The Livermore Amador Valley Transit Authority (LAVTA)

Zero-Emission Bus Rollout Plan

Prepared by Center for Transportation and the Environment

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List of Abbreviations

ADA: Americans with Disabilities Act
A&E: Architecture and Engineering
ACTC: Alameda County Transportation Commission
BEB: Battery Electric Bus
CA: California
CARB: California Air Resources Board
CNG: Compressed Natural Gas
COVID/COVID-19: Coronavirus Disease 2019 (SARS-CoV-2)
CTE: Center for Transportation and the Environment
DAC: Disadvantaged Community
FCEB: Fuel Cell Electric Bus
HVAC: Heating, Ventilation, and Air Conditioning
ICE: Internal Combustion Engine
ICT: Innovative Clean Transit
kW: Kilowatt
kWh: Kilowatt-Hour
LAVTA: Livermore Amador Valley Transit Authority
MTC: Metropolitan Transportation Commission
MV: MV Transportation
MW: Megawatt
OEM: Original Equipment Manufacturer
OET: Operator Excellence Training
PM: Particulate Matter
PPI: Producer Price Index
RCNG: Renewable Compressed Natural Gas
RFP: Request for Proposals
SCE: Southern California Edison (SoCal Edison)
TDA: Transportation Development Act
VTT: Verification of Transit Training
ZEB: Zero-Emission Bus
A glossary of useful terms can also be found in Appendix C – Glossary

Executive Summary

Livermore Amador Valley Transit Authority (LAVTA) provides transportation services to communities in Alameda County and the cities of Dublin, Livermore, and Pleasanton. LAVTA's mission is "to provide equal access to a variety of safe, affordable and reliable public transportation choices, increasing the mobility and improving the quality of life of those who live or work in and visit the Tri-Valley area." LAVTA's bus service provides key transportation access to the state-designated low-income community of North Livermore.

LAVTA currently operates 60 diesel-hybrid buses of varying sizes: 30-ft., 35-ft., and 40-ft. buses. LAVTA has future plans to expand to a 68-bus fleet. The paratransit service is currently operated by a third party and uses sedans and accessible vans.

Based on outcomes of the transition planning study completed by the Center for Transportation and the Environment (CTE), LAVTA plans to transition its fleet entirely to fuel cell electric buses (FCEB). By 2034, LAVTA expects to operate a zero-emission fleet of 68 40-ft. FCEBs. The paratransit service was excluded from LAVTA's ZEB Transition Plan at this time as sedans and vans are currently exempt from the ICT Regulation.

All of LAVTA's services operate out of a single operations/maintenance/administrative facility at 1362 Rutan Court in Livermore, California. The population grow in the Tri-Valley is expected to increase by 50 percent by 2040, it is expected LAVTA will increase service proportionately for the same period. For this reason, LAVTA is conducting site planning for a new depot, which will be designed to accommodate the storage, maintenance, and fueling of up to 120 FCEBs. LAVTA has also developed a contingency plan for maintaining and fueling FCEBs at the current facility should construction of the new depot lag behind bus procurement. The agency estimates that pursuing a ZEB fleet in place of an ICE fleet will cost an additional $61.8 million in bus and infrastructure costs between 2021 and 2034.

To support this fleet transition process, LAVTA will build upon an existing training protocol to provide the necessary FCEB-specific training. LAVTA also plans to pursue funding opportunities at the federal, state, and local levels. which will require significantly more funding opportunities.

A

Transit Agency Information

LAVTA Profile

Livermore-Amador Valley Transit Authority (LAVTA) operates the *Wheels* bus system and provides bus services to communities in Alameda County and the cities of Dublin, Livermore, Pleasanton. The agency operates 29 fixed-service bus routes and door-to-door service for disabled riders and partners with Uber and Lyft for riders to supplement bus services. Before the COVID-19 pandemic, LAVTA provided 7,500 rides per day on fixed-route service and 150 trips per day on paratransit. LAVTA is currently operating at approximately 70 percent of pre-pandemic levels of service and is planning to increase service as demand increases over the next several years.

LAVTA currently has one depot, located on Rutan Court. LAVTA expects to move to a new facility located at Atlantis Court by 2025.

1. LAVTA Current Facility: 1362 Rutan Court, Livermore, CA 94551
2. LAVTA Future Facility: 875 Atlantis Court, Livermore, CA 94551

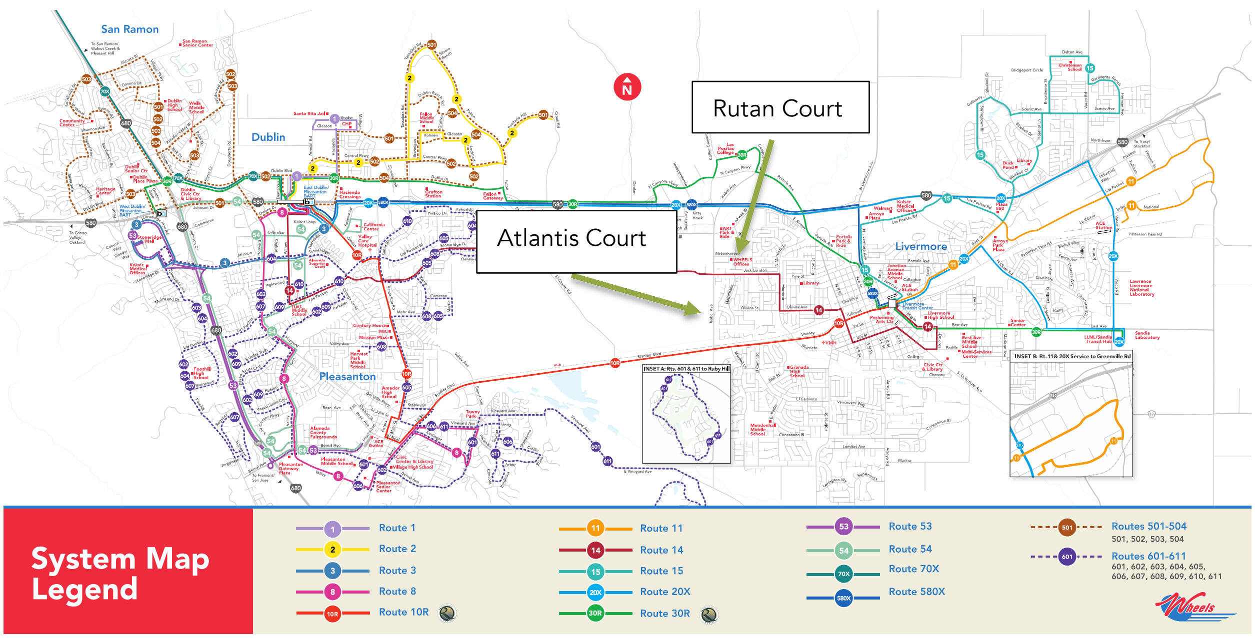

Figure 1 - LAVTA System Map Highlighting Facility Locations

LAVTA Basic Information

Transit Agency's Name:
Livermore-Amador Valley Transit Authority

Mailing Address:
Livermore-Amador Valley Transit Authority
1362 Rutan Court, Suite 100
Livermore, CA 94551

Transit Agency's Air Districts:
San Francisco Bay Area

Transit Agency's Air Basin:
San Francisco Bay Area

Total Number of Buses in Annual Maximum Service:
60 diesel-hybrid buses and 9 paratransit vehicles (sedans and accessible vans)

Urbanized Area:
40 square miles

Population of Urbanized Area:
238,310 people

Contact Information for Inquiries on the LAVTA ICT Rollout Plan:
Toan Tran, *Director of Operations and Innovation*
ttran@lavta.org

Is your transit agency part of a Joint Group?
No

LAVTA's Sustainability Goals

LAVTA has developed a plan to transition to a fully fuel cell electric bus (FCEB) fleet by 2034, which exceeds the Innovative Clean Transit (ICT) goal of 2040 by six years. LAVTA has committed to purchasing exclusively zero-emission vehicles beginning in 2025, demonstrating the agency's commitment to reducing emissions. In line with the environmental values of LAVTA's Short Range Transit Plan (SRTP), expediting the plan is a means to improve air quality and conserve natural resources. This initiative also contributes to the SRTP's goal for community and economic development, by advocating for increased transit-oriented developments while responding to the SB 375 directive to address climate change and reduction of greenhouse gases (GHG).

The LAVTA Board has been fully supportive throughout the development of the FCEB transition plan. The cities of Dublin, Livermore, and Pleasanton, and also Alameda County, have all adopted Climate Action Plans that strategize to meet GHG reduction targets, ultimately benefiting communities through cleaner air, greater independence from fossil fuels, and more environmental sustainability.

B

Rollout Plan General Information

Overview of the Innovative Clean Transit Regulation

On December 14, 2018, CARB enacted the Innovative Clean Transit (ICT) regulation, setting a goal for California public transit agencies to have zero-emission bus fleets by 2040. The regulation specifies the percentage of new bus procurements that must be zero-emission buses for each year of the transition period (2023–2040). The annual percentages for Small Transit agencies are as follows:

ICT Zero-Emission Bus Purchase Requirements for Small Agencies:

January 1, 2026 - 25% of all new bus purchases must be zero-emission

January 1, 2027 - 25% of all new bus purchases must be zero-emission

January 1, 2028 - 25% of all new bus purchases must be zero-emission

January 1, 2029+ - 100% of all new bus purchases must be zero-emission

March 2021-March 2050 – Annual compliance report due to CARB

This purchasing schedule guides agency procurements to realize the goal of zero-emission fleets in 2040 while avoiding any early retirement of vehicles that have not reached the end of their 12-year useful life. Agencies have the opportunity to request waivers that allow purchase deferrals in the event of economic hardship or if zero-emission technology cannot meet the service requirements of a given route. These concessions recognize that zero-emission technologies may cost more than current internal combustion engine (ICE) technologies on a vehicle lifecycle basis and that zero-emission technology may not currently be able to meet all service requirements.

LAVTA’s Rollout Plan General Information

LAVTA’s Rollout Plan achieves a zero-emission fleet ahead of the ICT’s 2040 target. The last of the agency’s diesel-hybrid buses will reach end of life in 2033.

Rollout Plan’s Board Approval Date: April 4, 2022

Resolution No. (optional): 12-2022

Is a copy of the Board-approved resolution attached to the Rollout Plan? Yes, a copy of the Board-approved resolution in included as **Appendix A** – Approved Board Resolution

Contact for Rollout Plan follow-up questions:

Toan Tran, *Director of Operations and Innovation*
ttran@lavta.org

Livermore/Amador Valley Transit Authority
1362 Rutan Court, Suite 100
Livermore, CA 94551

Who created the Rollout Plan?

LAVTA with assistance from the Center for Transportation and the Environment (CTE).

LAVTA created their ICT Rollout Plan in combination with its Zero-Emission Bus Transition Master Plan, which explains LAVTA's plans for transition in greater detail. The Master Plan will be maintained and updated annually. As a result of CTE's fleet transition planning methodology described herein and in greater detail in the Master Plan, LAVTA decided to pursue a zero-emission fleet comprised of all fuel cell electric buses (FCEB). LAVTA's fleet transition strategy is to replace each ICE bus with an FCEB as they reach the end of their useful life, thus avoiding the early retirement of ICE buses.

This document, the ICT Rollout Plan, contains the information for LAVTA's zero-emission fleet transition trajectory as requested by the ICT Regulation. It is intended to outline the high-level plan for implementing of the transition. The Rollout Plan provides estimated timelines based on information on bus purchases, infrastructure upgrades, workforce training, and other developments and expenses that was available at the time of writing. LAVTA may update the Rollout Plan as needed as the industry continues to develop and as the Master Plan is updated.

C

Technology Portfolio

ZEB Transition Technology Selection

LAVTA has elected to pursue an FCEB Only fleet. The fleet is projected to be zero-emission in 2034 when it will be comprised of 68 40' FCEBs. As detailed below, LAVTA explored three possible ZEB transition scenarios: BEB Only, Mixed Fleet (BEB & FCEB), and FCEB Only. LAVTA decided against a BEB Only fleet due to the limited range of the vehicles and the difficulty of adding on-route chargers which would be required to meet the agency's service energy. LAVTA also decided not to pursue a fleet composed of both BEB and FCEB technologies since such a fleet would require the construction of infrastructure to support fueling and maintaining both technologies at the depot. This would present would be a spatial and land acquisition challenge. Also, having a small group of mechanics maintaining three technologies would pose an insurmountable challenge. A Mixed Fleet would also complicate block assignment at pullout since there would be certain blocks that could only be run by FCEBs. Although the FCEB Only scenario appeared to be slightly more expensive than the other scenarios when using 2022 pricing as the basis for fuel and fleet capital cost estimates, this technology is also newer and the agency is confident that the prices will reduce over time. LAVTA also plans to participate in the LCFS credit program, which will help offset the agency's fuel costs. LAVTA's decision to pursue an FCEB Only fleet was also encouraged by the developments in the hydrogen and FCEB markets outlined above, as well as their board and the local community.

Local Developments and Regional Market

California has become a global leader for zero-emission buses, as well as the zero-emission fuel and fueling infrastructure required to support these vehicles. California is home to four bus OEMs that manufacture zero-emission buses. Although three of these OEMs do not currently build FCEBs, growing demand for this vehicle technology may encourage these manufacturers to enter the market.

California has one of the most mature hydrogen fueling network in the nation. The state legislature has fostered growth in zero-emission fuels through the state's Low-Carbon Fuel Standard (LCFS) program, which incentivizes the consumption of fuels with a lower carbon intensity than traditional combustion fuels. California's hydrogen market has developed to support the growing number of fuel cell electric vehicles on the roads in the state. California has four medium-and-heavy-duty fueling stations in operation and four more in development. Additionally, the number of hydrogen production and distribution centers is growing to meet increased hydrogen demand as it gains popularity as a transportation fuel. One of these distribution centers, operated by First Element Fuel, is located in Livermore, CA, which is also where LAVTA's depot is located.

ZEB Transition Planning Methodology

LAVTA's ICT Rollout Plan was created in combination with LAVTA's ZEB Transition Master Plan, utilizing CTE's ZEB Transition Planning Methodology. CTE's methodology consists of a series of assessments that enable transit agencies to understand what resources and decisions are necessary to convert their fleets to zero-emission technologies. The results of the assessments help the agency decide on a step-by-step process to achieve its transition goals. These assessments consist of data collection, analysis, and modeling outcome reporting stages. These stages are sequential and build upon findings in previous steps. The assessment steps specific to LAVTA's Rollout Plan are outlined below:

1. Planning and Initiation
2. Requirements Analysis & Data Collection
3. Service Assessment
4. Fleet Assessment
5. Fuel Assessment
6. Facilities Assessment
7. Maintenance Assessment
8. Total Cost of Ownership Assessment

For **Requirements Analysis & Data Collection,** CTE collects data on the agency's fleet, routes and blocks, operational data (e.g., mileage and fuel consumption), and maintenance costs. Using this data, CTE establishes service requirements to constrain the analyses in later assessments and produce agency-specific outputs for the zero-emission fleet transition plan.

The **Service Assessment** phase initiates the technical analysis phase of the study. Using information collected in the Data Collection phase, CTE evaluates the feasibility of using zero-emission buses to provide service to the agency's routes and blocks over the transition plan timeframe from 2021 to 2040. Results from the Service Assessment are used to guide ZEB procurement plans in the Fleet Assessment and to determine energy requirements in the Fuel Assessment.

The **Fleet Assessment** projects a timeline for the replacement of existing buses with ZEBs that is consistent with LAVTA's existing fleet replacement plan and known procurements. This assessment also includes a projection of fleet capital costs over the transition timeline and is optimized to meet state mandates or agency goals, such as minimizing cost or maximizing service levels.

The **Fuel Assessment** merges the results of the Service Assessment and Fleet Assessment to determine annual fuel requirements and associated costs. The Fuel Assessment calculates energy costs through the full transition timeline for each fleet scenario, including the agency's existing fossil-fuel buses. To more accurately estimate battery electric bus (BEB) charging costs, a focused Charging Analysis is performed to simulate daily system-wide energy use. As older technologies are phased out in later years of the transition, the Fuel Assessment calculates the changing fuel requirements as the fleet transitions to ZEBs. The Fuel Assessment also provides a total fuel cost over the transition timeline.

The **Facilities Assessment** determines the infrastructure necessary to support the projected zero-emission fleet composition over the transition period based on results from the Fleet Assessment and Fuel Assessment. This assessment evaluates the required quantities of charging infrastructure and/or hydrogen fueling station projects and calculates the costs of infrastructure procurement and installation sequenced over the transition timeline.

The **Maintenance Assessment** calculates all projected fleet maintenance costs over the transition timeline. Maintenance costs are calculated for each fleet scenario and include costs of maintaining existing fossil-fuel buses that remain in the fleet and maintenance costs of new BEBs and FCEBs.

The **Total Cost of Ownership Assessment** compiles results from the previous assessment stages to provide a comprehensive view of all fleet transition costs, organized by scenario, over the transition timeline.

Requirements Analysis & Data Collection

The Requirements Analysis and Data Collection stage begins by compiling operational data from LAVTA regarding its current fleet and operations and establishing service requirements to constrain the analyses in later assessments. CTE requested data such as fleet composition, fuel consumption and cost, maintenance costs, and annual mileage from LAVTA to use as the basis for analyses. CTE also collected GPS data from a representative sample of LAVTA's routes, which was used as the basis for modelling energy efficiencies for BEBs operating in LAVTA's service area. The calculated efficiencies were then used in the Service Assessment to determine the energy requirements of LAVTA's service.

CTE evaluated BEBs and FCEBs in LAVTA's service to support LAVTA's technology selection. The range of FCEBs, however, does not have the same level of sensitivity to environmental and operating conditions as BEBs. After collecting route and operational data, CTE determined that LAVTA's longest block is 305 miles long. Based on observed performance, CTE estimates FCEBs are able to complete any block under 350 total miles, which means that FCEB technology already has the capability to meet LAVTA's service requirements. Although FCEBs were determined to have the capability of serving all of LAVTA's routes, LAVTA did not have a full picture of which technology or combination of technologies would be the best fit for the agency at this stage of the analysis, so it was necessary to determine how much of LAVTA's service could feasibly be served by depot-only charged BEBs in order to develop a set of ZEB transition scenarios that would allow the agency to make an informed decision on what technology or technologies would be most suitable to the agency's needs.

The energy efficiency and range of BEBs are primarily driven by bus specifications, such as on-board energy storage capacity and vehicle weight. Both metrics are affected by environmental and operating variables including the route profile (e.g., distance, dwell time, acceleration, sustained top speed over distance, average speed, and traffic conditions), topography (e.g., grades), climate (e.g., temperature), driver behavior, and operational conditions such as passenger loads and auxiliary loads. As such, BEB efficiency and range can vary dramatically from one agency to another or even from one service day to another. It was therefore critical for LAVTA to determine efficiency and range estimates based on an accurate representation of its operating conditions.

To understand BEB performance on LAVTA's routes, CTE modeled the impact of variations in passenger load, accessory load, and battery degradation on bus performance, fuel efficiency, and range. CTE ran models with different energy demands that represented *nominal* and *strenuous* conditions. Nominal loading conditions assume average passenger loads and moderate temperature over the course of the day, which places low demands on the motor and heating, ventilation, and air conditioning (HVAC) system. Strenuous loading conditions assume high or maximum passenger loading and near maximum output of the HVAC system. This nominal/strenuous approach offers a range of operating efficiencies to use for estimating average annual energy use (nominal) or planning minimum service demands (strenuous). Route modeling ultimately provides an average energy use per mile (kilowatt-hour/mile [kWh/mi]) for each route, bus size, and load case.

In addition to loading conditions, CTE modeled the impact of battery degradation on a BEB's ability to complete a block. The range of a battery electric bus is reduced over time due to battery degradation. A BEB may be able to service a given block with beginning-of-life batteries, while later it may be unable to complete the entire block at some point in the future as batteries near their end-of-life or derated capacity (typically considered 70-80% of available service energy).

Service Assessment

Given the conclusion that FCEBs could meet the range requirements for LAVTA's service, the Service Assessment focused on evaluating the feasibility of BEBs in LAVTA's service. The efficiencies calculated in the Requirements Analysis & Data Collection stage were used to estimate the energy requirements of LAVTA's service. The main focus of the Service Assessment is called the block analysis, which determines if generic battery electric technology can meet the service requirements of a block based on range limitations, weather conditions, levels of battery degradation and route specific requirements. The Transit Research Board's Transit Cooperative Research Program defines a block as "the work assignment for only a single vehicle for a single service workday".[1] A block is usually comprised of several trips on various routes. The energy needed to complete a block is compared to the available energy of the bus assigned to service the block. If the bus's usable onboard energy exceeds the energy required by the block, then the conclusion is that the BEB can successfully operate on that block.

The Service Assessment projects the performance of a BEB that is charged overnight at the depot and operates on LAVTA's service schedule at the time of the plan's writing. The results are used to determine if or when along the transition timeline, a fleet of overnight depot-charged BEBs can feasibly serve LAVTA's territory or if another zero-emission technology is required to maintain service. This information can then be used to inform the scale and timing of BEB procurements in the Fleet Assessment.

Modeling & Procurement Assumptions

CTE and LAVTA defined the following assumptions and requirements used throughout the study:

- The Service Assessment energy profile assumed a 5% improvement in battery capacity every two years with a starting battery capacity of 530 kWh, which was the average battery capacity seen in commercially-available buses in 2022.
- This analysis also assumed LAVTA will maintain blocks in a similar distribution of distance, relative speeds, and elevation changes to pre-COVID-19 service because buses will continue to serve similar locations within the service area and general topography remains constant even if specific routes and schedules change.

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[1] TRB's Transit Cooperative Research Program. 2014. TCRP Report 30: Transit Scheduling: Basic and Advanced Manuals (Part B). https://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_30-b.pdf

- Fleet size and vehicle length distribution change over time to incorporate LAVTA's planned adjustments, which include adding eight buses—expanding the fleet from 60 to 68 buses—and replacing 30' and 35' buses with 40' buses going forward.
- Buses are assumed to operate for a 12-year service life.
- Usable on-board energy is assumed to be that of a mid-life battery (10% degraded) with a reserve at both the high and low end of the battery's charge potential. As previously discussed, battery age affects range, so a mid-life battery was assumed as the average capacity of the battery's service life. Charging batteries to 100% or dropping the charge below 10% also degrades the batteries over time, which is why the analysis assumes that the top and bottom portions of the battery are unusable.
- CTE accounts for battery degradation over the transition period with the assumption that LAVTA can rotate the ZEBs to battery capacity to block energy requirements. As the zero-emission fleet transition progresses, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding blocks to account for battery degradation in BEBs over time. LAVTA can rotate the fleet to meet demand, assuming there is a steady procurement of BEBs each year to match service requirements. CTE accounts for this variability in battery age by using a mid-life usable battery capacity to determine block feasibility.

Results

The Service Assessment determines the timeline for when LAVTA's service may become achievable by BEBs on a single depot charge. Coupled with the FCEB range-to-block length comparison, the block analysis determines when, or if, a full transition to BEBs or FCEBs may be feasible. LAVTA and CTE can then use these results to inform ZEB procurement decisions in the Fleet Assessment. Results from this analysis are also used to determine the specific energy requirements and fuel consumption of the fleet over time. These values are then used in the Fuel Assessment to estimate the costs to operate the transitioning fleet.

While routes and block schedules are unlikely to remain the same over the course of the transition period, these projections assume the blocks will maintain a similar distribution to current service because LAVTA will continue to serve similar destinations within the city. This core assumption affects energy use estimates and block achievability in each year.

The results of LAVTA's Service Assessment can be seen below in **Figure 2**. Based on CTE's analysis, 58% of LAVTA's blocks could be served by a single charge of a depot-only BEB and with the assumed 5% improvement every 2 years, 88% of LAVTA's blocks could be served by this technology by 2040, which would leave 12% of LAVTA's service infeasible with an overnight charged BEB.

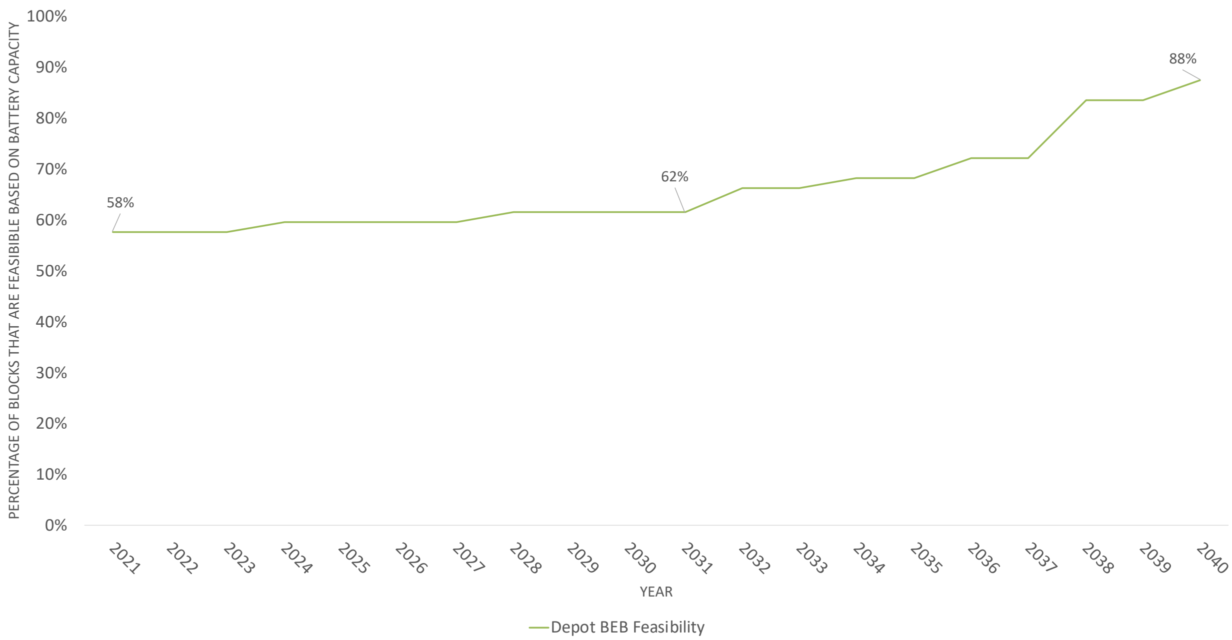

Figure 2 – BEB Block Achievability Percentage by Year

As noted previously, FCEBs are assumed to be able to complete any block under 350 total miles and LAVTA's longest block is 305 miles long, which means that FCEB technology already has the capability to meet LAVTA's service requirements.

Description of ZEB Technology Solutions Considered

The Service Assessment identified that 12% of LAVTA's blocks would not be feasible with today's BEB technology on a single charge, so CTE developed two transition scenarios that provide zero-emission solutions for serving the more energy-intensive blocks by supplementing the range of BEBs, as well as a third scenario that would entirely avoid the range limitations of BEBs. The scenarios are: (a) BEB Only, which includes on-route charging, (b) Mixed Fleet, which assumed BEBs would be deployed on the blocks that could be served by with the onboard energy of an overnight depot-charged BEB and that FCEBs would be deployed on the longer blocks, and (c) an FCEB Only scenario, in which FCEBs would serve every route because they meet LAVTA's range requirements for every route.

CTE developed the BEB Only scenario to model a fleet consisting entirely of BEBs that could meet LAVTA's range requirements with on-route charging. Operating BEBs in LAVTA's service without on-route charging would necessitate the purchase of additional buses to act as relief buses. As shown by the Service Assessment, depot-charged BEBs cannot meet the range requirements of some routes. A relief bus would therefore be required to complete the block when the first bus returned to the depot to charge. On-route charging removes the need for additional bus purchases by extending the range of in-service buses and reducing the depot time necessary for charging. Selecting a uniform technology—battery electric, in this case—throughout the fleet allows for the installation of a single fueling technology at the depot. On-route charging faces some challenges, however, including but not limited to accessing strategic placements along the routes for chargers, modification to service to accommodate charging layovers, and the additional costs of land acquisition, equipment, and infrastructure installation.

In the Mixed Fleet scenario—BEBs and FCEBs—all of the blocks that depot-charged BEBs cannot serve due to range limitations are served by FCEBs. FCEBs have a longer range between refueling than BEBs and are capable of completing blocks that BEBs cannot. FCEBs can therefore replace ICE buses at a 1:1 ratio. FCEBs and hydrogen fuel, however, are more expensive than BEBs and electricity, so a mixed fleet allows an agency to use the less expensive BEB technology where possible and cover service needs with FCEBs only as needed. A mixed fleet may also be more resilient to service interruptions if either fuel becomes temporarily unavailable. For agencies such as LAVTA that operate only one depot, however, mixed fleets present the spatial challenge of hosting both infrastructure types in one depot.

The FCEB scenario identifies benefits and challenges associated with transitioning the entire fleet to fuel cell technology. An FCEB fleet can replace ICE buses at a 1:1 ratio. Committing to hydrogen fueling also avoids the need to install two types of fueling infrastructure and the acquisition of additional land for on-route charging. An FCEB fleet may lack the redundancy provided by diverse fuels that a mixed fleet utilizes. LAVTA's depot is located near a hydrogen distribution center, which will provide greater fuel availability in the event of fuel supply interruptions on a national scale. Finally, the cost of buses and fuel for FCEBs still exceed the comparable costs for BEBs, despite the savings in infrastructure costs for hydrogen fueling compared to the cost of chargers at scale.

D

Current Bus Fleet Composition and Future Bus Purchases

Fleet Assessment Methodology

The Fleet Assessment projects a timeline for the replacement of existing buses with FCEBs. The timeline is consistent with LAVTA's fleet replacement plan that is based on the 12-year service life of transit buses. This assessment also includes a projection of fleet capital costs over the transition timeline.

ZEB Cost Assumptions

CTE and LAVTA developed cost assumptions for future bus purchases. Key assumptions for bus costs for the LAVTA Transition Plan are as follows:

- Diesel-hybrid bus costs are based on LAVTA's most recent procurement price, and FCEB prices are based on the 2022 Metropolitan Transit Commission (MTC) Pricelist. MTC is the transportation planning, financing, and coordinating agency for the nine-counties in the San Francisco Bay Area and provides financing for transit vehicle purchases made by its agencies.
- Annual costs were not adjusted for inflation.
- Bus costs shown below are inclusive of estimates for configurable options and taxes.
- Costs for retrofits or bus conversions are not included because LAVTA does not plan to convert any diesel-hybrid buses to battery electric powertrains.

Table 1 – Fleet Assessment Vehicle Cost Assumptions

Bus Type & Length	Source	Total Price with tax (9.25%)
Diesel-Hybrid 40'	LAVTA's most recent bus procurement	$843,000
Fuel Cell 40'	2022 MTC Pricelist	$1,381,000

Description of LAVTA's Current Fleet

LAVTA's current service and fleet composition provide the baseline for evaluating the costs of transitioning to a zero-emission fleet. LAVTA staff provided the following key data on current service:

- Fleet composition by powertrain and fuel
- Routes and blocks
- Mileage and fuel consumption
- Maintenance costs

Fleet

LAVTA's fleet is currently comprised of 60 GILLIG diesel-hybrid buses. Presently, 17 of these buses are 30', 10 are 35', and 33 are 40'. All buses are housed at a 1362 Rutan Court, Livermore, CA. Buses range in age from model year 2007 to 2017. LAVTA has placed an order for 16 diesel-hybrids that are expected to enter service at the end of 2022. LAVTA's ZEB Transition Plan provides for the growth of the fixed-route fleet to 68 buses in 2025 and that all 30' and 35' buses will be replaced with 40' buses during its next procurement round.

Routes and Blocks

LAVTA's service operates 29 fixed-service routes within 103 blocks. Routes range in length from 3.1 miles to 42.2 miles and blocks range in distance from 10.9 miles to 305.0 miles. Buses pull out as early as 04:21 and return as late as 22:17. LAVTA's routes service Livermore, Dublin, Pleasanton, San Ramon and Walnut Creek.

Current Mileage and Fuel Consumption

LAVTA currently operates a diesel-hybrid fixed-route fleet.

Annual mileage of the fleet:
2.09 million miles

Annual fuel consumption:
416,000 gallons of diesel

Fleet average efficiency:
5.01 mpg

LAVTA current fuel expense:
$927,000 per year

Average diesel cost:
$2.20 per gallon

LAVTA's ZEB Transition Plan assumes that the amount of service miles will remain the same.

Diesel-Hybrid Maintenance Costs

In 2019, LAVTA spent approximately $1.8 million on scheduled and unscheduled maintenance, including both parts and labor, for the entire fleet. This results in an average maintenance cost of $0.38 per mile. Buses also undergo one engine overhaul at an average cost of $40,000 and two transmission overhauls during their lifetime at an average cost $11,000 each.

Zero-Emission Bus Procurement Plan and Schedule

FCEBs will be sufficient to meet LAVTA's service demands because they have a projected range of 350 miles. LAVTA's fleet transition strategy is to replace each diesel-hybrid bus with an FCEB as the diesel-hybrids reach the end of useful life beginning in 2025. LAVTA does not plan to retrofit any diesel-hybrids for zero-emission service. **Figure 3** provides the number of each bus type that is purchased each year through 2040 with this replacement strategy.

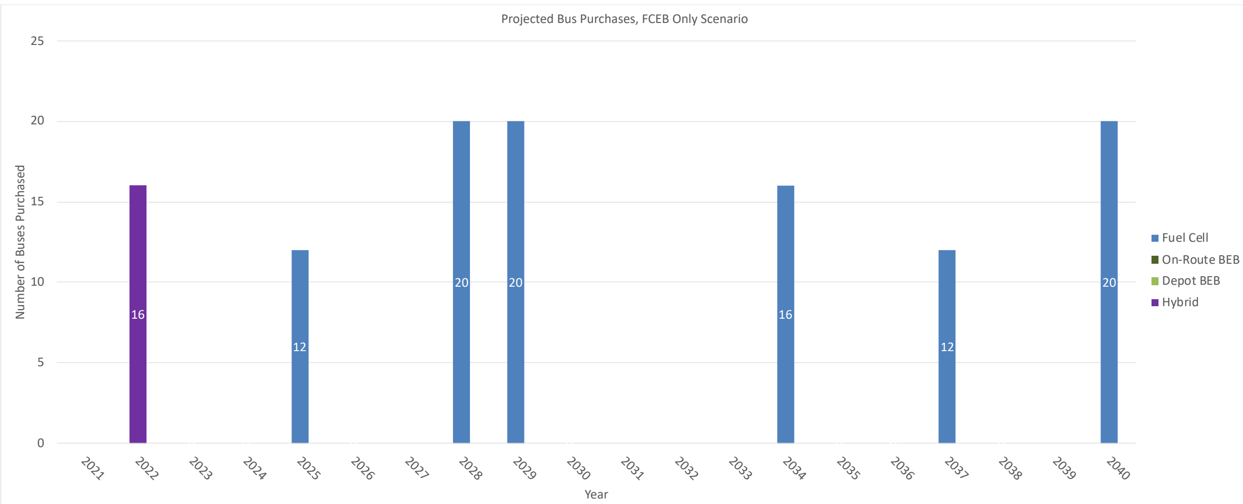

Figure 3 – Projected Bus Purchases

Figure 4 depicts the annual composition of the LAVTA fleet through 2040. By 2034, LAVTA's fleet consists entirely of FCEBs. The fleet increases by eight buses in 2025.

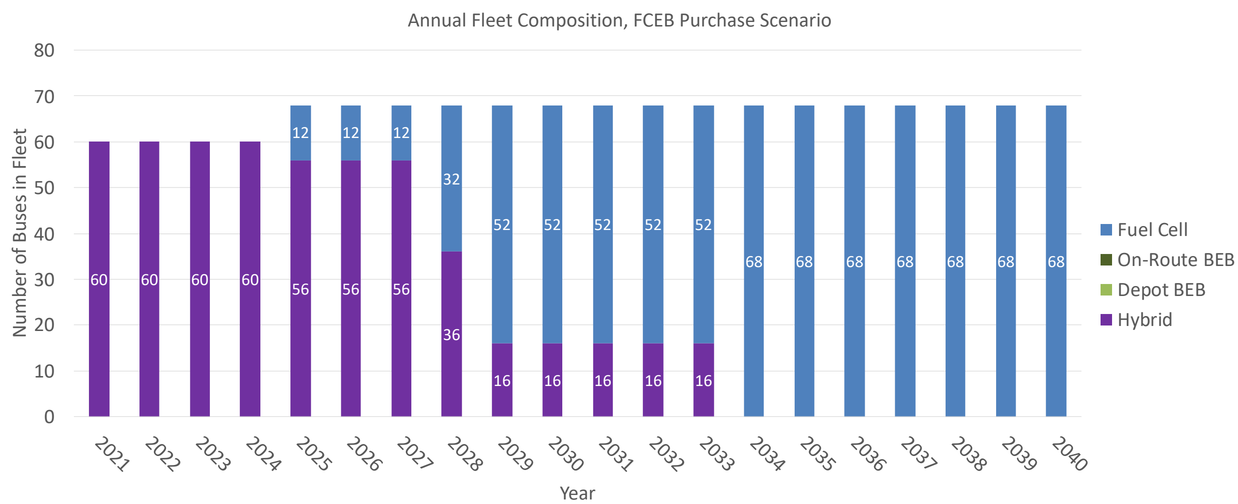

Figure 4 – Annual Fleet Composition, FCEB Only Scenario

Projected Annual Capital Costs for ZEB Purchases

The total capital cost over the entire transition period is estimated at $151.6 million, compared to the $97.7 million that would have been incurred by continuing to purchase diesel-hybrid replacement buses over that period. Costs are incurred cyclically, according to the 12-year replacement cycle of transit buses. **Figure 5** below shows the annual capital costs for all ZEBs purchased in a given year through 2040.

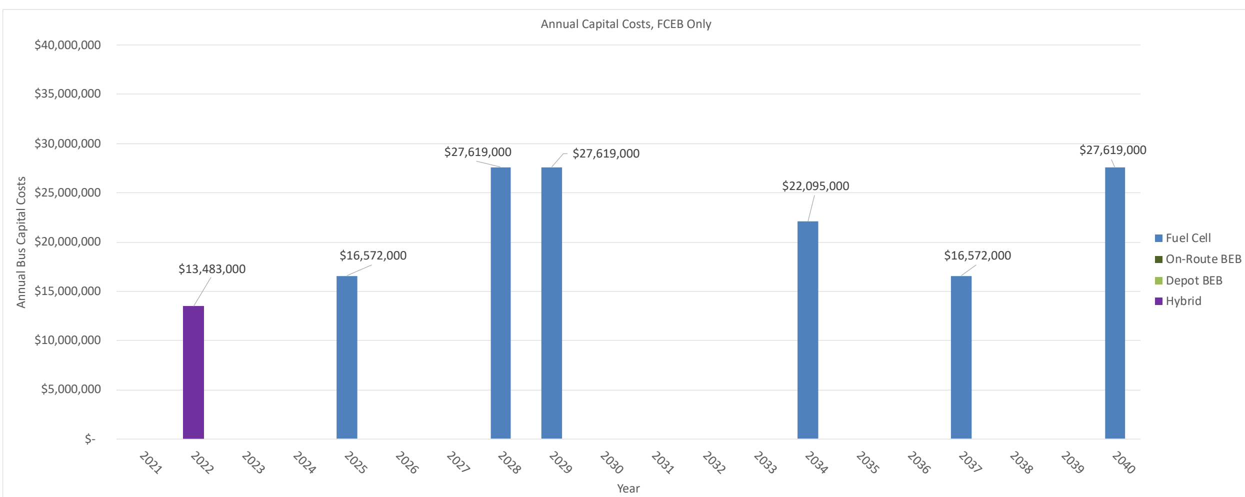

Figure 5 – Annual Capital Costs, FCEB Only Scenario

Table 2 – LAVTA Bus Capital Investment to transition to a 100% ZEB fleet by 2040

	Baseline	ZEB Incremental Costs	Total Investment
Bus Capital Costs	$97.7M	$53.9M	$151.6M

As seen in **Table 2** the capital investment for purchasing ZEBs is over $50 million higher than for diesel-hybrid buses over the transition period. This highlights the importance of staying vigilant in the search for funding opportunities to help fill this gap.

Additional Considerations

LAVTA presently purchases diesel-hybrid buses through MTC and plans to do the same for FCEBs. Although the procurement process may be similar in this respect, the agency will need to consider several factors that should be given more attention in FCEB procurements than may be needed in diesel-hybrid purchasing given that fuel cell is a newer technology. First, when contracting with an FCEB manufacturer, LAVTA should ensure expectations are clear between the bus OEM and the agency. As with a diesel-hybrid purchase the agreement should be clear regarding bus configuration, technical capabilities, build and acceptance process, production timing with infrastructure, warranties, training, and other contract requirements. Additionally, by developing and negotiating specification language collaboratively with the bus vendor(s), LAVTA can work with the vendor(s) to customize the bus to their needs as much as is appropriate, help advance the industry based on agency requirements and recommended advancements, ensure the acceptance and payment process is fully clarified ahead of time, fully document the planned capabilities of the bus to ensure accountability, and generally preempt any unmet expectations. Special attention should be given in defining the technical capabilities of the vehicle, since defining these for FCEBs may differ from diesel-hybrid buses.

When developing RFPs and contracting for FCEB procurement, LAVTA should specify the source of funding for the vehicle purchases to ensure grant compliance, outline data access requirements, define the price and payment terms, establish a delivery timeline, and outline acceptance and performance requirements. LAVTA should test the buses upon delivery for expected performance in range, acceleration, gradeability, highway performance, and maneuverability. Any such performance requirements must be included in the technical specification portion of the RFP and contract to be binding for the OEM. Defining technical specifications for FCEBs will also differ slightly from diesel-hybrids since they will need to include requirements for hydrogen fuel cell and battery performance. It is also recommended that LAVTA purchase an extended battery warranty for the vehicle, which should be specified in the RFP and contract.

FCEB procurement will also differ from diesel-hybrid procurement since there are fewer OEMs presently manufacturing these vehicles, although this is expected to change with increasing demand. FCEBs are included in the MTC Pricelist, however, so this should not greatly affect LAVTA's procurement process. LAVTA will also be able to apply for additional funding for these vehicles through zero-emission vehicle specific funding opportunities, which are discussed further in which are discussed further in **Section H: Potential Funding Sources.**

E

Facilities and Infrastructure Modifications

LAVTA Facility Configuration and Depot Layout

Current Depot Address:
1362 Rutan Court, Livermore, CA 94551

Future Depot Address:
875 Atlantis Court, Livermore, CA 94551

Electric Utility:
PG&E

Located in a NOx Exempt Area?
No

Bus Parking Capacity:
100+

Current Vehicle Types Supported:
LAVTA's depot at Rutan Court currently supports diesel-hybrid fueling and maintenance. The Atlantis Court Depot will be built to support all vehicle types and will include hydrogen gas detection.

Propulsion Types That Will be Supported at Completion of ZEB Transition:
Fuel cell electric propulsion

Facilities Assessment Methodology

FCEB deployments require installation of a fueling station and may require improvements to existing electrical infrastructure, such as upgrades to the switchgear or utility service connections. Planning and design work, including the detailed electrical and construction drawings required for permitting, is also necessary once specific fueling equipment has been selected. LAVTA's new depot at 875 Atlantis Court will be designed to support FCEBs, which avoids the need to retrofit existing infrastructure.

To project the costs of hydrogen fueling infrastructure, CTE used industry pricing provided by A&E subcontractors and an infrastructure build timeline based on the procurement timeline. This plan assumes that infrastructure projects will be completed prior to each bus delivery. These projects are described in detail below.

Infrastructure Upgrade Requirements to Support Zero-Emission Buses

The FCEB Only scenario assumes that LAVTA deploys FCEBs to service all of its routes by 2034. CTE assessed the hydrogen infrastructure costs needed to support a fleet of 68 FCEBs. The project timeline assumes the new depot is completed to serve the agency's first FCEB deployment in 2025.

Permanent hydrogen refueling infrastructure requires planning including permitting and fuel demand requirements. The cost projections indicate that planning occurs in 2022, the year prior to construction. The total cost of planning for the Atlantis court depot is approximately $200,000.

Construction of the hydrogen fueling station requires installation of mechanical equipment and hydrogen storage, as well as upgrades to maintenance bays to meet the safety requirements for indoor hydrogen vehicle maintenance. These cost projections show station construction beginning in 2023 and concluding by 2025 when the vehicles are delivered for testing and acceptance. The entire station construction project is anticipated to cost approximately $7.5 million.

Maintenance bays at each depot will require hydrogen detection and exhaust equipment. This construction will also have to be completed prior to FCEB deployment in 2025. A total of 11 maintenance bays will be outfitted for hydrogen gas detection. CTE estimates that installing the required ventilation systems and hydrogen detection equipment will cost $13,600 per bay. To outfit the 11 maintenance bays at Atlantis Court with these require safety measures will cost $151,000 more than if the maintenance bays were constructed to work on diesel-hybrids.

FCEB Only Infrastructure Summary

Table 3 provides the total infrastructure costs for the FCEB Only scenario for the entire transition period. The required infrastructure to fuel, operate, and maintain FCEBs will cost approximately $7.85 million.

Table 3 – Total Infrastructure Costs, FCEB Only Scenario

Depot	Cost
Atlantis	$ 7,850,000
Total	$ 7,850,000

Figure 6 shows a cumulative summary of infrastructure costs by year.

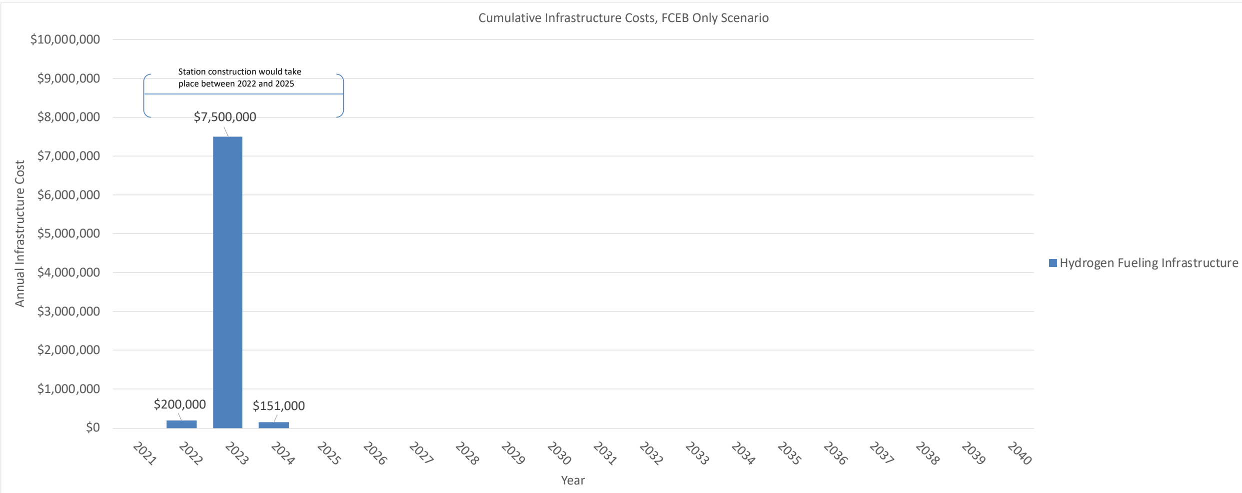

Figure 6 - Cumulative Infrastructure Costs, FCEB Only Scenario

These facilities costs are estimated based on the assessed infrastructure requirements for the given fleet and the selected fueling technology. These costs will need to be confirmed or revised to reflect conditions at time of construction and installation.

Description of Changes to Depot

Given LAVTA's plans to construct a new depot at Atlantis Court to support FCEBs, it is unlikely that it will be necessary to retrofit or change LAVTA's current depot at Rutan Court. In the event that LAVTA needs to pursue a contingency plan for fueling and maintaining the FCEBs, LAVTA will upgrade two maintenance bays at Rutan Court and will fuel vehicles at the hydrogen distribution center operated by First Element in Livermore.

F

Providing Service in Disadvantaged Communities

Providing Zero-Emission Service to DACs

In California, CARB defines disadvantaged communities (DACs) as communities that are both socioeconomically disadvantaged and environmentally disadvantaged due to local air quality. In the Bay Area, lower income neighborhoods, such as West Oakland, are exposed to greater vehicle pollution levels due to proximity to freeways and the port of Oakland, which puts these communities at greater risk of health issues associated with tailpipe emissions.[2] Though LAVTA has no census tracts identified as DACs as defined by SB 535 and CARB, it provides service for a block group that meets disadvantaged community criteria in Livermore, California. The agency's routes 10 and 14 serve Block Group number 60014516021. In 2019, the ridership totals on these routes were 409,363 and 108,571 respectively. Between these two routes, 63,475 boardings occurred specifically in this block group. Routes 10 and 14 will be fully electrified by 2034. Additionally, DACs located in Hayward and Oakland, which border LAVTA's service area, will also benefit from the emissions reduction resulting from LAVTA's ZEB transition.

Environmental impacts, both from climate change and from local pollutants, disproportionately affect transit riders. For instance, poor air quality from tailpipe emissions and extreme heat harm riders waiting for buses at roadside stops. The transition to zero-emission technology will benefit the region by reducing fine particulate pollution and improving overall air quality. In turn, the fleet transition will support better public health outcomes for residents in DACs served by the selected routes.

Public transit has the potential to improve social equity by providing mobility options to low-income residents lacking access to a personal vehicle and helping to meet their daily needs. In California, transit use is closely correlated with carless households as they are five times more likely to use public transit than households with at least one vehicle. [3] Although 21% of Californians in a zero-vehicle household are vehicle free by choice, 79% do not have a vehicle due to financial limitations. Many low-income people

[2] Reichmuth, David. 2019. Inequitable Exposure to Air Pollution from Vehicles in California. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/inequitable-exposure-air-pollution-vehicles-california-2019

[3] Grengs, Joe, Jonathan Levine, and Qingyun Shen. (2013). Evaluating transportation equity: An inter-metropolitan comparison of regional accessibility and urban form. FTA Report No. 0066. For the Federal Transit Administration

therefore rely solely on public transportation for their mobility needs.[4] LAVTA's current diesel-hybrid fleet consumes an annual average of 417,000 gallons of diesel. The combustion of this fuel exposes those who are reliant on this transportation option to diesel exhaust, which has been classified as a probable human carcinogen with links to asthma and other lung related health issues.[5] Portions of LAVTA's service area are in the 90th-100th percentile for diesel particulate matter (PM) according to CalEnviroScreen 4.0. Moving LAVTA's fleet to zero-emission technology will help alleviate this pollution, which will improve the health of communities impacted by high diesel PM and all Bay Area communities.

Access to quality transit services provides residents with a means of transportation to go to work, to attend school, to access health care services, and run errands. By purchasing new vehicles and decreasing the overall age of its fleet, LAVTA is also able to improve service reliability and therefore maintain capacity to serve low-income and disadvantaged populations. Replacing diesel-hybrid vehicles with zero-emission FCEBs, will also benefit these populations by improving local air quality and reducing exposure to harmful emissions from diesel exhaust.

Map of LAVTAs Service to Census Block Group 4516.02-1

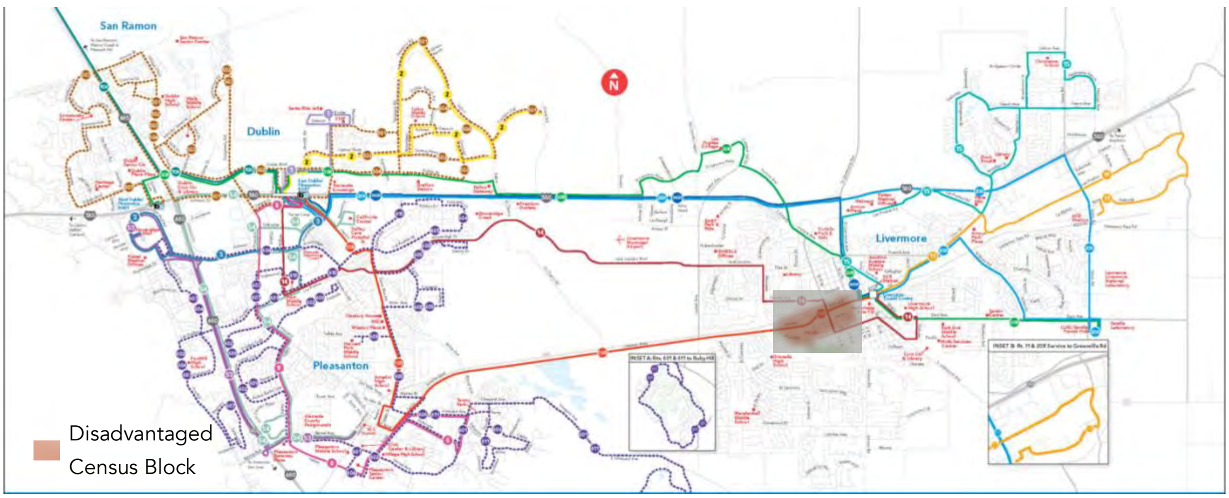

Figure 7 – Map of Census Block Group 4516.02-1 in LAVTA's Service Area

Emissions Reductions for DACs

Greenhouse gases (GHG) are the compounds primarily responsible for atmospheric warming and include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The effects of greenhouse gases are not

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[4] Paul, J & Taylor, BD. 2021. Who Lives in Transit Friendly Neighborhoods? An Analysis of California Neighborhoods Over Time. Transportation Research Interdisciplinary Perspectives. 10 (2001) 100341. https://reader.elsevier.com/reader/sd/pii/S2590198221000488?token=CABB49E7FF438A88A19D1137A2B1851806514EF576E9A2D9462D3FAF1F6283574907562519709F8AD53DEC3CF95ACF27&originRegion=us-east-1&originCreation=20220216190930

[5] National Resources Defense Council Coalition for Clean Air. No breathing in the aisles — diesel exhaust inside school buses. New York: The Council; January 2001. Available: www.nrdc.org/air/transportation/schoolbus/sbusinx.asp

localized to the immediate area where the emissions are produced. Regardless of their point of origin, greenhouse gases contribute to overall global warming and climate change.

Criteria pollutants include carbon monoxide (CO), nitrogen oxides (NO_x), particulate matter under 10 and 2.5 microns (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOC), and sulfur oxides (SO_x). These pollutants are considered harmful to human health because they are linked to cardiovascular issues, respiratory complications, or other adverse health effects.[6] These compounds are also commonly responsible for acid rain and smog. Criteria pollutants cause economic, environmental, and health effects locally where they are emitted. CARB defines DACs in part as disadvantaged by poor air quality because polluting industries or freight routes have often been sited in these communities. The resulting decrease in air quality has led to poorer health and quality of life outcomes for residents.

By transitioning to ZEBs from diesel-hybrid buses, LAVTA's fleet will produce fewer carbon emissions and fewer harmful pollutants from the vehicle tailpipes. Communities disadvantaged by pollution served by LAVTA's fleet will therefore benefit greatly from the reduced tailpipe emissions of ZEBs compared to ICE buses.

[6]Institute of Medicine. Toward Environmental Justice: Research, Education, and Health Policy Needs. Washington, DC: National Academy Press, 1999; O'Neill MS, et al. Health, wealth, and air pollution: Advancing theory and methods. Environ Health Perspect. 2003; 111: 1861-1870; Finkelstein et al. Relation between income, air pollution and mortality: A cohort study. CMAJ. 2003; 169: 397-402; Zeka A, Zanobetti A, Schwartz J. Short term effects of particulate matter on cause specific mortality: effects of lags and modification by city characteristics. Occup Environ Med. 2006; 62: 718-725.

G

Workforce Training

LAVTA's Current Training Program

LAVTA is experienced in recruiting, hiring, training, and integrating new staff to ensure that LAVTA's employees are qualified to provide quality services to their riders. The level of training that LAVTA drivers and maintenance staff engage in is dependent upon their level of experience at time of hiring. LAVTA's training is conducted by contractors specialized in operator and maintenance training. Examples of the raining required by experience level are shown below:

Not licensed (Class C only):

- A 28.5-hour classroom curriculum
- Obtain a Class B Commercial License Permit (CLP) by passing three California Department of Motor Vehicles (DMV) written tests: air brake, passenger, and general knowledge
- A 40-hour behind-the-wheel instruction period. This includes six hours of skills and 33 hours of city driving. A one-hour final check ride is required and must be approved by the Safety Manager
- Successful completion of a vehicle inspection, including air brake test, basic control skills, and road test with a certified DMV third party tester
- Obtain a Verification of Transit Training (VTT). This consists of 20 hours of city driving which is part of the 33 hours of behind-the-wheel instruction
- Successful completion of a "cadet" program which includes 16 hours or more riding in revenue service with a mentor on several routes and a final 1-hour check ride is also required and given by the Safety Manager

Licensed but no verification of transit training (Class B):

- A 21-hour classroom curriculum
- A 20-hour behind-the-wheel instruction period inclusive of six hours of skills to receive a VTT from the DMV. A one-hour final check ride is required and must be approved by the Safety Manager
- Successful completion of a "cadet" program which includes 14 hours or more riding in revenue service with a mentor on several routes and a final one-hour check ride is also required and given by the Safety Manager

Incumbent (fully licensed)

- A 12-hour classroom curriculum
- An 11-hour behind-the-wheel instruction period, which includes six hours of skills and final one-hour check ride is also required and given by the Safety Manager
- Successful completion of a "cadet" program including 14 hours or more riding in revenue service with a mentor on several routes and a final one-hour check ride is also required and given by the Safety Manager

Requirements for all operators

All operators are required to keep their credentials current. Maintaining credentials is described as follows:

- Must have a driver proficiency certificate on file which is good for duration of employment
- Annual renewal of the Platinum Care Customer Service class
- Annual renewal of the Americans with Disabilities Act (ADA) sensitivity class
- Annual renewal of the Mobility Device securement process
- Annual driving record review
- Annual pull notice
- Annual or Biannual renewal of the medical certificate
- Quinquennial (five year) VTT renewal which is completed by attending monthly Safety Meetings
- Quinquennial License renewal, obtained by following DMV requirements and having a current medical on file

Hiring process for mechanics

Mechanics are also required to obtain their Class B Commercial Driver's License. The process is the same as above with the following addition:

- Mechanics must attend monthly Occupational Safety and Health Administration meetings.

LAVTA's ZEB Training Plan

OEM Training

LAVTA plans to take advantage of trainings from the bus manufacturers and station suppliers, including maintenance and operations training, station operations and fueling safety, first responder training and other trainings that may be offered by the technology providers. OEM trainings provide critical information on operations and maintenance aspects specific to the equipment model procured. Additionally, many procurement contracts include train-the-trainer courses through which small numbers of agency staff are trained and subsequently train agency colleagues. This method provides a cost-efficient opportunity to provide widespread agency training on new equipment and technologies.

Bus and Fueling Operations and Maintenance

The transition to a zero-emission fleet will have significant effects on LAVTA's workforce. Meaningful investment is required to upskill maintenance staff and bus operators trained in ICE vehicle maintenance and fossil fuel fueling infrastructure.

LAVTA training staff will work closely with the OEM providing vehicles to ensure all mechanics, service employees, and bus operators complete necessary training prior to deploying ZEB technology and that these staff undergo refresher training annually and as needed. LAVTA staff will also be able to bring up any issues or questions they may have about their training with their trainers. Additionally, trainers will observe classes periodically to determine if any staff would benefit from further training.

ZEB Training Programs Offered by Other Agencies

Several early ZEB adopters have created learning centers for other agencies embarking on their ZEB transition journeys. One such agency is SunLine Transit Agency, which provides service to the Coachella Valley and hosts the West Coast Center of Excellence in Zero Emission Technology (CoEZET). The Center of Excellence supports transit agency adoption, zero-emission commercialization and investment in workforce training. Similarly, AC Transit offers training courses covering hybrid and zero-emission technologies through their ZEB University program. LAVTA plans to take advantage of these trainings offered by experienced agencies and has already met with AC Transit to discuss the agency's FCEB operations.

H

Potential Funding Sources

Sources of Funding for ZEB Transition

LAVTA is prepared to pursue funding opportunities at the federal, state, and local level, as necessary and as available.

Federal

LAVTA is exploring federal grants through the following funding programs: Federal Transit Administration's (FTA) Urbanized Area Formula program; discretionary grant programs such as the Bus and Bus Facilities (B&BF) program, Low or No Emission Vehicle Deployment Program (Low-No), and Better Utilizing Investments to Leverage Development (BUILD) grant; and other available federal discretionary grant programs.

Annual Reliable Funding

- Federal Transportation Administration (FTA)
    - Urbanized Area Formula program
    - State of Good Repair Grants

Future Funding Opportunities

- United States Department of Transportation (USDOT)
    - Better Utilizing Investments to Leverage Development (BUILD) Grants
- Federal Transportation Administration (FTA)
    - Bus and Bus Facilities Discretionary Grant
    - Urbanized Area Formula program
    - State of Good Repair Grants
    - Capital Investment Grants – New Starts
    - Capital Investment Grants – Small Starts
    - Low-or No-Emission Vehicle Grant
    - Metropolitan & Statewide Planning and Non-Metropolitan Transportation Planning
    - Flexible Funding Program – Surface Transportation Block Grant Program
- Federal Highway Administration (FHWA)
    - Congestion Mitigation and Air Quality Improvement Program
- Environmental Protection Agency (EPA)
    - Environmental Justice Collaborative Program-Solving Cooperative Agreement Program

State

LAVTA will also seek funding from state resources through grant opportunities including but not limited to Senate Bill 1 State of Good Repair (SGR), Transit and Intercity Rail Capital Program (TIRCP), Low Carbon Transit Operations Program (LCTOP) funding, the California Energy Commission's Clean Transportation Program as well as Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) for bus purchases when available.

Secured Funding

- California Department of Transportation (Caltrans)
  - State Transit Assistance (STA) + STA SB1

Future Funding Opportunities

- California Air Resources Board (CARB)
  - Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)
  - State Volkswagen Settlement Mitigation
  - Carl Moyer Memorial Air Quality Standards Attainment Program
  - Cap-and-Trade Funding
  - Low Carbon Fuel Standard (LCFS)
- California Transportation Commission (CTC)
  - Solution for Congested Corridor Programs (SCCP)
- California Department of Transportation (Caltrans)
  - Low Carbon Transit Operations Program (LCTOP)
  - Transportation Development Act
  - Transit and Intercity Rail Capital Program
  - Transportation Development Credits
  - New Employment Credit
- California Energy Commission

Local

Additionally, LAVTA will pursue local funding opportunities to support zero-emission bus deployment such as Transportation Development Act (TDA) 4.0 and Alameda County Transportation Commission (ACTC) Measure B/BB/VRF funding. Funds from these opportunities will also be used to fund the Atlantis Bridging Documents. LAVTA also purchases buses through the Metropolitan Transportation Commission (MTC), which will help finance 80% of the vehicle's capital costs. While the aforementioned funding opportunities are mentioned by name, LAVTA will not be limited to these sources and will regularly assess opportunities for fiscal support for the ZEB program.

I

Start-up and Scale-up Challenges

Financial Challenges

Challenges can arise with any new propulsion technology, its corresponding infrastructure, or in training operators and maintenance staff. Nearly all transit agencies must contend with the cost barriers posed by zero-emission technologies. The current market cost of ZEBs is between $750,000 and $1,200,000, which is about $250,000 to $700,000 more costly than traditional diesel buses. Additionally, the necessary infrastructure to support these buses adds to the financial burden of transitioning to a ZEB fleet, as outlined below in **Table 4.** LAVTA will seek financial support to cover the cost of their FCEBs from the resources discussed in Section H.

Table 4 – Incremental Cost of ZEB Transition

Incremental cost of ZEB Transition			
	Diesel-hybrid Baseline	FCEB Incremental Costs	FCEB Transition Scenario Costs
Bus Capital Expense	$97.7M	$53.9M	$151.6M
Fueling Infrastructure	$0	$7.9M	$7.9M
Total	$97.7M	$61.8M	$159.5M

As seen in **Table 4,** costs of required fueling infrastructure and fueling operations for ZEB technologies pose another hurdle for transit agencies transitioning to zero-emission service. Continued financial support at the local, state and federal level to offset the capital cost of this new infrastructure is imperative. For alternative fuels such as hydrogen, financial support from state and federal grant opportunities for green hydrogen supply chains and increasing economies of scale on the production side will ultimately benefit transit agencies deploying and planning for FCEBs.

CARB can support LAVTA by ensuring continued funding for the incremental cost of zero-emission buses and fueling infrastructure. Funding opportunities should emphasize proper transition and deployment planning and should not preclude hiring consultants to ensure best practices and successful deployments. The price and availability of hydrogen, both renewable and not, continue to be challenges that can be allayed by legislation subsidizing and encouraging renewable fuel production.

Limitations of Current Technology

Beyond cost barriers, transit agencies must also ensure that available zero-emission technologies can meet basic service requirements of the agency's duty cycles. The applicability of specific zero-emission technologies will vary widely among service areas and agencies. As such, it is critical that transit agencies in need of technical and planning support have access to these resources to avoid failed deployment efforts. Support in the form of technical consultants and experienced zero-emission transit planners will be critical to turning Rollout Plans into successful deployments and tangible emissions reductions.

Appendix A – Approved Board Resolution

RESOLUTION NO. 12-2022

A RESOLUTION OF THE BOARD OF DIRECTORS OF THE LIVERMORE AMADOR VALLEY TRANSIT AUTHORITY ADOPTING LAVTA'S ZERO-EMISSION ROLLOUT PLAN

WHEREAS, in 2018, the California Air Resources Board (CARB) adopted the Innovative Clean Transit (ICT) Regulation, which requires public transit agencies to transition to a 100 percent zero-emission bus (ZEB) fleet by 2040; and

WHEREAS, the ICT includes the following requirements for bus purchases for small agencies such as LAVTA:

- January 1, 2026 - 25% of all new bus purchases must be zero-emission
- January 1, 2027 - 25% of all new bus purchases must be zero-emission
- January 1, 2028 - 25% of all new bus purchases must be zero-emission
- January 1, 2029+ - 100% of all new bus purchases must be zero-emission
- March 2021-March 2050 – Annual compliance report due to CARB

WHEREAS, the ICT regulation requires each agency to submit a ZEB Rollout Plan (Rollout Plan) to CARB by July 1, 2023. The Rollout Plan is a living document intended to guide the agency's conversion to a ZEB fleet; and

WHEREAS, the Rollout Plan must be approved by the transit agency's governing body through the adoption of a resolution prior to submission to CARB; and

WHEREAS, per the requirements of the ICT, the Rollout Plan includes the following components:

- Introduction, including LAVTA's operations, service area, and environmental factors;
- Current Fleet Composition and Future Bus Purchases;
- Facilities and Infrastructure Modifications, including a description of each operating and maintenance facility and potential facility modifications needed to support a ZEB fleet;
- Disadvantaged Communities, which describes the disadvantaged communities (DACs) that will be impacted by the ZEB transition;
- Workforce Training, which provides background on personnel training requirements for ZEB implementation;
- Costs and Funding Opportunities, which outlines rough order-of-magnitude costs and potential funding sources for ZEB implementation; and
- Start-Up and Scale-Up Challenges, which describes challenges the agency will have to mitigate during ZEB implementation

NOW, THEREFORE, BE IT RESOLVED, that the Board of Directors of the Livermore Amador Valley Transit Authority hereby adopts LAVTA's Zero-Emission Bus Rollout Plan and approves it for submission to CARB.

PASSED AND ADOPTED this 4th day of April 2022.

Karla Brown

Karla Brown, Chair

ATTEST:

Michael Tree, Executive Director

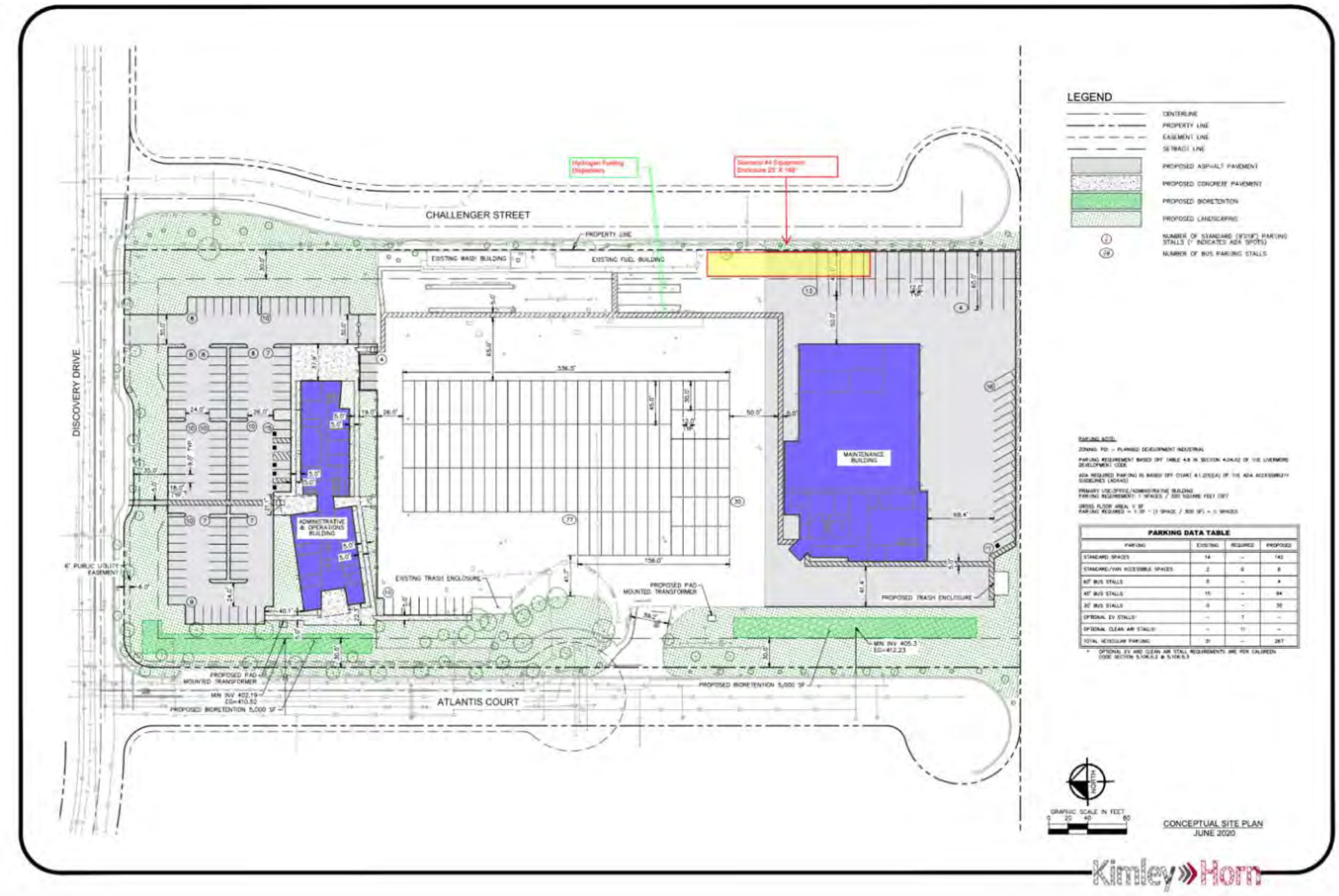
APPROVED AS TO FORM:

Michael Conneran

Michael Conneran (Apr 8, 2022 11:18 PDT)

Michael Conneran, Legal Counsel

Appendix B – ZEB Transition Site Plans



Appendix C – Glossary

Auxiliary Energy: Energy consumed (usually as a by time measure, such as "x"kW/hour) to operate all support systems for non-drivetrain demands, such as HVAC and interior lighting.

Battery Electric Bus: Zero-emission bus that uses onboard battery packs to power all bus systems.

Battery Nameplate Capacity: The maximum rated output of a battery under specific conditions designated by the manufacturer. Battery nameplate capacity is commonly expressed in kWh and is usually indicated on a nameplate physically attached to the battery.

Block: Refers to a vehicle schedule, the daily assignment for an individual bus. One or more runs can work a block. A driver schedule is known as a "run."

Charging Equipment: The equipment that encompasses all the components needed to convert, control and transfer electricity from the grid to the vehicle for the purpose of charging batteries. May include chargers, controllers, couplers, transformers, ventilation, etc.

Depot Charging: Centralized BEB charging at a transit agency's garage, maintenance facility, or transit center. With depot charging, BEBs are not limited to specific routes, but must be taken out of service to charge.

Energy: Quantity of work, measured in kWh for ZEBs.

Energy Efficiency: Metric to evaluate the performance of ZEBs. Defined in kWh/mi for BEBs, mi/kg of hydrogen for FCEBs, or miles per diesel gallon equivalent for any bus type.

Fuel Cell Electric Bus: Zero-emission bus that utilizes onboard hydrogen storage, a fuel cell system, and batteries. The fuel cell uses hydrogen to produce electricity, with the waste products of heat and water. The electricity powers the batteries, which powers the bus.

Greenhouse Gas Emissions: Zero-emission buses have no harmful emissions that result from diesel combustion. Common GHGs associated with diesel combustion include carbon dioxide (CO2), carbon monoxide (CO), nitrous oxides (NOx), volatile organic compounds (VOCs), and particulate matter (PM). These emissions negatively impact air quality and contribute to climate change impacts.

Hydrogen Fueling Station: The location that houses the hydrogen production (if produced onsite), storage, compression, and dispensing equipment to support fuel cell electric buses.

On-route Charging: BEB charging while on the route. With proper planning, on-route charged BEBs can operate indefinitely, and one charger can charge multiple buses.

Operating Range: Driving range of a vehicle using only power from its electric battery pack to travel a given driving cycle.

Route Modeling: A cost-effective method to assess the operational requirements of ZEBs by estimating the energy consumption on various routes using specific bus specifications and route features.

Useful Life: FTA definition of the amount of time a transit vehicle can be expected to operate based on vehicle size and seating capacity. The useful life defined for transit buses is 12-years. For cutaways, the useful life is 7 years.

Validation Procedure: to confirm that the actual bus performance is in line with expected performance. Results of validation testing can be used to refine bus modeling parameters and to inform deployment plans. Results of validation testing are typically not grounds for acceptance or non-acceptance of a bus.

Zero-Emission Vehicle: A vehicle that emits no tailpipe emissions from the onboard source of power. This is used to reference battery-electric and fuel cell electric vehicles, exclusively, in this report.

Well-to-wheel Emissions: Quantity of greenhouse gas, criteria pollutants, and/or other harmful emissions that includes emissions from energy use and emissions from vehicle operation. For BEBs, well-to-wheel emissions would take into account the carbon intensity of the grid used to charge the buses. For FCEBs, well-to-wheel emissions would take into account the energy to produce, transport, and deliver the hydrogen to the vehicle.

Prepared by Center for Transportation and the Environment