OEM-provided training can use different teaching methods effectively, depending on the content being covered. These range from online courses and videos, to in-depth, hands-on training workshops. Furthermore, in the case of BEB manufacturers, it is common for a dedicated, on-site maintenance technician to be provided by the OEM to assist with initial training and operational phases. OEM-provided training should also generally cover training in any specialized equipment needed for the routine preventative maintenance of equipment. This OEM support offered by many BEB manufacturers is a key benefit that should be used to the transit agency's advantage whenever possible.

Regarding maintenance of charging equipment, charging manufacturers may split the responsibilities between the transit agency and themselves. For example, there may be some activities that the Carson City Public Works facility maintenance team would be responsible for, while the OEM or third-party contractor would handle other critical or OEM-specific activities. Training or certification may be required for Carson City Public Works employees performing work on charging equipment.

4.6.3 First Responders

As discussed in Section 4.5.2.1, OEM first responder guides, including recommended fire suppression techniques, are available on the NFPA website (NFPA 2024). It is recommended that the Carson City Public Works fleet and facility maintenance teams and the drivers and dispatchers of JAC vehicles be provided with and always maintain copies of the OEM first responder guides.

An incident may require first responders to be near BEBs, hybrid diesel-electric buses, or charging infrastructure. JAC should coordinate with relevant first responders, providing the first responder guide documentation for any JAC-operated BEBs or hybrid diesel-electric buses. In preparation, JAC should consider providing the fire department with a tour of the JAC Yard and upgraded maintenance facility and participating heavily in the development of the fire department's pre-planning for emergency response.

Some vehicle OEMs offer specific training for first responders. This training may include, but is not limited to, the means of rapidly identifying BEBs and hybrid diesel-electric buses, the recommended approach to dealing with battery fires and how those fires differ from conventional fires or fuel fires, the location of key BEB components such as emergency cutoff switches for BEB electrical systems, and the proper procedures for quickly isolating and disconnecting batteries from the electrical system. It is recommended that the potential need for training be discussed and evaluated with relevant first responders at the time of procurement.

4.6.4 Training Extents and Costs

The extents and costs of OEM-provided training varies between the manufacturers. While the precise costs of training cannot be predicted precisely, market research has indicated that OEM-provided training for drivers or maintenance staff can generally be expected to total $5,000 per 3-day training week. It is recommended that a train the trainer system be employed for drivers and maintenance staff wherein specific staff are provided additional focused training to become long-term in-house resources for new staff.

Some OEMs offer their own staff to provide long-term boots on the ground support for maintenance and drivers. An interview with RTC Washoe has indicated that this approach was used for multiple years and remains highly successful in educating both new and existing staff, demystifying the stigmas around these newer technologies, and reducing the workload of maintenance personnel. Conversations with Carson City Public Works maintenance staff indicated that the existing maintenance needs of JAC's fleet already surpasses the maintenance staff's capacity. While the long-term maintenance costs and needs of BEBs are lower than conventional vehicles, the maintenance needs in the immediacy of purchase may be higher because of the learning curve of new vehicles and new technologies. One to 2 years of boots on the ground OEM staff support is a tried-and-true method for offsetting the learning curve.

The primary funding mechanism of the zero-emission transition, the Low-No Emission Bus Program, requires that set portions of funding be dedicated to workforce development. Under Phase 1, this funding can be used to support workforce training or boots on the ground OEM staff services. With implementation of Phase 2 and subsequent purchases of BEBs or hybrid diesel-electric buses, additional funding from the grant mechanism can be used to continue to support longer-term OEM staff services.

5.0 Expected Costs of Zero-Emission Transition

5.1 Total Cost of Ownership

The TCO analysis performed in this section compares the relative capital and variable costs of the recommended fixed-route vehicles for Phase 1 of the transition to a zero-emission fleet, described in Section 4.3, and their associated capital infrastructure, described in Section 4.4, over each vehicle option's expected 12-year useful life. Additionally, the TCO analysis illustrates when the expected return on investment for a low and no emission bus may occur, given the higher up-front costs of hybrid diesel-electric buses or BEBs relative to diesel pusher buses.

The TCO is presented in 2022 dollars in costs to CAMPO. It excludes the share of costs covered by the federal share of Grants for Buses and Bus Facilities Competitive Program, discussed in more detail in Section 5.3.

5.1.1 Vehicles Considered and Assumptions

The TCO serves as an illustrative example of a Phase 1 transition (two buses) by comparing the costs and return on investment for following vehicles:

- A typical 30- to 40-foot hybrid diesel-electric pusher
- A 30-foot standard-range BEB that uses mid-route charging
- A 35-foot extended-range BEB
- A 34- to 35-foot diesel pusher typical of the current JAC fixed-route fleet

The vehicle purchase price, their associated capital costs, ongoing maintenance costs, and efficiency ratings for the three low or no emission options were based on vehicle manufacturer specification sheets and transit industry white papers.

For the calculation of annual operational fleet costs, fleet fuel economy and per-mile maintenance costs were applied to actual 2023 JAC fleet operating data. All buses were assumed to accrue 35,712 service miles annually, which represents the annual average per-bus vehicle miles traveled (VMT) necessary to serve JAC's current fixed routes. For future years, fuel costs were adjusted based on transportation sector energy prices from the U.S. Energy Information Administration (EIA) Annual Fuel Outlook 2023 (EIA 2024) and maintenance costs were adjusted based on U.S. Bureau of Labor Statistics National Compensation Survey for service workers. All costs are presented in adjusted 2022 dollars.

The cost of staff training is not included in the TCO calculation because much of that cost is covered by the Low-No Emission Bus Program, so the cost to the agency would be expected to be negligible.

5.1.2 Phase 1 Total Cost of Ownership

The results of the TCO are presented graphically in Figure 11, which illustrates the capital costs (Year 0) and the cumulative costs for each subsequent year through the 12-year vehicle lifetime. The years at which the low or no emission vehicle cost lines cross the diesel cost line is the year when each zero-emission bus option becomes cumulatively more affordable than the diesel bus option. It is important to recognize that this TCO analysis considers only Phase 1 of the ZETP. In Phase 2, it is expected that investments made during Phase 1 provide continued utility for JAC's fleet and low and no emission vehicles would show increasing cumulative cost benefits over conventional diesel buses.

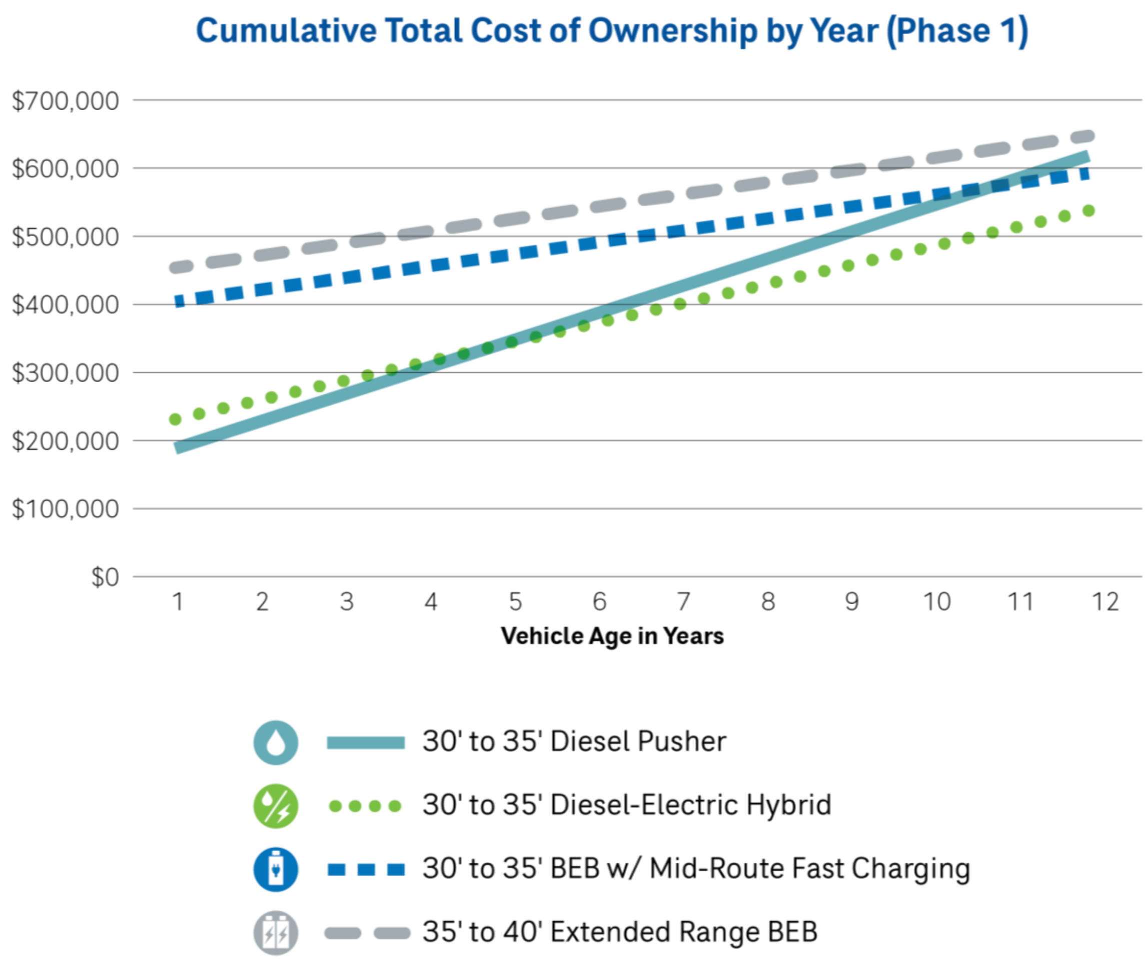

Figure 11: Total Cost of Ownership for Phase 1

5.1.2.1 Hybrid Diesel-Electric Buses

Hybrid diesel-electric buses have a significantly higher list price (37%) than a comparable conventional diesel pusher bus. Both the diesel and hybrid diesel-electric buses qualify for an 85% FTA funding match through the Americans with Disabilities Act (ADA) and the Low-No Emission Bus Program respectively. Hybrid diesel-electric buses require no additional capital infrastructure compared to diesel buses.

As hybrid diesel-electric buses achieve roughly 20% better fuel efficiency than diesel pushers and have an estimated per-mile maintenance cost that is 38% lower than JAC's actual 2023 per-mile diesel pusher fleet maintenance cost, the hybrid buses become more cost-effective to run in their fifth year of operation. Over a period of 12 years, use of two hybrid diesel-electric buses instead of diesel pushers would represent a savings to JAC of $77,804 (13%) after consideration of FTA cost shares.

5.1.2.2 Battery Electric Buses

Both BEB options (standard-range and extended-range) have significantly higher list prices than conventional diesel pushers. The 30-foot standard-range BEB is $400,000 more per unit, and the extended-range BEB is $780,000 more per unit (when including the required additional battery packs for longer range). Both the diesel buses and BEBs qualify for an 85% FTA funding match through the ADA and the Low-No Emission Bus Program respectively. With grant funding considered, the cost to JAC for the Phase 1 BEBs (2 buses) would be $120,000 (standard-range) or $234,000 (extended-range) higher than a conventional diesel pusher.

BEBs require significant capital improvements to the JAC Yard in the form of chargers and transformers (approximately $516,000). Purchasing of standard-range BEB models will require the additional installation of a mid-route charger and electrical upgrades (approximately $685,500). However, with a FTA funding match of 90% on the cost and installation of these upgrades via the Low-No Emission Bus Program, JAC's costs of Phase 1 capital improvements would be $90,150 (standard-range) or $51,600 (extended-range).

Through their regular use serving JAC's fixed routes, the two standard-range BEBs become more cost-effective than conventional diesel pushers in the 10th year of operation and would be less cost effective than hybrid diesel-electric buses over the 12-year Phase 1 vehicle operating lifetime. This is due, in part, to the significantly lower cost of charging a BEB relative to fueling a diesel bus, as well as the reduced maintenance costs associated with BEBs, which have mechanically simpler powertrains and fewer moving parts that wear and break. Over a period of 12 years, use of two standard-range BEBs instead of diesel pushers would represent a savings to JAC of $24,405 (4%) after consideration of FTA cost shares.

The total cost of ownership for the two extended-range variants would be greater (less cost effective) than the diesel buses, hybrid diesel-electric buses, or standard-range BEBs with mid-route charging over the 12-year Phase 1 vehicle operating lifetime. Over a period of 12 years, use of two extended-range BEBs instead of diesel pushers would represent a increase to JAC of $31,412 (5%) after consideration of FTA cost shares.

A Phase 1 rollout of standard-range BEBs with mid-route charging has several additional benefits. A standard-range BEB with mid-route charging strategy would reduce the total cost of acquiring more standard-range BEBs in Phase 2 because all future standard-range BEBs could leverage the mid-route charging infrastructure upgrades made during Phase 1. Additionally, the neighboring transit agencies RTC Washoe and TTD, which have routes that go into Carson City, could potentially use the mid-route charging infrastructure, potentially enabling them to serve those routes with BEBs. This presents an opportunity for cost sharing and further amortization across the overall region's transit fleet.

5.1.3 Phase 1 Ultimate Per-Mile Cost

TCO can be considered both for the point of return on investment, as presented previously, or can be considered amortized over the applicable operating period. For long-running operations, it is often helpful to distill TCO into simplified amortized cost metrics, in this case ultimate per-mile costs. Table 5 describes the total per-mile cost of purchasing and operating the analyzed bus options, including infrastructure and equipment costs, over an assumed 12-year useful life. The per-mile cost estimates rely on the same assumptions summarized previously, and present costs to JAC after consideration of FTA cost shares.

Table 5: Phase 1 Per-Mile Cost to Own and Operate Fixed-Route Rolling Stock Options

Cost Category	34- or 35-Foot Diesel Pusher	Hybrid Diesel-Electric Pusher	30-Foot BEB with Mid-Route Charging	35-Foot Extended-Range BEB
Rolling Stock	$0.18	$0.24	$0.32	$0.45
Per-Mile Energy Consumption	$0.25	$0.20	$0.10	$0.11
Maintenance	$0.30	$0.19	$0.14	$0.14
Infrastructure (Chargers, Transformer, Utility Upgrades, Installation)	N/A	N/A	$0.14	$0.06
Overall Total Per-Mile Cost	$0.72	$0.63	$0.69	$0.76
Cost Reduction over Diesel Pushers	**N/A**	**13%**	**4%**	**(5%)**
Overall Total Per-Mile Cost (Excluding Infrastructure)	$0.72	$0.63	$0.55	$0.70
Cost Reduction over Diesel Pushers (Excluding Infrastructure)	**N/A**	**13%**	**23%**	**3%**

Note: BEB = battery electric bus; N/A = not applicable

Ultimately, when considering only Phase 1, hybrid diesel-electric buses would cost about 13% less than conventional diesel pushers to own and operate on a per-mile basis, while the standard-range and extended-range BEBs would cost 4% less and 5% more, respectively. This assessment underestimates the potential savings from the operation of BEBs, as the costs of infrastructure upgrades is amortized over a fleet of only two buses in Phase 1. In practice, charging stations and electrical upgrades have ongoing utility well beyond a single 12-year rolling stock lifetime (up to 40 years).

When comparing the ultimate per-mile costs excluding infrastructure, standard-range and extended-range BEBs would cost 23% less and 3% less than conventional diesel pushers to own and operate. The real world per-mile costs would be somewhere between the cost including and costs excluding infrastructure over JAC's continued service.

5.2 Greenhouse Gas Impacts

As shown in Table 6, the operation of diesel-electric hybrids or BEBs in lieu of diesel pushers on JAC fixed routes would represent a substantial reduction in carbon dioxide (CO_2) emissions in addition to the lower operational costs offered by BEBs and hybrid buses.

A Phase 1 fleet of hybrid diesel-electric buses would abate approximately 17 MT of CO_2 of tailpipe emissions per year compared to its diesel counterpart. This is approximately 210 MT over the vehicles' expected 12-year useful life, a reduction of 17% compared to the diesel buses. A Phase 1 rollout of BEBs would eliminate tailpipe emissions. If emissions from electricity consumption are considered, a Phase 1 rollout of BEBs would abate between 69 and 65 MT of CO_2 annually depending on the variant (i.e., standard-range versus extended-range), a reduction of between 66% and 62% over the 12-year useful life, given the region's current mix of electricity generation (EPA 2024a). This GHG analysis does not consider the BEBs as having diesel heaters. The addition of diesel heaters on the buses will increase the efficiency of the BEBs in cold weather but will add emissions. These added emissions are considered minimal compared to the emissions saved from switching from an internal combustion engine to an electric motor.

Over time, GHG emissions from the electricity used to charge BEBs could be further reduced as the percent of renewable electricity in the grid increases.

Table 6: Annual and Lifetime Carbon Dioxide Release of Fixed-Route Rolling Stock Options

	34- or 35-Foot Diesel Pusher (tailpipe emissions)	**Hybrid** (tailpipe emissions)	**30-Foot BEB with Mid-Route Charging** (tailpipe emissions)	**35-Foot Extended-Range BEB** (tailpipe emissions)	**30-Foot BEB with Mid-Route Charging** (emissions from electricity)	**35-Foot Extended-Range BEB** (emissions from electricity)
Annual CO_2 Release (MT) per Bus **(Phase 1)**	52 **(105)**	44 **(87)**	0	0	18 **(36)**	20 **(40)**
Lifetime CO_2 Release (MT) per Bus **(Phase 1)**	630 **(1,259)**	525 **(1,049)**	0	0	213 **(426)**	240 **(480)**
Annual CO_2 (MT) Abated per Bus **(Phase 1)**	N/A	9 **(17)**	52 **(105)**	52 **(105)**	35 **(69)**	32 **(65)**
Lifetime CO_2 (MT) Abated per Bus **(Phase 1)**	N/A	105 **(210)**	630 **(1,259)**	630 **(1,259)**	417 **(833)**	390 **(779)**
% Difference	N/A	17%	100%	100%	66%	62%

5.3 Funding Opportunities

CAMPO finances their vehicle purchases with federal funds. However, the agency has faced difficulty in meeting the local match requirement. An example of this is the FTA's Section 5310 program designed to meet the transportation needs of older adults and people with disabilities. The local match requirement for capital costs is 20%.

CAMPO is developing this ZETP with the goal of qualifying to compete for the FTA's Low-No Emission Bus Program, which is discussed further in Section 5.3.1. Since one of CAMPO's major funding challenges is meeting the local match requirement, that is the focus of this section.

The following strategies should be considered for meeting the local match requirement:

- Assemble funding piecewise. Various sources can be combined to fulfill the full local match requirement. Guidance for this can be found in the Federal Fund Braiding Guide (DOT 2020).
- Consider fulfilling the local match over several years, rather than all at once. Federal agencies may approve plans that span multiple years and allow the local match to come out of multiple years budgets.

- Local match funding can sometimes be reduced or waived for services supporting underserved populations—this is done by an appeal to the secretary. The DOT's Grant Project Location Verification tool (DOT n.d.-a) can be used to determine if a project is in an urban area, an Area of Persistent Poverty, or a Historically Disadvantaged Community.

5.3.1 Federal Transit Authority's Low or No Emission Grant Program

FTA has authorized $390 million of its FY 2024 funding to the Grants for Buses and Bus Facilities Competitive Program (DOT n.d.-b). As a part of this program, the Low or No Emission Grant Program (DOT n.d.-c) provides funding to state and local governments for the purchase or lease of low or no emission buses, construction or lease of facilities and related support equipment for low or no emission buses, and construction/rehabilitation/improvement of public transportation facilities to accommodate low or no emission buses.

The Notice of Funding Opportunity (NOFO) for the FTA's Low-No Emission Bus Program (GovInfo 2024) specifies that 0.5% of a request may be for workforce development training and an additional 0.5% may be for training at the National Transit Institute, even if that request is just for infrastructure funding. Any project involving the procurement of zero-emission vehicles is required to spend 5% of their award on workforce development and training as outlined in their ZETP, unless the applicant certifies that their financial need is less.

The financial match requirements are as follows:

- Purchase or lease of a low or no emission transit bus: 85% federal, 15% local
- Construction or lease of low or no emission bus-related equipment and facilities: 90% federal, 10% local

Funds from the DOT cannot be used as a local match. Federal funds from non-DOT sources can be used to fulfill the local match if the other federal program providing the matching funds expressly authorizes its funds to fulfill the match requirement of other federal programs.

5.3.2 Other Funding Opportunities

Several options were considered for additional funding opportunities, with emphasis on finding sources that could be used as a local match component for the FTA's Low-No Emission Bus Program. Given the capital investment costs required to acquire vehicles, upgrade infrastructure, and train staff, this portion of funding has the potential to be an obstacle to implementing the objectives outlined in this plan. A variety of grant programs and sources were consulted in this analysis, with relevant programs listed in the following section. These range from other federal funding sources to state- and utility-run grants. Some contain stipulations on eligible recipient organizations (i.e., these could be local organizations serving Carson City or educational institutions like Western Nevada College). Other requirements, such as uses of funding and award amount, are also listed whenever this information is available.

The funding opportunities discussed in Section 5.3.2.1 highlight the following key details, as applicable:

- Purpose of the program, eligible entities
- Possible eligible uses by CAMPO (i.e., infrastructure, vehicles, personnel)

- Application period
- Funding term
- Range of available funding
- Other special considerations (e.g., required partnership)

5.3.2.1 Other Federal Funding

Inflation Reduction Act Environmental and Climate Justice Program

Created by the Inflation Reduction Act, the EPA-administered Environmental and Climate Justice Program provides funding opportunities via the Community Change Grants program. This program funds projects that reduce pollution, increase climate resilience, and strengthen local capacity in communities disproportionately impacted by climate change and other environmental challenges. To be eligible for funding, a governmental entity must partner with a non-profit, community-based organization. The organization must demonstrate that it "supports and/or represents a community and/or certain populations within a community through engagement, education, and other related services provided to individual community residents and community stakeholders" (EPA 2024b). Under Funding Track I of the program, applicants must address the following six requirements in their proposal:

- Alignment with at least one of the program's climate action strategies
- Alignment with at least one of the program's pollution reduction strategies
- Submittal of a Community Engagement and Collaborative Governance Plan
- Submittal of a Community Strength Plan
- Completion of the project within a 3-year period
- Submittal of a Compliance Plan

Funding may be used for a variety of projects, with funding for the purchase of zero-emission vehicles and training for the maintenance of such vehicles highlighted as examples of strategies to meet some of the preceding requirements. Applications are currently open and may be submitted through November 21, 2024. Track I project awards range from $10 to $20 million with no cost sharing requirement.

Another program to consider is the U.S. Department of Housing and Urban Development's Community Development Block Grants. These are typically used for housing and other buildings, with limits on the portion used to provide public services. However, one of the requirements is for funded programs to benefit low- and moderate-income (LMI) persons. Figure 7 shows JAC's fixed routes in relation to Carson City's low-income population, which could be used to demonstrate the zero-emission transition's benefit to the LMI population. In addition to the benefit from zero-emission transit vehicles, a potential upgraded transfer area (with public bathrooms and increased shelter from the elements) may also be considered a benefit to the LMI population, depending on its location.

5.3.2.2 State and Regional Funding

Volkswagen Mitigation Fund

The Nevada Division of Environmental Protection (NDEP) administers a competitive grant program using funding from the 2017 Volkswagen settlement. These grants fund projects designed to reduce nitrogen oxide emissions in areas of the state with a disproportionately high air pollution burden (NDEP n.d.-a). While the application period is currently closed, NDEP may announce additional funding opportunities at a future date. Eligible grant recipients include operators of diesel-powered medium- and heavy-duty transit buses with a 2009 or older engine model year. Grants may be used to cover up to the incremental cost of acquiring new vehicles: the difference in purchase cost between a low emissions model and a conventionally powered one. Additionally, under prior guidelines for the program, applicants have a 2-year window in which the project must be completed (NDEP 2021).

Economic Recovery Transportation Electrification Plan

NV Energy states the following about their Economic Recovery Transportation Electrification Plan (ERTEP) Transit Electrification Grant program:

> prioritize[s] projects providing incremental electrification and by their ability to electrify transit services in historically underserved communities. Charging stations are highlighted as a potential use for awarded funds, though vehicle purchases may also be eligible. Planning services, such as those currently used in the development of this zero-emission transition plan, are another potential use. Additional priority will be given to projects with infrastructure located in historically underserved communities. (NV Energy n.d.-a)

A total of $6 million in funding will be allocated by a working group consisting of transit agencies, metropolitan planning organizations, and NDOT. Potential applicants may submit proposals via ERTEP's online portal (NV Energy and PowerClerk n.d.-a). Though it is unlikely that significant funding will be awarded from the current amount, additional appropriations may be available if ERTEP is updated or renewed in subsequent plan years.

State Infrastructure Bank

In 2017, Assembly Bill 399 established the Nevada State Infrastructure Bank (SIB) within the Department of Transportation, which is tasked with supporting transportation infrastructure development throughout Nevada by providing financial assistance to qualified borrowers for the development, construction, repair, improvement, operation, maintenance, decommissioning and ownership of certain facilities and infrastructure as necessary for public purposes (Nevada Revised Statutes 408.55069, as amended). Among other criteria, projects eligible for SIB loans or other financial support include those which are shovel-ready and those located in census areas with high levels of social vulnerability, tribal lands, or communities where tribal members commonly reside.

A low-interest loan through the SIB is one possible mechanism to offset the higher initial capital investment of the zero-emission transition, allowing CAMPO to distribute those costs over a greater-term and offset them through the operational cost reductions anticipated of the BEB fleet.

5.3.2.3 Ineligible Funding Sources

Several other potential funding sources were explored as options. However, the sources listed below were ruled out as viable funding mechanisms. Common reasons for ineligibility include not meeting recipient qualifications, prohibitions on use as a local match component, and incompatibility of the originating funding source (i.e., another grant program administered by DOT).

- EPA Clean Communities Investment Accelerator (recipient must be a non-profit organization with no partnering opportunities)
- National Electric Vehicle Infrastructure funding (administered by Federal Highway Administration, part of DOT)
- EPA Diesel Emissions Reduction Act (NOFO prohibits its use as local match for other federal grant programs)
- Nevada Governor's Office of Economic Development (limited opportunities, and the Low-No Emission Bus Program already stipulates a portion of funding for workforce development)

6.0 Stakeholder Outreach Strategy

6.1 Outreach Strategy

Outside of the development of the ZETP, continued engagement of JAC's many stakeholders is an important activity to maximize the benefits of the zero-emission transition and enable the agency to best serve the community.

Table 7 is a recommendation for structuring this outreach. The following subsections offer additional context to the columns in the table.

6.1.1 Outreach Goals

For outreach to be most effective it should be tailored for each stakeholder group. The outreach goals include:

- Funding support: To execute a zero-emission transition, JAC will need support from the CAMPO Board.
- Agency collaboration: Bringing zero-emission transit vehicles online will require different entities to provide their support in the form of resources. This transition is also an opportunity to support transit in the greater region by partnering with regional agencies.
- Increase ridership: To enhance the benefits of this transition, a mode shift from personal internal combustion vehicles to zero-emission transit vehicles should be encouraged.
- Support of program: Achieving the preceding outreach goals will be easier if more people understand the benefits of the transition and speak positively about it in their circles of influence.

6.1.2 Outreach Strategies

JAC's outreach strategy can be structured by considering four different components: information for CAMPO to share, information for CAMPO to gather, method of outreach, and frequency of outreach.

6.1.2.1 Information for Carson Area Metropolitan Planning Organization to Share

CAMPO can enhance the success of its outreach by focusing on the stakeholder group's main interests when CAMPO shares information. Sharing information may be related to describing real changes that the program will bring or staying ahead of incorrect assumptions. This column in Table 7 lists the information that may be the most valuable for each stakeholder group. The subsequent cross-references provide content on the following main interests:

- Description of benefits (Section 4.1)
- Project funding needs (Section 5.0)
- Operational support needs (Section 4.5)
- Description of JAC's new resources (Section 4.2.1.1)

- Explanation of any changes to transit operations (Section 4.2.1.1)
- Methods of collecting feedback (Appendix C)
- Implementation timeline (Section 4.2)

6.1.2.2 Information for Carson Area Metropolitan Planning Organization to Gather

Interacting with different stakeholder groups is a valuable opportunity for CAMPO to gather information. Content gathered should be used for project planning, customization of outreach content, or staying aware of any misconceptions. This column in Table 7 lists important information that CAMPO should gather from each group.

- Plans for future transfer station
- Future regional plans
- Resources needed by other departments
- Future electrification plans in the region
- Opportunities for future collaboration
- Questions/concerns
- Preferred communication methods

6.1.2.3 Method of Outreach

The method of outreach that a stakeholder group will be most receptive to varies. This column in Table 7 lists possible effective methods. Appendix C provides examples of these outreach methods.

6.1.2.4 Frequency of Outreach

This column states the recommended frequency of engagement that can balance CAMPO's limited resources for outreach with its need to perform important activities to achieve outreach goals.

- Progress updates during quarterly meetings: These stakeholders should receive regularly scheduled updates of the project's development.
- One time and then as needed: After an initial information sharing session, these stakeholders should have focused engagement only when there are major changes that directly impact them. Otherwise, these stakeholders can obtain project information in the same way that the general community members do.
- Continuously as needed: Collaboration is needed with these stakeholders for operational changes during periods throughout the project.
- Quarterly, evolving from written methods to in-person events: Periodic engagement should ramp up from written methods to in-person interactions, leading up to major milestones (i.e., Phase 1 or Phase 2 deployment).

6.1.3 Outreach Strategy Table

The most effective strategies for information gathering, education of stakeholders, and outreach methods and frequencies can vary depending on the specific needs of each stakeholder group. Table 7 presents a matrix summarizing the recommendations for outreach by stakeholder group.

Table 7: Matrix of Outreach Strategies, Organized by Stakeholder Type

Stakeholder Group	Outreach Goals				Outreach Strategy			
	Funding Support	Agency Collab-oration	Increase Ridership	Support of Program	Information for CAMPO to Share	Information for CAMPO to Gather	Method of Outreach	Frequency of Outreach
Board/Council								
CAMPO Board	✓				▪ Description of benefits ▪ Project funding needs	▪ Plans for future transfer station	▪ Tailored formal presentation	Progress updates during quarterly meetings
Carson City Board of Supervisors				✓	▪ Description of benefits	▪ Future regional plans	▪ Tailored formal presentation	One time and then as needed
Stakeholders/Community Groups								
Carson City Public Works (fleet maintenance, facility maintenance)		✓			▪ Operational support that the transition will require	▪ Resources needed by other departments	▪ Tailored formal presentation	Continuously as needed
NV Energy		✓			▪ Operational support that the transition will require	▪ Future electrification plans in the region	▪ Dedicated meeting	Continuously as needed
Other transit agencies (RTC Washoe, TTD, DART)		✓			▪ Description of JAC's new resources	▪ Opportunities for future collaboration	▪ Dedicated meeting	One time and then as needed
Transit Stakeholders		✓		✓	▪ Description of benefits ▪ Description of JAC's new resources	▪ Opportunities for future collaboration ▪ Questions/concerns	▪ Dedicated meeting (present at transit stakeholder meetings)	Progress updates during quarterly meetings
NDOT		✓			▪ Description of JAC's new resources	▪ Opportunities for future collaboration	▪ Dedicated meeting	One time and then as needed
Ridership (JAC has identified these groups as transit-dependent populations)								
Youth (5–17 years old)			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials (e.g., school newsletters) ▪ In-person events (e.g., parent-teacher association events) ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)

Stakeholder Group	Outreach Goals				Outreach Strategy			
	Funding Support	Agency Collab-oration	Increase Ridership	Support of Program	Information for CAMPO to Share	Information for CAMPO to Gather	Method of Outreach	Frequency of Outreach
Seniors (65+ years old)			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials (e.g., Carson Tahoe Regional Medical Center, paratransit vehicles) ▪ In-person events (e.g., senior center events) ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)
Low Income			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials (e.g. recreational centers) ▪ In-person events (e.g., events run by community non-profits) ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)
Disabled			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials (e.g., Carson Tahoe Regional Medical Center, paratransit vehicles) ▪ In-person events ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)
Zero-Vehicle Households			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials (e.g., mailers) ▪ In-person events ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)

Stakeholder Group	Outreach Goals				Outreach Strategy			
	Funding Support	Agency Collab-oration	Increase Ridership	Support of Program	Information for CAMPO to Share	Information for CAMPO to Gather	Method of Outreach	Frequency of Outreach
Non-Ridership/General Public								
Other commuters (bikers, walkers, drivers)			✓	✓	▪ Explanation of any changes to transit operations (e.g., transfer time) ▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials ▪ In-person events (e.g., Muscle Powered) ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)
Community members				✓	▪ Description of benefits ▪ Methods of collecting feedback	▪ Questions/concerns ▪ Preferred communication methods	▪ Physical marketing materials ▪ In-person events (e.g., farmers markets, seasonal/holiday festivals) ▪ Digital marketing	Quarterly (evolving from written methods to in-person events)
All groups								
All groups					▪ Implementation timeline			

6.1.3.1 Outreach Example: Other Commuters

Other commuters in Carson City are identified as bicyclists, walkers, and drivers of personal vehicles. JAC should target this group to increase its ridership (a mode shift from personal vehicle to bus would have climate implications) and garner support for the project more generally, which could influence decision-making parties (i.e., the CAMPO Board). JAC should aim to share information on the benefits of the zero-emission transition (improved local air quality may be particularly meaningful for bicyclists and walkers), changes to its operations, the ways in which these people can provide their feedback/ideas to the agency, and the project implementation timeline. JAC should work to understand any particular questions or concerns about the transition and ask these commuters how they prefer to receive their communication.

JAC should consider using physical marketing materials, targeting locations specific to this group like meeting locations of walking groups and bicycling clubs and bulletin boards at parks and tailheads. In-person events could include short presentations to targeted community groups like Muscle Powered (a local non-profit working in bike and pedestrian advocacy) and the Carson City Chapter of Citizens' Climate Lobby. JAC can also staff a table at a local farmers market or bike race. Acknowledging that JAC has limited resources for performing outreach, engagement is recommended on a quarterly basis starting from a year before the first BEB is deployed. The methods should start with written outreach to give people an initial introduction to the plan and evolve into in-person events so JAC can have more engaging conversations with this community.

6.1.4 Outreach Guidelines

The following should be considered for outreach generally. Appendix C provides examples of outreach methods.

- Brand outreach activities in a consistent manner. Branding should be established before outreach activities start.
- Outreach for this project does not need to be performed in isolation. Outreach for the zero-emission transition project could be incorporated into other JAC and CAMPO outreach initiatives.
- Any feedback or questions posed to CAMPO should be recorded. Analyzing trends and themes in topics that stakeholders raise to the agency will give CAMPO insight into how to tailor future outreach to answer common questions and address misconceptions. This can also inform the development of a list of frequently asked questions, which should be accessible to the public (e.g., made available on the JAC website).
- Create a contact list of people who sign up for events or reach out with questions. This list can be used for future communications.
- Make a record of project support (e.g., polling results, quotes, feedback buttons), which can be used as evidence of the public's backing.
- Where possible, outreach should have accommodations for non-English speakers (e.g., Spanish translation), as well as hearing/visually impaired community members.

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Appendix A – Stakeholder Interviews

A.1 Regional Transit Agencies

A.1.1 Regional Transportation Commission of Washoe County, Nevada

An interview with Regional Transportation Commission of Washoe County (RTC Washoe) Director of Public Transit James Gee, was held on February 20, 2024. RTC Washoe's current fleet is considerably larger than JAC's, consisting of 66 fixed-route transit and 56 paratransit vehicles. RTC Washoe was an early adopter of zero-emission transit vehicles for their fixed-route fleet—roughly one-third of the fleet consists of electric pusher buses and the remainder is made up of hybrid biodiesel or renewable diesel pusher buses. RTC Washoe also recently procured two hydrogen fuel cell buses (FCEBs) with six more on order. The agency has invested in infrastructure to make hydrogen fuel. As an early adopter, RTC Washoe currently operates vehicles from across four generations of battery electric buses (BEBs) in its fleet. RTC Washoe's paratransit fleet is fueled entirely by gasoline and compressed natural gas vehicles.

RTC Washoe shared several key lessons learned from their zero-emission transition experience including:

- In RTC Washoe's cold semi-arid climatological conditions (which Jump Around Carson [JAC] shares), current-generation nonextended-range pusher BEBs can reliably achieve ranges of 150 miles while using light and intermittent mid-route charging.
- RTC Washoe has experienced overwhelming positive community feedback regarding the zero-emission transition. The additional federal dollars supporting the zero-emission transition was seen as a major benefit with no major negative pushback.
- Workforce challenges came in the form of range anxiety among drivers of BEBs (particularly with the earlier generation BEBs) and concerns about explosive hazards of FCEBs. RTC Washoe found that with mid-route charging and the purchase of BEBs with slightly higher than needed range, combined with driver education (through an on-site maintenance champion), the agency was able to overcome these challenges.
  - As part of their bus purchase agreement, the manufacturer of RTC Washoe's BEBs, Proterra, stationed maintenance personnel in the RTC Washoe maintenance yard for multiple years to train RTC Washoe staff, assist in BEB maintenance, and serve as a local maintenance champion.

RTC Washoe still continues to face challenges unique to the zero-emission transition. These challenges include:

- The manufacturer of RTC Washoe's existing BEBs, Proterra, experienced significant financial challenges in recent years. This has led to very long lead times for support, replacement parts, and BEB deliveries. RTC Washoe's barriers when considering the procurement of BEBs made by other manufacturers include the agency's existing investments in spare parts and manufacturer-specific charging infrastructure.

- For RTC Washoe's longest routes, as well as the routes that do not allow for intermittent mid-route charging, the current-generation BEB cannot achieve the necessary daily range to meet RTC Washoe's needs. One example of this is RTC Washoe's route from Reno to Carson City.
    - On the scale of RTC Washoe's fleet, hydrogen FCEBs are expected to be similar in operating costs to hybrid diesel buses and are intended to be the zero-emission solution for these longer routes. However, hydrogen FCEBs have faced unique challenges related to maintenance, diagnosis of errors such as fuel leaks, and delays in fueling infrastructure installation. The FCEBs have not yet entered service.

Potential for partnerships between JAC and RTC Washoe exist where routes and infrastructure needs overlap. If JAC were to consider adopting FCEBs, RTC Washoe has expressed a willingness to share its fueling infrastructure (which is currently under development). Similarly, if JAC were to install mid-route bus chargers in Carson City, RTC Washoe would consider utilizing BEBs for the Reno to Carson City route.

A.1.2 Tahoe Transportation District

An interview with Tahoe Transportation District (TTD) staff including Transportation Director George Fink, Operations General Manager Chris Jacobs, and TTD Transportation Planners Tara Frank and Donnie McBath was held on February 27, 2024. TTD's current transit services are predominantly fixed-route transit—the fleet consists of approximately 20 conventionally fueled buses and 3 pusher BEBs. Fixed-route vehicles generally run less than 150 miles/day. TTD's paratransit services are supported by a fleet of six conventionally fueled cutaway buses. TTD's three BEBs are recent-generation Proterra vehicles. The agency is relatively early in its zero-emission transition. TTD currently has four hybrid pusher buses on order.

TTD witnessed meaningful benefits, but also has faced significant challenges related to their zero-emission transition. Key takeaways include:

- The BEBs are not all-wheel drive and have challenges in the hilly terrain of the TTD service area, particularly in icy conditions. The specific design of TTD's BEBs does now allow for the installation or use of drop-down tire chains which are typically used during these conditions.
- TTD's charging strategy relies on drop-down, overhead, non-proprietary mid-route charging. This approach has been highly successful. However, only one mid-route charger was installed, which previously rendered TTD's BEBs nonoperational when software issues resulted in extended downtime of the charger.
- Community feedback has been overwhelmingly positive about the adoption of zero-emission buses. There have been no complaints to date related to the brief 5- to 10-minute mid-route charging period between the end of a cycle and the beginning of the next. TTD noted that the reduced noise levels of the BEBs over conventional diesel buses has reduced complaints from residents living near the transit line.
- Mid-route charging combined with regenerative braking has been instrumental in maintaining BEB range.

- Workforce challenges stemmed from a lack of driver familiarity with the BEBs and different maintenance demands of BEBs compared to conventional buses.
  - TTD's BEBs have separate switches to engage high-voltage and low voltage power separately, which occasionally has led to low-voltage (conventional lead-acid battery) power being left on when a bus was shut down. This caused a de-powering of the lead-acid battery, leading to operational issues with the bus.
  - Similar to RTC Washoe, TTD used manufacturer support services for on-site maintenance personnel; however, this program was only in place for a few weeks and occurred well in advance of the bus charging infrastructure being completed. Since charging infrastructure was incomplete, buses were out of service for 6 months after the maintenance training was completed and many of the benefits of the manufacturer training were not actualized.
  - TTD's maintenance facility required improvements, such as procurement of new vehicle lifts that could accommodate the heavier BEBs.
- TTD's infrastructure was procured entirely using federal and state funding in partnership with the local non-profit Lake Tahoe Community College. Additional cost savings were achieved through cross-utilization of infrastructure deployment teams already working on projects at the college.

Potential for partnerships between JAC and TTD exist where routes and infrastructure needs overlap. TTD operates one route into Carson City. TTD expressed interest in using mid-route charging for that route if JAC were to install a mid-route charger as part of its zero-emission transition.

A.1.3 Douglas Area Rural Transit

An interview with Douglas Area Rural Transit (DART) staff including Interim Director of Community Services Adie Brook, DART Transportation Supervisor Linda Skaggs, Budget Analyst Geoff Bonar, and Community Services Manager Amanda Reid was held on February 27, 2024. DART's current transit services are predominantly paratransit, with fixed-route operations being comparatively low. Similar to JAC, DART's current transit fleet consists entirely of conventionally fueled vehicles, and DART is considering the potential benefits and drawbacks of a zero-emission transition.

The challenges DART faces with a zero-emission transition are primarily related to the reliability and operating range of zero-emission paratransit vehicles. Concerns related to zero-emission support equipment and infrastructure include limited availability, use of the equipment by the general public, and uncertainty over the maintenance burden. DART also faces challenges related to prioritization of funds, wherein available monies could be used either to expand existing services or to transition existing services to zero-emission services. The cost and benefits of the zero-emission transition is not yet clear.

A potential for partnership exists if JAC were to adopt hybrid or zero-emission paratransit vehicles, demonstrating the operational feasibility of those vehicles, the rightsizing of charging infrastructure, and the maintenance obligations. Because of the lack of overlap in the current service area, it is not anticipated that charging infrastructure installed by Carson Area Metropolitan Planning Organization (CAMPO) could be used by DART vehicles.

Key takeaways from this outreach are:

- Transit fleet reliance on publicly available charging infrastructure would likely present challenges related to availability of the equipment.
- The zero-emission transition should be contextualized via a cost-benefit analysis.
- Identification and consideration of maintenance responsibilities is important information for decision-makers.

A.2 Other Regional Entities

A.2.1 State Agency – Nevada Department of Transportation

An interview with Division Chief for Sustainability and Emerging Transportation Kandee Bahr Worley, from the Nevada Department of Transportation (NDOT), and her team was held on March 6, 2024.

NDOT has a vision for creating an electric highway, which is expressed in its One Nevada Transportation Plan. Bahr Worley shared that this charging infrastructure is geared toward passenger vehicles, so NDOT does not envision that it could be shared with nearby public transit vehicles. When asked about the potential for smaller paratransit vehicles to qualify as passenger vehicles, Bahr Worley mentioned past discussions with Douglas County's DART transit agency: NDOT and DART were hypothesizing about the possibility of a DART van or cutaway bus topping up at an NDOT charger in front of the Douglas Senior Center while the passengers are using the facility. The charger would need to have another port that the general public could use. Although this project never came to fruition because of disruptions from COVID-19, NDOT's openness to potential infrastructure sharing of this nature is notable.

Bahr Worley highlighted that a challenge in collaborating with other entities to build chargers is the differences in standards. NV Energy's charging standards do not always align with NDOT's National Electric Vehicle Infrastructure Formula Program (NEVI) standards.

Bahr Worley expressed that in the future NDOT could deliberate the merits of building a hydrogen fueling station. However, hydrogen is not particularly popular at the moment. Smaller entities are struggling to transition to hydrogen fuel.

This conversation also covered the challenges of public perception. Bahr Worley mentioned that getting public buy-in can be a challenge. In Clark County, NDOT found that some people would get upset about the installation of electric vehicle chargers because the community does not drive those vehicles; they would rather the investment go into improving the roads. This part of the conversation highlighted the importance of communicating the benefits of electrification projects to the public.

A.2.2 Utility Provider – NV Energy

An interview with Brett Jenkins, a senior project manager at NV Energy on March 14, 2024, provided valuable insights into the electrification efforts for the JAC transit yard as well as NV Energy's larger electrification plans for the Carson City area. Jenkins detailed NV Energy's processes and support systems for developing electric vehicle infrastructure, emphasizing the importance of submitting comprehensive load data to understand project scope and to deliver their utility-side upgrades to local infrastructure on schedule.

Preliminary load information was sent to NV Energy later, and they confirmed the availability of power near the JAC Yard to feed all necessary new infrastructure for Phase 1 and Phase 2. NV Energy also performs the work and has transformers in stock to upgrade the electrical infrastructure without waiting for extended transformer lead times. This will allow electrical contractors to come in and finish work on schedule before the buses are delivered.

Jenkins addressed the substantial costs and long-term planning needed to upgrade distribution systems to meet future power demands of the region. Jenkins described their planning to evaluate power requirements as more homes get residential vehicles but noted that costs for residential charging have held back expansion in the area. NV Energy is watching the development and keeping up with substation upgrades locally to provide enough power as the requirements change.

The potential collaboration with NDOT and the use of NEVI funds for new charging stations were explored, with Jenkins explaining NV Energy's Transportation Electrification Plan and its alignment with NEVI compliance. Jenkins discussed the strategic planning and funding aspects, including the importance of securing site hosts for charging stations and understanding financial incentives. Most of this work is for public charging. It was noted that CAMPO could use these NEVI chargers but would not be able to reserve them or utilize these chargers with any higher a priority than the general public. Jenkins also provided insights into NV Energy's monitoring of electric vehicle market trends, the impact of remote work on energy demand, and innovative approaches like bidirectional charging and submetering trials. Engaging the community on charger locations and the transition to electric vehicles was highlighted as essential for successful implementation.

Key takeaways from this outreach are:

- Long-term planning and substantial financial investment are required to upgrade distribution systems to meet future power demands.
- NV Energy offers support in outlining costs and timelines, aiding in the evaluation of site viability. Reach out to NV Energy during early phases of design and construction to ensure power is set up on schedule.
- Collaboration with NDOT and leveraging NEVI funds are potential pathways for expanding charging infrastructure in the future. Most NEVI chargers are for public use and would be difficult to share with CAMPO. NEVI chargers would be 150 kilowatt direct current fast chargers (DCFCs) and one may be near the hospital on the north side of Carson City.
- Community education and engagement are essential for the successful transition to electrified transit.
- Keeping chargers under warranty has made maintenance easier. It is more critical to keep up with the maintenance of DCFCs as they are much more expensive. In their experience, smaller Level 2 AC chargers are typically just replaced.

A.2.3 Carson City Regional Transportation Stakeholder Coalition

The Carson City Regional Transportation Stakeholder Coalition (RTSC) is an informal group of individuals that meets periodically to discuss transportation issues, concepts, and projects. These individuals represent the values of various stakeholder groups including the Carson City Regional Transportation Commission, Carson City School District, the Citizens' Climate Lobby, the Western Nevada Development District, Carson City Parks and Recreation, the Carson City Planning Commission, the Carson City Board of Supervisors, and various other transportation related groups.

The RTSC was asked to give their input during a live poll facilitated over Microsoft Teams on March 20, 2024, and were given the opportunity to provide additional details via a Google Forms webform submission on April 8, 2024. The questions covered various elements of the zero-emission transition and the transit system in general, including:

- Topics specific to the zero-emission transition including what elements of the transition will pose the biggest challenges, influential trends in the transition, and community advocates that can help JAC get community buy-in for the transition
- Topics related to transit more generally including concerns of ridership/non-ridership, challenges/approaches to meet ridership needs, challenges for ridership/non-ridership to stay informed, and effective methods to communicate with ridership/non-riders

Individuals expressed that since zero-emission buses are a new idea for the region, they are still early in the learning process of understanding more about the benefits/implications of a zero-emission transition. They generally expressed support of the transition because of alignment with regional plans but highlighted various elements as potential challenges. This included concerns about vehicle performance (especially in cold weather), balancing charging needs with schedule demands, and difficulties with charging infrastructure suppliers. When asked to share which elements they felt would transition smoothly, respondents expressed confidence that impacts to operational elements, like fleet maintenance, would be manageable with sufficient planning. Several members also expressed confidence that JAC's stakeholders and partners will collaborate in the planning to move forward with the transition.

Regarding elements of the transit system that are not specific to the zero-emission transition, the following are a selection of the popular sentiments: infrastructure support during inclement weather is a challenge in meeting the needs of all transit riders, a difficulty faced by non-riders is knowing where to get information related to the transit system as well as how to provide feedback, and online news specific to Carson City would be an effective method of communicating with transit riders.

In addition to providing insight into effective methods of communication for JAC to leverage, the RTSC was asked to share the names of community advocates that JAC can partner with to get project buy-in.

Appendix B– Geographic Information System Maps

The subsequent figures provide the JAC routes in relation to the senior population, minority population, limited English population, and people with disabilities population.

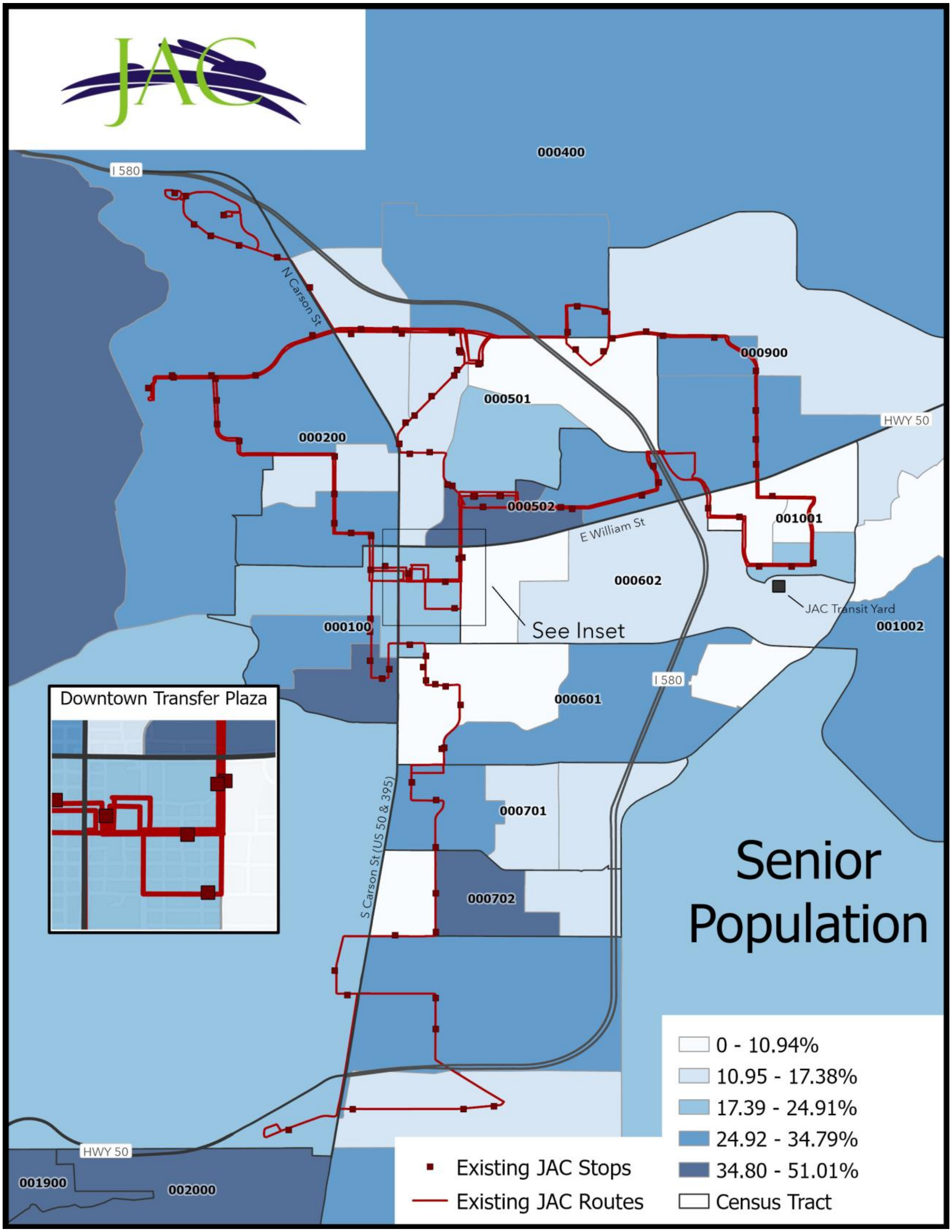

Figure 12: Jump Around Carson Fixed Routes in Relation to Carson City's Senior Population

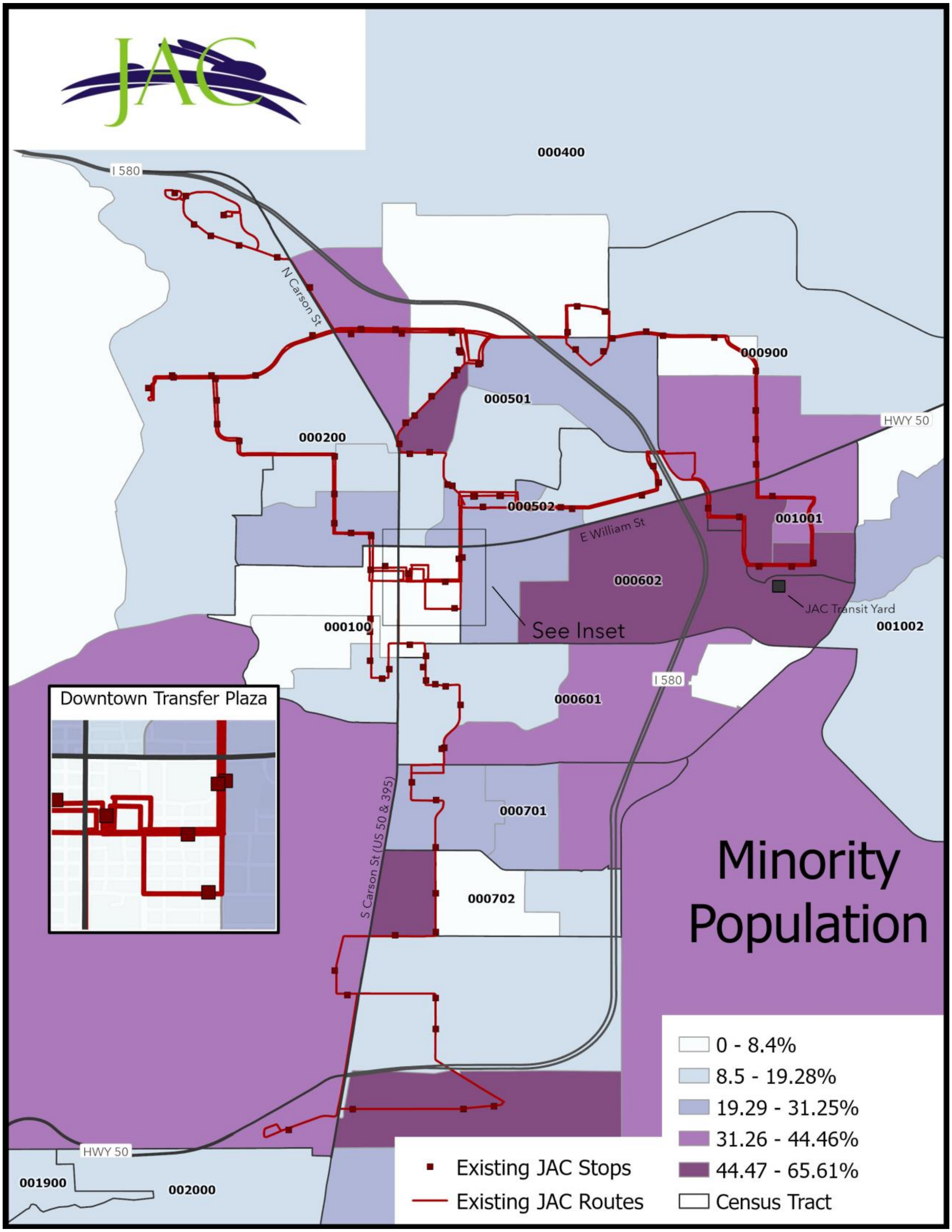

Figure 13: Jump Around Carson Fixed Routes in Relation to Carson City's Minority Population

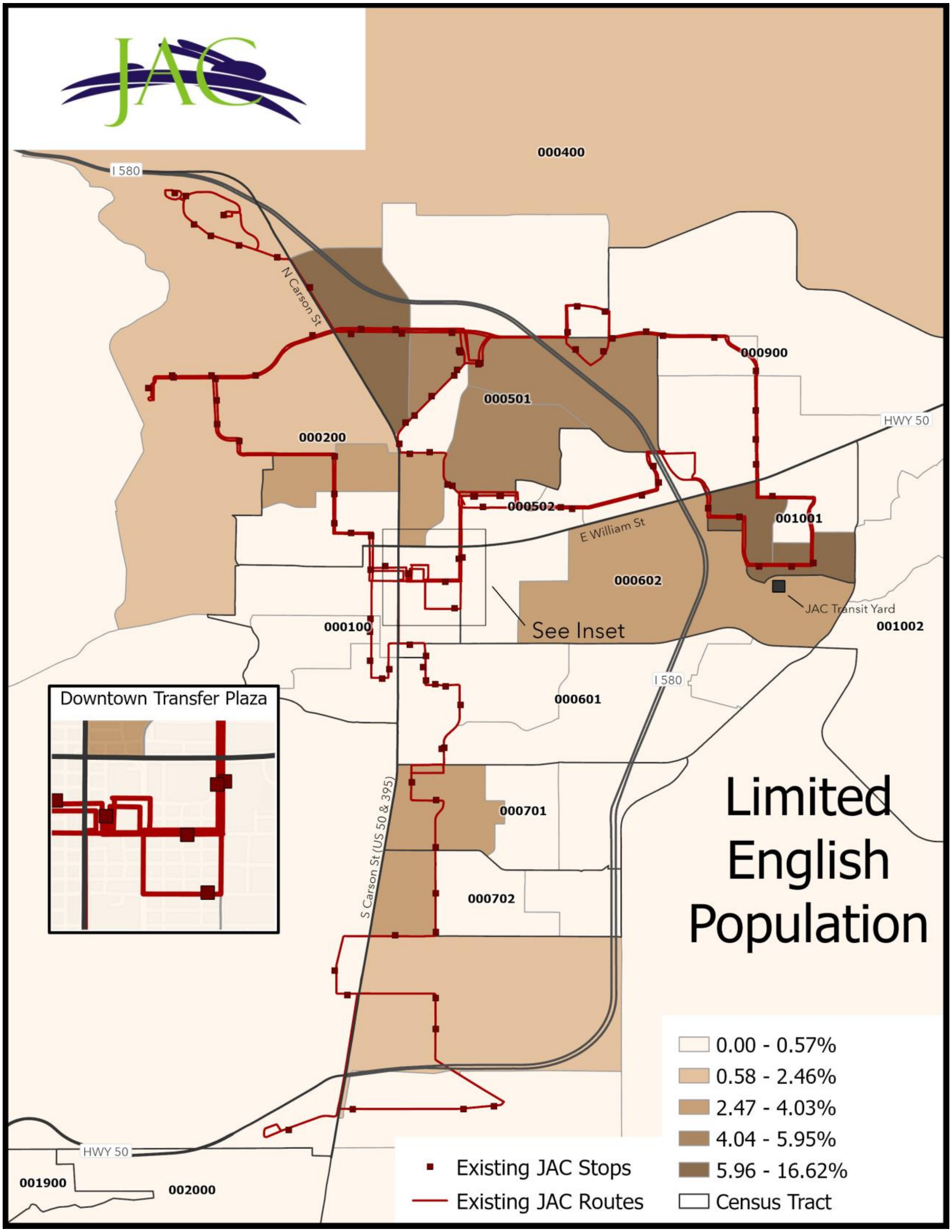

Figure 14: Jump Around Carson Fixed Routes in Relation to Carson City's Limited English Population

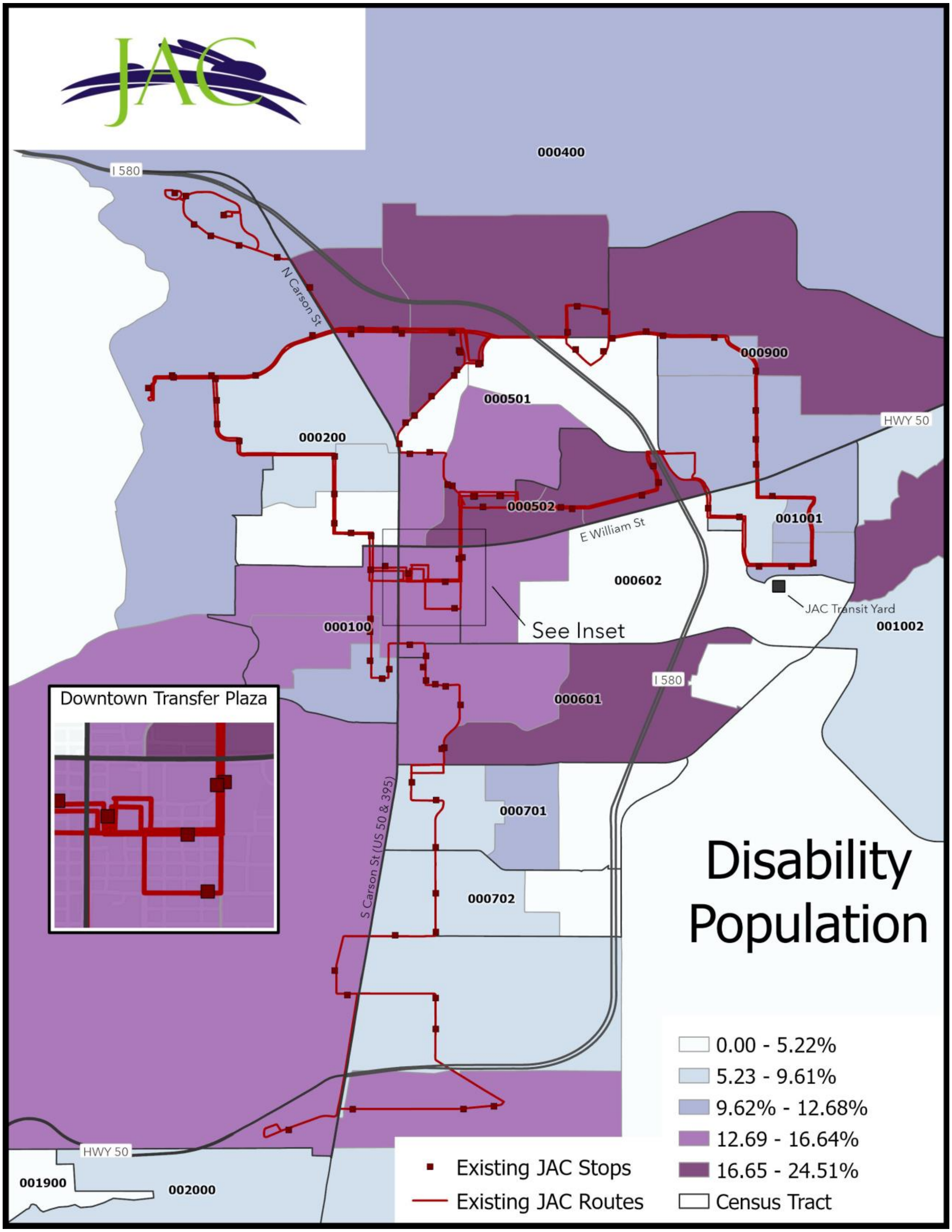

Figure 15: Jump Around Carson Fixed Routes in Relation to Carson City's Population of People with Disabilities

Appendix C – Outreach Methods

The following are recommended outreach methods (for sharing information and/or collecting feedback), target locations, and engagement considerations:

Tailored Formal Presentation, Dedicated Meeting

Methods: Lunch and learns, town halls

Target locations: In person, virtual

Considerations: A standard slide deck can be easily customized for the audience, an initial group meeting could be arranged for similar stakeholders (e.g., all regional transit agencies), a presentation roadshow can help maintain outreach momentum

Printed/Physical Marketing

Methods: Leaflets for distribution at events, flyers for bulletin boards, mailers (e.g., inserts into water/electric bills), freestanding banners, advertisements in newsletters, advertisements in newspapers, on-bus advertisements

Target locations: Downtown Transfer Plaza, community centers (e.g., Carson City Senior Center, Carson City Community Center), medical centers (e.g., Carson Tahoe Regional Medical Center), churches

Considerations: Use quick-response codes (QR codes) to direct stakeholders to locations they can learn even more or provide feedback, advertise in-person events

Digital Marketing

Methods: Advertisements, online surveys, virtual public input sessions, push notifications, press release

Target locations: Websites (Carson Now, Carson.org, JAC webpage), social media sites (e.g., Facebook, Nextdoor application), email (e.g., a mailing list used for transit updates), JAC's transit app, radio, TV

Considerations: Digital methods are good ways to make announcements in advance of in-person events, social media posts can be used more regularly than other methods, interactive elements and infographics increase engagement with digital methods

Events

Methods: Tabling, ride-alongs or other vehicle demonstrations, opinion polls/surveys, activities or games (e.g., trivia)

Target locations: Carson City Senior Center, Carson City Community Center, Downtown Transfer Plaza, events hosted by community groups (e.g., Muscle Powered, Carson City Chapter of Citizens' Climate Lobby, Carson City School District parent-teacher associations, homeowner associations), Carson City Farmers Market, holiday celebrations (e.g., Fourth of July celebration)

Considerations: Community groups can act as a mouthpiece to spread the message to the larger public