SR 25-346 Attachment 1

Zero Emission Program
ANNUAL PROGRESS REPORT

Publication Date: June 25, 2025

Leading the way to a
ZERO EMISSION FUTURE.

Abstract

The Zero Emission Program Annual Progress Report provides a detailed overview of the two-year leading analysis of Zero Emission Transit Bus Technology, commonly known as the 5X5 Study. This report outlines the District's capital investments in the Zero Emission Bus (ZEB) Program since it began and presents the financial projections necessary for a complete transition of the fleet. By monitoring and reporting on its progress, the District ensures compliance with the requirements set by the Federal Transit Administration (FTA) and the California Air Resources Board's (CARB) Innovative Clean Transit (ICT) regulation.

The deployment of ZEBs is guided by the District's Clean Corridors Plan, which focuses on deploying ZEBs into historically disadvantaged communities. This approach aims to improve air quality and public health while promoting social equity.

Additionally, the report contains an integrated master schedule that consolidates ongoing projects outlined in the District's current Capital Improvement Program (CIP). It also includes a comprehensive analysis of assets to determine their eligibility for replacement. This ensures alignment with the District's Strategic Plan and its associated goals and objectives.

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Executive Summary

AC Transit has spent the last two decades developing the most extensive Zero Emission Program in the United States. This initiative has already logged over 7.7 million operational miles and provided more than 30,000 hours of workforce training, resulting in a substantial reduction of 16,000 metric tons of carbon dioxide emissions. The program has expanded from operating a single hydrogen fuel-cell electric bus to a diverse fleet that now includes both hydrogen fuel-cell and battery electric buses. Our Zero Emission Bus (ZEB) infrastructure features on-site hydrogen fueling stations, electric charging facilities, fleet maintenance operations, and comprehensive workforce development programs.

ZEB Program Highlights:

First ZEB Pilot:
2002

ZEB Workforce Training:
30,264
Hours

CO^2 Emissions Eliminated:
16,000
Metric Tons

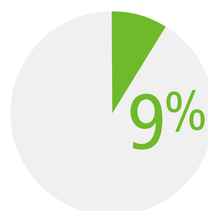
Current Investment:
$417M
(2005-2026)

Transition plan:

ZEBs by 2026= 17%

Facility capacity by 2026= 56%

ZEB Fleet:



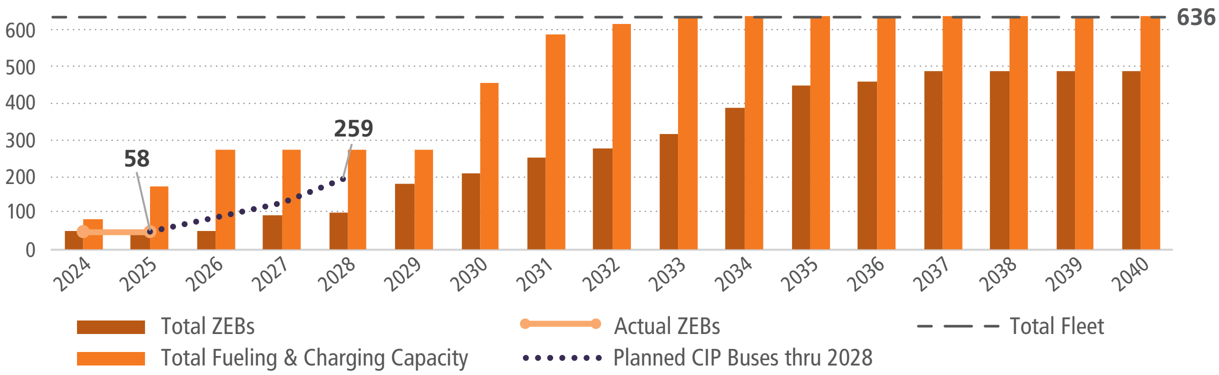
Life-to-Date Miles:
7.7 Million

$44M **LoNo Grant Award** **to realize ZEBU and support ZEB purchases**

The District's ZEB Transition Plan aims to completely replace the current diesel fleet with 100% Zero Emission Buses by the year 2040, in alignment with the California Air Resources Board (CARB) Innovative Clean Transit (ICT) regulation. This vision anticipates a fleet composed of 70% fuel-cell electric buses (FCEBs) and 30% battery electric buses (BEBs), with an estimated funding requirement of $1.9 billion. So far, the ZEB transition has achieved 9% of its targeted goal and is expected to reach 17% by 2026.

The transition schedule has been updated to reflect the latest Capital Improvement Plan, and the District now anticipates acquiring 259 ZEBs by 2028, provided the necessary funding is secured. The Program Build Sheet Summary estimates a total cost of $2.4 billion, with a funding gap of $463 million dependent on potential grants the district may secure.

ZEB Transition Schedule



Funding requirements for the Zero Emission Bus (ZEB) Program are projected through 2036 and are crucial for completing the final phase of bus acquisitions and infrastructure projects needed to comply with the California Air Resources Board's Innovative Clean Transit (ICT) regulation by 2040. AC Transit's proactive purchase of Zero Emission buses has resulted in the district earning 57 bonus credits, which can be used in subsequent years until December 31, 2028. These credits allow the district to replace the purchase of a Zero Emission bus with a diesel bus on a per-credit basis, providing flexibility and helping to manage potential risks.

Program Build Sheet Summary (Millions)

Investment Type	Investments	ZEB Transition Forecast*	Program Estimated Cost	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	$292	$1,721	$2,014	$1,398	($324)
Infrastructure	$103	$234	$337	$131	($103)
Supporting Projects	$21	$36	$57	$0	($36)
ZEB Program Total	**$417**	**$1,991**	**$2,408**	**$1,529**	**($463)**

**Uses 2024 quote information as baseline for revenue vehicle cost with escalation factor for future years. Includes some pending investments to be reconciled in the upcoming fiscal year.*

The program faces several risks, particularly due to recent federal legislative changes that have created uncertainty about funding and the financial markets. Additionally, costs associated with procuring Zero Emission Buses (ZEBs) have risen due to inflation, fluctuating market conditions, and OEM/supply chain challenges. It is estimated that $234 million will be needed to transition to ZEB infrastructure. Resource constraints are also concerning, especially considering the anticipated fiscal cliff. Other hurdles include the capacity and reliability of the utility grid to support the charging needs of the Battery Electric Bus (BEB) fleet and the service range limitations of BEBs, which affect 60% of block assignments.

Additionally, a mitigation strategy the District can utilize is submitting an exemption request to the California Air Resources Board (CARB) for the purchase of ZEBs. Upon the granted request, the Board has the option to acquire conventional diesel buses that align with the District's TAM policy under the following CARB conditions:

- If the required ZEB type is unavailable;
- If daily mileage requirements cannot be fulfilled;
- If essential gradeability cannot be achieved;
- If the additional costs for charging battery electric buses cannot be justified despite seeking all available incentives and funding;
- If there are delays in the construction of necessary infrastructure; or
- If a transit agency faces a declared financial emergency.

The District is actively reviewing energy management strategies to ensure operational stability, cost-effectiveness, and efficiency while adapting to changing market demands. As the hydrogen fuel market evolves, the District will continually assess guiding principles for our hydrogen fuel purchases. All District operations are classified as "direct Scope 1" activities, while the production, transportation, and delivery of hydrogen fuel used by AC Transit are categorized as "upstream indirect Scope 3" activities.

AC Transit continues its involvement with the Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) and the development of the U.S. Department of Energy hydrogen hub initiative. ARCHES is a statewide public-private partnership dedicated to advancing the hydrogen economy and clean energy innovation that is supported by California's Governor's Office of Business and Economic Development (GO-Biz) prioritizing a renewable and clean hydrogen hub ecosystem.

AC Transit Overview

The Alameda-Contra Costa Transit District (AC Transit) is California's premier public bus-only transit agency. Based in Oakland, in the East Bay region of the San Francisco Bay Area, AC Transit was established in 1960. It took over the historic transit routes of the Key System and its predecessors, which have long provided vital transportation services through various means, including horse-drawn streetcars, electric streetcars, ferries, and buses.

AC Transit is committed to enhancing the quality and accessibility of transit services for the 1.57 million residents of the East Bay. Serving an area of 364 square miles, its network covers 13 cities in Alameda and Contra Costa counties, as well as nearby unincorporated regions.

Zero Emission Program

AC Transit has established itself as a pioneering force in Zero Emission bus (ZEB) initiatives, making significant strides both at home and abroad. For more than twenty years, the agency has been dedicated to evaluating and exploring technologies that reduce and eliminate emissions. The ZEB Program is closely aligned with the District's broader goals and environmental targets, emphasizing the reduction of carbon emissions from both buses and facilities. This commitment ultimately aims to enhance the quality of life within local communities.

To facilitate the rollout of ZEBs, AC Transit has refined its project delivery methods and embraced sustainable maintenance practices. Each phase of development has provided our internal experts with the chance to enhance best practices in areas like procurement, project execution, operational efficiency, ZEB technology performance, and workforce innovation.

Service Profile

AC Transit operates 132 fixed routes, offering two primary types of service: local service within the East Bay and Transbay express service. The East Bay local service includes regular routes, bus rapid transit options, and supplemental school services, with operating hours varying by route. Most local services run daily from approximately 5:30 a.m. to midnight, while the All-Nighter lines operate from 1:00 a.m. to 5:00 a.m.

In line with AC Transit's Clean Corridors Plan, ZEB deployment is prioritized in disadvantaged communities. These areas stretch from the northernmost part of the District to nearly the southernmost regions of Alameda County, encompassing all operating divisions, including Richmond, Emeryville, East Oakland, and Hayward.

AC Transit Service Area

Investing in Transitioning to Zero Emission Technologies

Zero Emission Transition

The Zero Emission Bus (ZEB) Transition Plan aims to completely replace the existing diesel bus fleet with a new combination of approximately 70% Fuel Cell Electric Buses (FCEB) and 30% Battery Electric Buses (BEB). This transition will necessitate upgrades to the infrastructure at all district division facilities to support effective fueling and maintenance operations. The plan also includes projects to modernize the Training and Education Center and to replace the non-revenue fleet, along with improved related infrastructure.

In parallel, the District is focused on enhancing systems for data integration, management, and analytics to support the ZEB Program. For a detailed overview of the bus procurement activities and infrastructure projects, please refer to the ZEB Program Investment Integrated Master Schedule included in Appendix A.

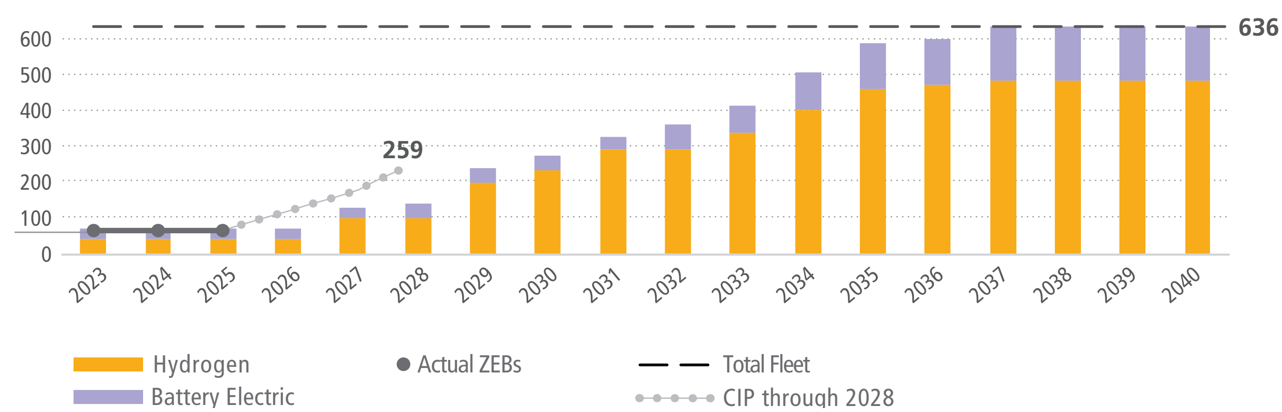
Bus Procurements

The transition to Zero Emission Buses (ZEB) is overseen by the Board of Directors, which must approve the required funding. As we move into the procurement phase, there may be opportunities to streamline various initiatives once the funds are secured. This phase involves developing technical specifications, issuing bids, awarding contracts, overseeing production, coordinating delivery, conducting inspections, and ultimately accepting the buses from the manufacturer.

Once the buses are accepted, AC Transit staff will prepare them for service, deploying them either directly into operations or for training purposes. If necessary, these buses will also be integrated into active service.

The bus replacement schedule is expected to be completed by 2039, in accordance with the District's Transit Asset Management Plan. Additionally, projects for Zero Emission Bus infrastructure will be finalized before the introduction of new ZEBs to ensure proper fueling, charging, and maintenance support.

Planned ZEB Procurements



Each bus procurement project falls into one of three categories: completed, current (which includes progress updates and upcoming initiatives), and future planned purchases necessary for regulatory compliance. Currently, the district operates 58 ZEB buses. The diagram below illustrates the completed bus purchase projects, categorized by technology type.

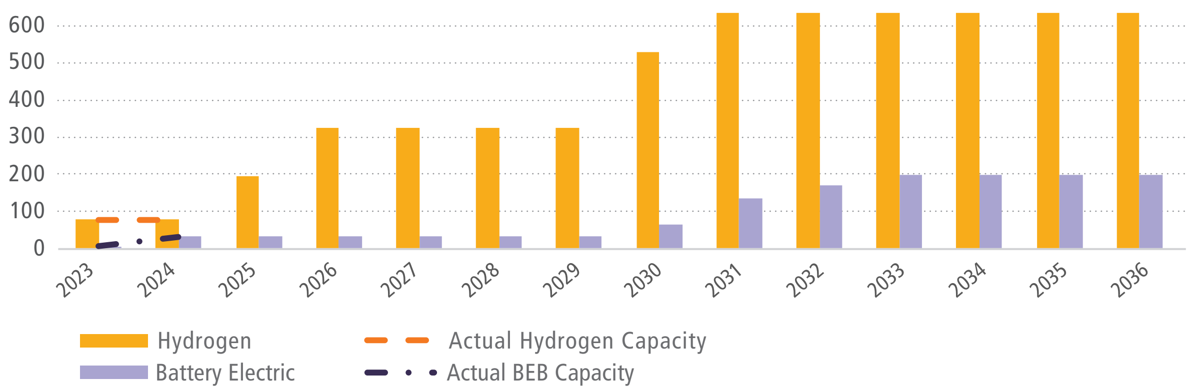
Current Revenue ZEBs by Technology

Project Description	FCEB Qty	BEB Qty
Bus Procurement Project (10 ZEBs)	10	
Bus Procurement Project (5 ZEBs)		5
Bus Procurement Project (40 ZEBs)	20	20
Bus Procurement Project (3 ZEBs)		3
Total	**30**	**28**

Infrastructure Investments

The ZEB transition schedule indicates that the full replacement of all buses is expected to be completed by 2039. At the same time, upgrades to the supporting infrastructure are set to be wrapped up by 2036, ensuring that we have sufficient fueling capacities and maintenance facilities in place. Both the bus replacement and infrastructure improvement timelines will be closely monitored, with adjustments made as needed to align with Transportation Asset Management (TAM) priorities, inflationary trends, and ongoing technological advancements. Below is a detailed schedule outlining these plans.

Planned ZEB Energy Capacity



AC Transit is actively implementing Zero Emission bus (ZEB) technologies at its facilities in Oakland (Division 4) and Emeryville (Division 2). The Oakland facility, built in 2014, features a hydrogen station capable of fueling thirteen (13) buses within a 24-hour period. Currently, this hydrogen station is undergoing an upgrade to increase its capacity to fuel over 130 buses in a 12-hour window. This enhancement includes expanding on-site liquid hydrogen storage to 25,000 gallons, upgrading to dual piston cryogenic pumping technology, and installing four new dispensers at the fueling island under a new canopy. Additionally, six (6) DC fast-charging stations, added in 2020, can deliver a maximum output of 62.5 kW each, or 125 kW when two are connected in a daisy chain configuration. Future plans include installing more charging infrastructure to support up to fifty (50) buses.

Current ZEB Facilities

	BATTERY ELECTRIC BUS		FUEL CELL ELECTRIC BUS	
Facility ▸	**Oakland Facility**	**Emeryville Facility**	**Oakland Facility**	**Emeryville Facility**
Bus Energy Capacity	6 Buses at a time	26 Buses at a time	Currently Upgrading to 130+ Buses per Fueling Window	65+ Buses per Fueling Window
In Service Date	2020	2024	Rehab late 2025	2020
Type of Fuel	PG&E Grid Electricity	PG&E Grid Electricity	Liquid Hydrogen	Liquid Hydrogen
Energy Supply	2500 Amp Service	4000 Amp Service	25,000 Gal LH2 Tank	15,000 Gal LH2 Tank
Technology	Stand-Alone Chargers	Charging Blocks with Dual Port Dispensers	Upgrading to Cryogenic Pumping	Cryogenic Pumping
Capital Cost (Build)	$896,937	$5,153,257	$9,851,230	$4,458,115
Core Hardware	(6) ChargePoint 62.5 kW CPE 250 Stand-alone Chargers	(13) ChargePoint 160 kW Express Plus Chargers connected to (13) Powerlink Dual Dispensers	Dual ADC MP-100 Duplex Cryogenic Pumps	Dual ADC MP-100 Simplex Cryogenic Pumpss
Related Hardware	600 Amp Distribution Panel with (6) 100-Amp Circuits	4000 Amp Distribution Panel with (13) 300-Amp Circuits	Pressure Build Vaporizers (4) Dispensers	Pressure Build Vaporizers (2) Dispensers
Dispenser Location	West Wall of Facility	East and South Walls of the Facility	Fuel Island	Fuel Island
Funding Source	Federal and Regional	State and Regional	Federal, State, and Regional	State and Regional
Total O&M Cost	$8,625	$0	$0	$220,812

At the Emeryville (Division 2) facility, AC Transit has expanded its hydrogen fueling capacity to accommodate seventy-five (75) buses per fueling window. The recent addition of three (3) portable DC fast-charging stations ensures reliable service during power interruptions, backing up the twenty-six (26) depot DC fast-charging stations commissioned in 2024.

Other Supporting Projects

The ZEB Program includes various supportive initiatives, such as the Zero Emission Bus University (ZEBU) and the modernization of the Training and Education Center (TEC). Additionally, it focuses on replacing non-revenue vehicles. The workforce development section of the report offers deeper insights into both the ZEBU initiative and the TEC modernization efforts.

Supporting Projects Cost

Project Title	Total Project Cost
Non-Revenue Fleet Replacement (ZEV Transition)	$12,800,000
TEC Modernization	$23,000,000

Non-Revenue Fleet Replacement

A transition plan for Zero Emission vehicles (ZEV) was developed and presented to the Board in June 2025. This plan is intended to complement the Zero Emissions Bus Transition Plan for the district's non-revenue fleet. Shifting to non-revenue vehicles will facilitate the introduction of Zero Emission service and administrative vehicles, which will bolster the district's Zero Emission bus initiative while following these guiding principles:

- Replace the fleet per the Federal Transit Administration (FTA) mandated Transit Asset Management (TAM) Plan Performance Targets
- Meet California Advanced Clean Fleets (ACF) Regulation when purchasing vehicles over 8,500 lbs GVWR
- Procure ZEVs based on funding/vehicle availability, infrastructure technology capabilities, and duty cycle
- Deploy ZEV technology that is the most efficient and sustainable to operate

Program Risk

AC Transit is committed to providing a transit service that is both accessible and reliable. To achieve this objective, it is crucial that all services and supporting functions within the District receive adequate funding. Several potential risks have been identified that could impact the successful implementation of AC Transit's Zero Emission bus (ZEB) program, hindering our ability to meet the directives set by the Board regarding our revenue fleet, infrastructure, and related projects.

The table below outlines these program risks in accordance with the District's guiding principles for the ZEB transition. These principles emphasize targets for asset replacement, vehicle and infrastructure capabilities, operational efficiencies, sustainability, and safety management challenges. Additionally, we have identified risks associated with federal policy. Each identified risk is accompanied by a specific action plan that is regularly monitored, allowing for timely adjustments in response to any changes that may affect the program.

Program Risk Matrix by Guiding Principle

Guiding Principle	Description	Action
Efficient and Sustainable to Operate	Hydrogen Cost Increase ($9.09 per kg)	Monitor
	Hydrogen Station Maintenance Cost ($440K Annually)	Monitor
	Inability to charge BEBs due to utility power safety shutoffs	Monitor
	Resource constraints caused from fiscal cliff forecast	Monitor
	Utility kWh cost escalation (14% Increase)	Monitor
Federal Policies	Legislature impacting ability to secure funding	Monitor
	Tariffs impacts on materials cost increases	Monitor
Safety Management Hazards	Potential ZEB thermal events caused by high voltage battery design	Monitor

Guiding Principle	Description	Action
TAM Replacement Target	ZEB Transition funding needs of $2.0 Billion	Monitor
Vehicle and Infrastructure Capabilities	BEB Charging Infrastructure Delays (Switchgear Supply)	Accept
	BEB Charging Infrastructure Reliability	Monitor
	BEB Service Range Limitation (60% of Block Assignments)	Accept
	Cost escalations from inflation and supply chain issues	Monitor
	Cost increase due to Project labor agreements and local workforce agreements	Monitor
	Utility Grid Capacity to Support BEB fleet charging needs	Mitigate

Additionally, a mitigation strategy the District can utilize is submitting an exemption request to the California Air Resources Board (CARB) for the purchase of ZEBs. Upon the granted request, the Board has the option to acquire conventional diesel buses that align with the District's TAM policy under the following CARB conditions:

- If the required ZEB type is unavailable;
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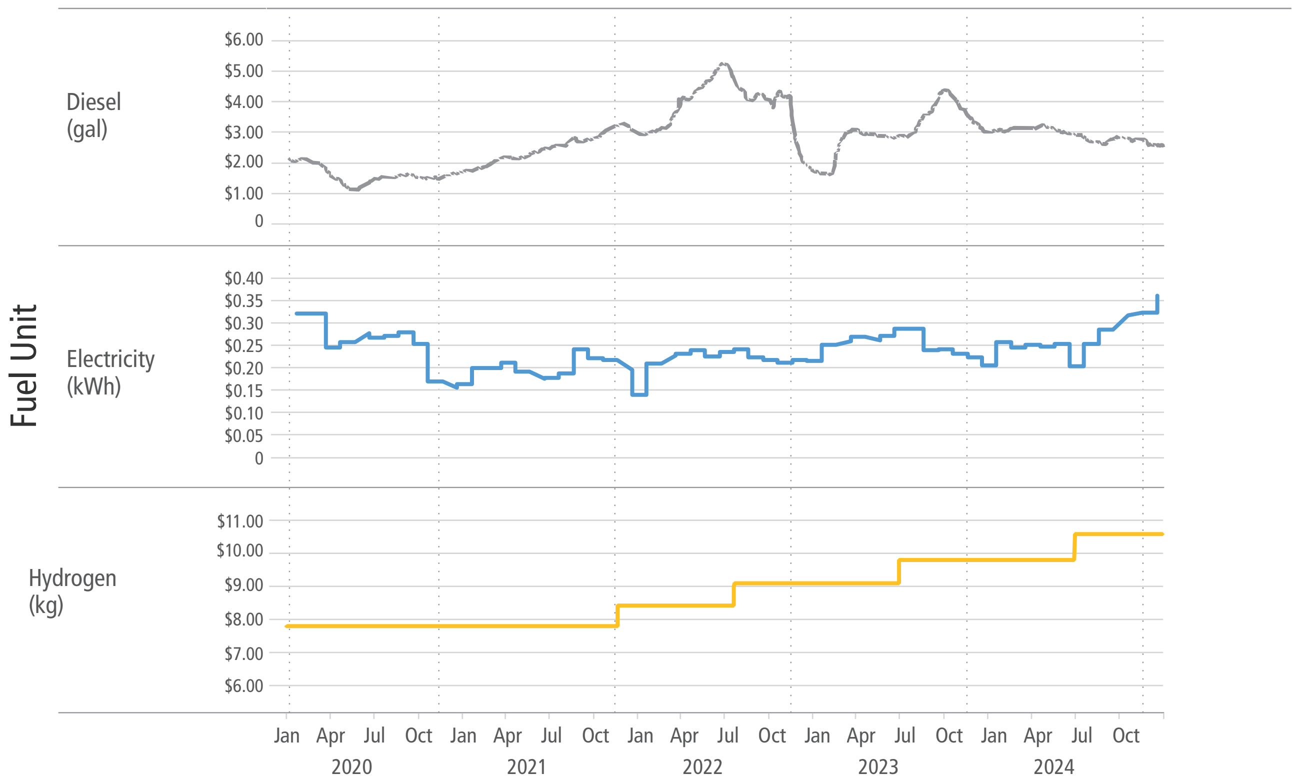
- If a transit agency faces a declared financial emergency.

Energy Trends

The figure below illustrates the current trends in energy sources. Compared to 2023, the price of diesel has seen a gradual decline of around 2%. In contrast, the prices for hydrogen and electricity have both gone up; hydrogen has increased by 8%, from $9.81 to $10.58, while off-peak electricity has risen by 2%, from $0.25 to $0.26. These fluctuations in energy costs are significant when evaluating the cost-per-mile metric and assessing overall operational performance.

Energy Price Trend (2020-2024)



The District is actively reviewing energy management strategies to ensure operational stability, cost-effectiveness, and efficiency while adapting to changing market demands. As the hydrogen fuel market evolves, the District will continually assess guiding principles for our hydrogen fuel purchases. All District operations are classified as "direct Scope 1" activities, while the production, transportation, and delivery of hydrogen fuel used by AC Transit are categorized as "upstream indirect Scope 3" activities.

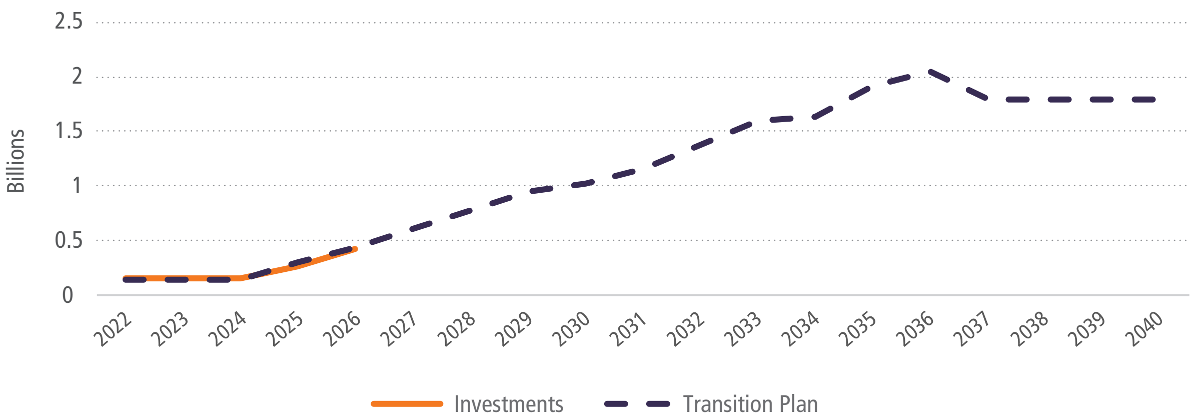
Financial Plan

Cost vs. Funding Outlook

The cost estimates for the fleet account for an increase in bus prices based on actual transactions for Zero Emission bus (ZEB) purchases and recent quotations. For bus models currently in development, estimates will be derived from the average costs per category outlined in the ZEB Transition Plan. The infrastructure cost estimates now include provisions for risk mitigation measures.

The forecasts for fleet and infrastructure expenses take into consideration annual increases that align with current market conditions over the next five years. After this initial period, the annual escalation rate will be adjusted based on the consumer price index and evaluated against market trends to ensure consistent oversight of program-related risks. Reasonable estimates have also been developed for grants to cover anticipated costs associated with the ZEB transition.

Investment Transition (Actual vs Planned)



The District is actively seeking funding options given the current financial situation and will continuously update its funding projections as necessary to reflect the financial requirements for completing the program in accordance with regulations. Current forecasts use some actual quotes with escalation to align with cost associated with grant awards and capital improvement plan cost estimates. Funding forecasts will be revised as the transition plan progresses.

Program Build Sheet Summary (Millions)

Investment Type	Investments	ZEB Transition Forecast*	Program Estimated Cost	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	$292	$1,721	$2,014	$1,398	($324)
Infrastructure	$103	$234	$337	$131	($103)
Supporting Projects	$21	$36	$57	$0	($36)
ZEB Program Total	**$417**	**$1,991**	**$2,408**	**$1,529**	**($463)**

**Uses 2024 quote information as baseline for revenue vehicle cost with escalation factor for future years. Includes some pending investments to be reconciled in the upcoming fiscal year.*

In 2024, the District secured $2.65 million in earmark funding to advance the Zero Emission Bus University (ZEBU) program. Of this funding, $1.8 million is designated for enhancements to our safety compliance facility, which includes installing hydrogen sensing technology and related equipment at the Central Maintenance Facility in East Oakland. The remaining $850,000 will be allocated toward architectural design for bids to modernize the Training and Education Center in Hayward, as well as to support the ZEBU construction project. These investments aim to improve worker safety, promote workforce development, and ensure the smooth operation of Zero Emission buses in underserved communities. Additionally, these initiatives will foster equity, enhance the quality of life in the areas we serve, and attract more riders by integrating reliable and environmentally friendly Zero Emission buses into our fleet.

The District's Zero Emission Bus (ZEB) Transition Plan serves as a strategic roadmap to achieving a fully Zero Emission fleet by 2040. This plan includes the construction of essential fueling and maintenance infrastructure to comply with the Innovative Clean Transit (ICT) regulation set forth by the California Air Resources Board (CARB). We anticipate that our fleet composition will consist of approximately 70% fuel cell electric buses (FCEBs) and 30% battery electric buses (BEBs), requiring an estimated total funding of about $1.9 billion.

In addition to the fleet transition, planned expenses for the ZEB program include $23 million earmarked for modernizing the Training and Education Center, as well as $12.8 million allocated for updating the non-revenue fleet and related infrastructure. A comparison of actual capital investments to projected costs is illustrated in the accompanying chart. The following figure outlines the $417 million investment made in ZEB technology, which encompasses expenditures on buses, infrastructure, and supporting projects through the fiscal year 2026.

Zero Emission Technology Investment (Millions)

Project Type	Scope	Time Period					Total
		2005 - 2015	2016 - 2019	2017 - 2022	2018 - 2022	2023- 2026	
Vehicles	FCEB	$31.00	$12.9 0		$23.00	$182.00	**$248.90**
	BEB		$5.30	$3.00	$22.00	$13.00	**$43.30**
Infrastructure	D2 FCEB	$10.30	$3.20		$18 .00		**$31.50**
	D2 BEB			$0.30	$2.00		**$2.30**
	D4 FCEB	$20.40				$10.80	**$31.20**
	D4 BEB		$1.60			$13.40	**$15.00**
	D6 FCEB					$14.00	**$14.00**
	Maint. Bays					$9.20	**$9.20**
Supporting Projects	Other					$21.24	**$21.24**
		$61.70	$23.00	$3.30	$65.00	$263.64	**$416.64**

Funding Requests

AC Transit continues its involvement with the Alliance for Renewable Clean Hydrogen Energy Systems (ARCHES) and the development of the U.S. Department of Energy hydrogen hub initiative. ARCHES is a statewide public-private partnership dedicated to advancing the hydrogen economy and clean energy innovation that is supported by California's Governor's Office of Business and Economic Development (GO-Biz) prioritizing a renewable and clean hydrogen hub ecosystem.

In 2024 and early 2025, the District secured over $44 million in federal, state, and regional funding to enhance its Zero Emission program. This funding will be used to acquire Zero Emission buses and upgrade facilities. Additionally, the District is actively pursuing more than $20 million in further funding from regional, state, and federal sources to strengthen its innovative Zero Emission initiative.

These financial investments will not only support the bus manufacturing sector by enabling the purchase of multiple new Zero Emission buses (ZEBs), but will also contribute to the construction of essential infrastructure and provide comprehensive workforce training through ZEBU.

Recently, the agency secured funding for the purchase of an additional fifty-six (56) ZEBs, which will consist of forty-seven (47) 40-foot and nine (9) 60-foot fuel cell electric buses, showcasing the latest Zero Emission technology. A funding application has been submitted to cover the costs of these new buses.

Empowering Our Future: Investing in Workforce Development

Workforce Development Overview

AC Transit understands that achieving success involves integrating investments in rolling stock and infrastructure with a commitment to transforming the workforce needed to effectively operate and maintain a Zero Emission Bus (ZEB) fleet. With a total of $25.5 million from two significant Federal Transit Administration (FTA) grants for Bus and Low- and No-Emission projects (Low-No Grant), Zero Emission Bus University (ZEBU) will be established. These grants will provide $16 million to design and construct a state-of-the-art Training and Education Center in Hayward, California. Additionally, $2.5 million will be dedicated to workforce development initiatives, further supporting the goal of establishing ZEBU by 2028.

ZEBU will provide a unique opportunity for local residents without advanced degrees to enter the green economy, offering competitive wages and essential benefits, including healthcare. Moreover, AC Transit's State of California Mechanic Apprenticeship has now gained full accreditation as a college program, recognized by Chabot College in Hayward, California.

ZEBU is central to our strategy to bolster Zero Emission bus services throughout the region. In the coming years, AC Transit aims to pursue $100 million in federal investments to roll out emission-free bus services, enhancing air quality, public health, and overall quality of life in the East Bay. This significant funding will include $5 million specifically directed towards an innovative workforce training and development program designed to equip transit workers with the skills needed for operating and maintaining advanced ZEB fleets.

AC Transit has reached a notable milestone with the recent award of a second consecutive Federal Transit Administration (FTA) Bus and Low-and No-Emission Grant Award (Low-No Grant) amounting to $25.5 million. Between FY23 and FY24, these grants will contribute $16 million towards the design and construction of a state-of-the-art Training and Education Center in Hayward, California. Additionally, $2.5 million will be allocated for workforce development initiatives, further supporting the realization of Zero Emission Bus University (ZEBU) by 2028.

Educational Eco-System: Zero Emission Bus University (ZEBU)

At its essence, ZEBU represents a groundbreaking initiative focused on advancing education in sustainable public transportation. This program actively engages both skilled and unskilled personnel at AC Transit through comprehensive training on Zero Emission buses (ZEBs), opening doors to transformative career opportunities. The bold vision of ZEBU is to create an educational ecosystem that promotes transformative learning and provides open access to the essential skills needed for the effective maintenance of ZEB operations.

This initiative is dedicated to establishing career pathways without barriers that have historically limited opportunities for individuals. Through this approach, AC Transit aims to cultivate a future workforce from the communities it serves, encouraging local residents to consider careers in public transit. A commitment of 5% from the two Low-No grants, totaling $2.5 million, will be allocated to the development of this ecosystem, ensuring that the workforce development plan robustly supports career initiatives and the successful adoption of ZEB technology.

With this workforce development funding, ZEBU is positioned to deliver:

1. Top-notch, advanced technological skills training for District employees,
2. Innovative training methods that foster active, immersive learning environments, boosting worker safety and effectiveness,
3. Transformative career and academic opportunities, and
4. ZEB training for any transit agency interested in implementing, maintaining, and sustaining Zero Emission buses.

Sustaining Career Ladder Initiatives

The development of ZEBU requires a shift from traditional training methods to more inclusive workforce development programs. This shift starts with AC Transit's labor and management partnership, Progress in Action (PIA). PIA consists of a leadership team made up of executives from both the District and the Amalgamated Transit Union, Local 192. The main goal of this partnership is to work together on establishing career ladder initiatives equipping employees for successful ZEB deployments. Each program within this framework plays a crucial role in helping employees gain the skills and create the career pathways necessary for effective ZEB implementation.

Career ladder initiatives that upskill frontline employees include:

1. **Mechanic Career Ladder Training Program:** Limited or no experience and a desire and willingness to enroll in one basic college automotive course (paid for by AC Transit's college tuition program) launch interested ATU Local 192 members into the Mechanic Helper Program (MH). MH is a one-year program that combines fundamental bus mechanic training with in-shop, real-world maintenance experiences. Upon completion, employees successfully enroll as State of California mechanic apprentices.

2. **State of California Heavy Duty Coach Mechanic Apprenticeship:** This four-year, eight-course, core competency maintenance mechanic program promotes apprentices as certified Journey Level Mechanics (JLM). The program includes over 900 hours of class combined with 8,000 hours of in-shop experiences, entailing bumper-to-bumper work, from preventive maintenance inspections to advanced electrical systems.
3. **Journey Level Mechanic Guide:** JLMs seeking new, upskilling opportunities to mentor, teach, or supervise are awarded this experience as Guides. JLM Guides directly support Mechanic Helpers during their in-shop learning. MH assists JLM Guides in their maintenance duties, getting first-hand experiences and a real-world appreciation of the competencies and proficiencies of what it takes to be a JLM.
4. **Master Journey Level Mechanic:** This classification is earned by JLMs who are ready for the highest level of excellence, serving as subject matter experts or liaisons between training and maintenance. Master JLMs are the "working mentors" of the shop floor, troubleshooting alongside JLMs to resolve some of the most challenging tasks. They are ideally situated in this ZEB transition to support training, new bus procurements, and the many sub-component learning modules innately necessary to master the skills of an evolving technological ZEB deployment.

5. **US Department of Labor Bus Coach Operator Apprentice and Mentorship:** Transforming the profession of operating in service, veteran Professional Bus Operators serve to mentor the newest certified Bus Operators, ensuring retention, health, and safety as priorities. Bus Operators are also Local 192 members and can apply to become MHs. This becomes a cross-over or bridge into maintenance, empowering all Local 192 members to develop sustainable transit careers in transportation or maintenance.

Career ladder initiatives that upscale include:

1. AC Transit's State of California Mechanic Apprenticeship (as described above) is now a fully accredited college program as recognized by a post-secondary institution, Chabot College (Hayward, California).
2. The eight-course, four-year apprenticeship is now a 32-unit college credit program on the degree track to an Associate of Science. It accounts for half of the required credits to attain the AS and perfectly positions employees to continue to a baccalaureate.
3. Curricula are entirely designed and taught by AC Transit's (ZEBU's) Local 192 Maintenance Trainers, who Chabot College also recognizes as Instructors of Record.
4. All apprentices completing the apprenticeship also earn a Certificate of Achievement from Chabot College and receive all the same benefits as any other students (attending Chabot).
5. Chabot College is the first rung of the ladder; climbing higher, the following steps entail building curricula substantiating a baccalaureate and opening even grander doorways to C-level and executive positions.

Transformative: Upskilling to a ZEB future

ZEBU is committed to transforming employee training through improved methodologies and innovative approaches. This initiative includes a thorough examination of propulsion systems, covering everything from the creation of a core curriculum to the use of various asynchronous and synchronous delivery methods. A standout feature of this program is an engaging two-week, hands-on course that emphasizes practical, experiential learning for the inspection, maintenance, and repair of Zero Emission buses (ZEBs).

The core curriculum spans a wide range of topics, ensuring comprehensive coverage. It includes orientation, personal protective equipment (PPE), procedures for working with high-voltage and high-pressure hydrogen, operational startup and shutdown protocols, emergency procedures, and a deep dive into critical fuel cell and battery electric components. Additionally, the training involves practical instruction on fueling and charging battery electric buses, energy storage systems, and powertrain technologies.

Moreover, the program features several innovative modules that delve into the functionality of major sub-components, such as Ballard fuel cells and their associated air and cooling systems. Looking ahead, ZEBU plans to roll out more modules focused on lithium-ion cells and the complex workings of battery modules and packs. This advancement could enable technicians to repair malfunctioning cells rather than replacing entire battery packs, significantly cutting down both the time and costs linked to bus downtime.

To further enrich the learning experience, ZEBU leverages mixed reality systems that simplify complex information, enhancing understanding. This approach reimagines workforce training by immersing staff in real-time learning scenarios. ZEBU's "learning-by-doing" framework gains added value as employees engage in hands-on tasks, guided by virtual demonstrations. Mixed reality systems provide "live assist" during on-the-job training, making it easier to tackle intricate, multilayered tasks in a less intimidating way. This method transforms traditional training presentations into vibrant, interactive three-dimensional learning experiences.

ZEBU effectively harnesses both augmented reality (AR) and virtual reality (VR) technologies. AR overlays virtual objects in the real world, while VR offers an immersive experience in a completely digital environment. In recent AR pilot programs, ZEBU has zeroed in on two vital areas of ZEB maintenance: conducting preventive maintenance inspections and replacing critical air compressors or sub-components of fuel cells.

With AR, mechanics are able to work hands-free in a live workshop environment, guided by virtual displays that showcase action videos or holograms demonstrating task execution. This on-the-spot learning and repairing process enhances overall efficiency. In the VR domain, ZEBU aims to immerse learners in safe practices related to high-voltage settings. The VR environment serves as a secure platform for practicing and mastering procedures without the associated risks of real-life arc flashes. Through this innovative training approach, individuals can develop safety habits and grasp the implications of their actions, reinforcing standard operating procedures for real-world scenarios and boosting their confidence in handling high-voltage operations.

ZEBU and Industry: A National Resource for ZEBs

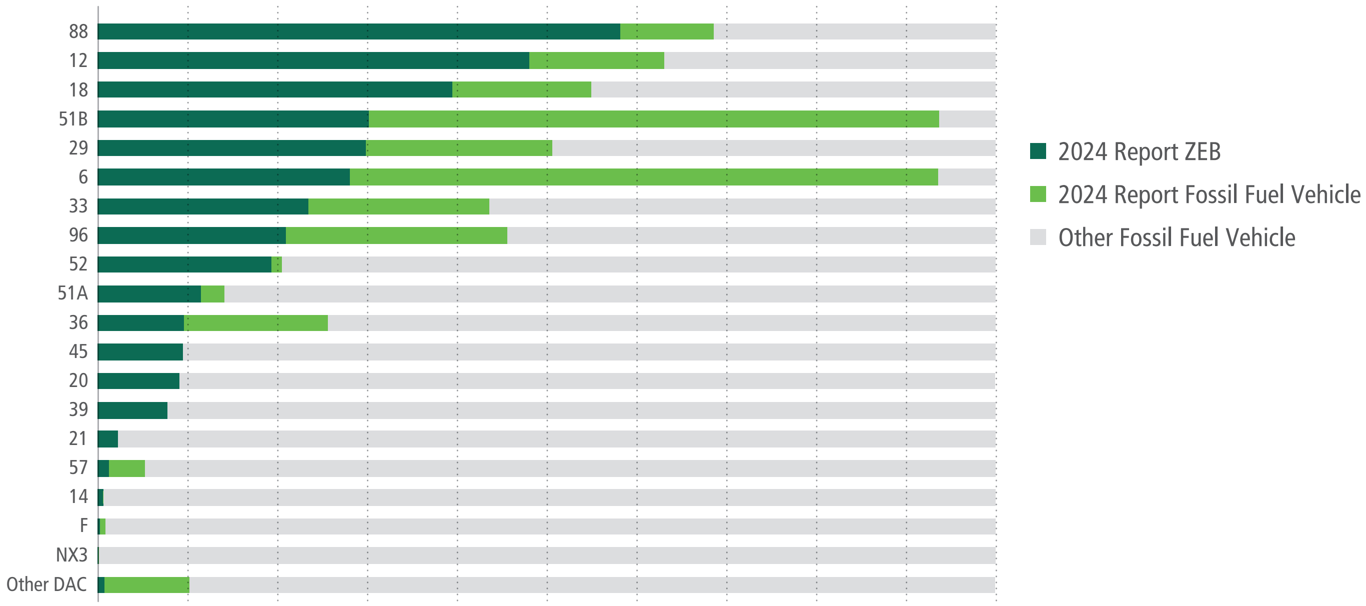
To support the District's rollout of Zero Emission buses (ZEB), we will create a comprehensive asset library. This knowledge-sharing platform aims to assist transit agencies in implementing, maintaining, and sustaining their Zero Emission bus initiatives. It will offer valuable insights into developing career ladder programs that nurture the talent needed for a sustainable ZEB future. Additionally, we will actively engage with frontline staff eager to enhance their skills. With appropriate funding, we will ensure that ZEBU is well-equipped to deliver Zero Emission bus training as a fundamental part of our core programming.

Transforming Comunities with Clean Corridors ZEB Deployments

Clean Corridors Plan

The District's landmark Clean Corridors Plan ensures that disadvantaged communities across our service area are the first to receive Zero Emission bus service. The California State Legislature passed SB 535 in 2012, requiring 25 percent of Cap & Trade program investments to be spent in Disadvantaged Communities (DACs). The legislation carried a methodology for identifying those communities' using information about income, race, pollution, and other factors. The state routinely updates state-wide maps of communities they identify as DACs. The focus on investments in disadvantaged communities aims to improve public health, quality of life, and economic opportunity in California's most burdened communities while reducing air pollution.

Distribution of ZEB Trip Deployments



The deployments feature lines only assigned to communities identified as DACs in the AC Transit Board-adopted Clean Corridors Plan (SR 20-017). By prioritizing ZEB deployment in these areas, the plan aims to reduce the environmental impact of transit operations, improve air quality, and enhance the mobility of underserved communities. The figure below illustrates which lines had buses from this program deployed in 2024. The results indicate that Lines 88, 12, 18, 51B, 29 and 6 had the highest number of deployments within the Clean Corridors program, which meets the compliance of the DAC assignments. These lines were chosen for the following reasons:

1. Serve disadvantaged communities that could benefit from reduced emissions from ZEBs
2. They have high ridership.
3. They are typically assigned 40-foot buses.
4. They are generally flat and most of the lines go no higher than the Macarthur/580 corridor.

The primary lines for the core service network in East Oakland have been operating with weekday schedules since August 2020. The emergency service (7-day Sunday levels) adjusted the schedule to reduce pass-ups as higher ridership returned to the lines.

The chart below tracks how the ZEBs were deployed in 2024. Each route was classified as serving a DAC or another route, and the proportion of trips on a DAC or another route was calculated. The results show that over 90% to 99% of ZEB deployments occurred on DAC routes. This means we meet the goal of utilizing ZEBs in Disadvantaged Communities as outlined in the Clean Corridor Plan.

Zeb Deployment by Route Type (January – December 2024)

		DAC Route	Other Routes
DIESEL		46.3%	53.7%
HYBRID		87.7%	12.3%
FCEB	7000	90.7%	9.3%
	7030	93.0%	7.0%
BEB	8000	91.8%	8.2%
	8006	98.1%	1.9%
	8008	94.1%	5.9%

The deployment of buses to the DAC routes answers how we use the available resources. The chart below demonstrates the trip distribution of the ZEB fleets on our DAC routes, where routes 88, 12, and 18 experienced more than 30% of the trips assigned to a Zero Emission bus.

Zero Emission Technologies Environmental Impacts

In recent years, increased focus on greenhouse gas emissions has highlighted transportation as a significant environmental contributor. This has led to a growing push for Zero Emission buses (ZEBs), which offer a sustainable alternative to conventional diesel or hybrid buses. ZEBs operate on electricity or hydrogen fuel cells, producing no greenhouse gas emissions during use.

While ZEBs have zero tailpipe emissions (Scope 1), it's crucial to consider Scope 2 and Scope 3 emissions. Scope 2 emissions arise from the electricity or hydrogen production, while Scope 3 emissions pertain to the manufacturing and disposal of ZEB components. Evaluating the full life cycle of ZEBs is essential for understanding their overall environmental impact.

AC Transit launched a Sustainability Program in 2022 to track life cycle emissions, focusing on Scope 1 emissions from diesel. In 2024, the ZEB fleet offset a total of 1,396 metric tons of CO_2, equivalent to burning 1.55 million pounds of coal or powering 187 homes for a year, with the FCEB 7030 model leading the way in emissions offset due to its operational mileage.

Operational Performance of ZEB Technology

Bus Evaluation and Performance Overview

This report examines 40-foot buses produced between 2016 and 2024. The fleet being analyzed includes a diverse mix of technologies: fuel cell, battery electric, diesel, and diesel-hybrid. Below, you will find a performance evaluation table that summarizes key statistics for six different fleet groups throughout the calendar year 2024.

Notable findings reveal that the battery electric bus (BEB) fleet achieved the lowest cost per mile. It is important to note that warranty expenses are included in the calculation of the annual cost per mile (CPM). The time required to process warranty claims can vary significantly, ranging from several months to as long as a year, which complicates direct comparisons. However, as mileage accumulates, warranty costs are gradually integrated into the CPM calculation over time.

Although the initial purchase price of BEB buses was high, this expense tends to decrease rapidly as the mileage increases.

ZEB Performance Evaluation (2024)

FLEET	DIESEL (BASELINE)	DIESEL HYBRID	FUEL CELL ELECTRIC (FCEB)	BATTERY ELECTRIC (BEB)
Bus Quantity	35	25	30	28
Life-to-Date Mileage (Per Bus Avg.)	313,066	343,665	97,560	33,521
2024 Mileage	1,898,100	1,057,301	809,428	451,795
Cost/Mile (w/credits)	2.13	2.28	2.75	2.10
Fleet Availability	90.93%	84.89%	53.17%	63.90%
Reliability (MBCRC)	23,726	7,774	7,859	13,691
MPG (DGE)	4.69	5.24	7.68	14.24

An analysis of bus technology trends was conducted using the cost-per-mile metric. The accompanying figure shows normalization patterns for various fuel sources, highlighting the value ranges for different fleets.

The District is experiencing increased variability in its battery electric bus (BEB) and fuel cell electric bus (FCEB) fleets compared to diesel and hybrid buses, primarily due to limited sample sizes: 35 diesel, 25 hybrid, and 30 FCEB buses.
Diesel and hybrid buses demonstrate more consistency and lower costs than FCEB buses. However, FCEB performance may improve with increased mileage. BEBs show significant cost variability but a decreasing cost-per-mile trend. As most BEBs are new, further research is needed to assess their long-term costs as more service miles are accumulated.

ZEB Fleet Evaluation

This report expands the evaluation of Zero Emission bus (ZEB) technologies beyond the 5X5 control fleet in the ZETBTA reports. It assesses all 40-foot buses manufactured between 2016 and 2024, covering various propulsion technologies: fuel cell, battery electric, diesel, and diesel-hybrid systems, focused on the calendar year 2023.

The analysis includes 118 buses, detailing service activation dates, cumulative mileage, and design specifications. AC Transit typically needs an 18-month lead time for orders to service activation. A cost-per-mile metric was used to analyze bus technology trends, highlighting the variability in performance and costs among different bus types.

Currently, battery electric bus (BEB) and fuel cell electric bus (FCEB) fleets exhibit greater variability compared to diesel and hybrid buses, attributed to smaller sample sizes. Overall, diesel and hybrid buses show more consistency and lower costs, though FCEB performance may improve with increased mileage. While BEBs show significant cost variability, a downward trend in cost-per-mile is observed. More research is needed as BEBs accumulate service miles to better understand their long-term costs.

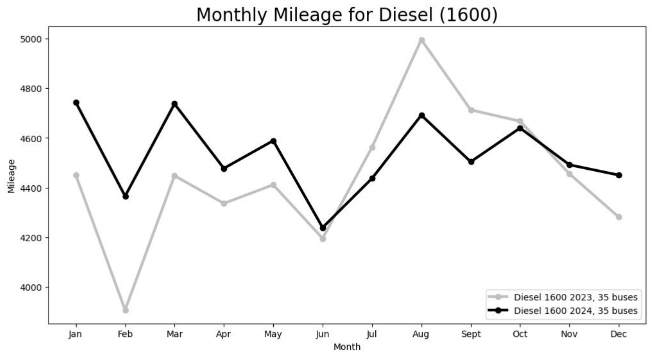
ZEB Fleet Matrix

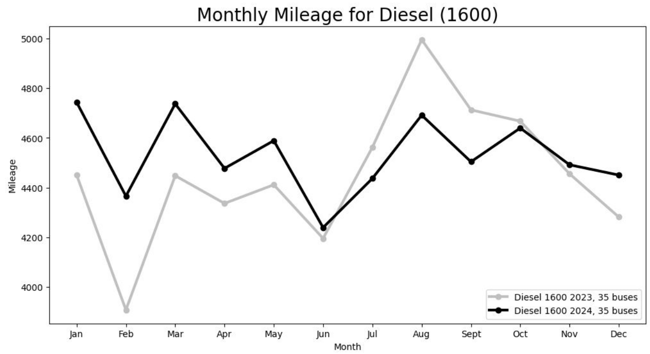
FLEET	DIESEL (BASELINE)	DIESEL HYBRID	FUEL CELL ELECTRIC (FCEB)		BATTERY ELECTRIC (BEB)		
			7000	7030	8000	8006	8008
Series Grouping	1600	1550	7000	7030	8000	8006	8008
Year Model	2018	2016	2019	2022	2019	2021	2022
Manufacturer	Gillig	Gillig	New Flyer	New Flyer	New Flyer	Gillig	Gillig
Bus Purchase Cost	$488,247	$699,060	$1,156,044	$1,212,161	$938,184	$963,009	$964,859
Energy/ Fuel Capacity	120 gal	120 gal	38 kg	38 kg	466 kW	444 kW	444 kW
Range Specification	450 miles	500 miles	300 miles	300 miles	180 miles	130 miles	130 miles
Propulsion Design	Conventional Diesel	Diesel/ Battery	Battery Dominant	Battery Dominant	Battery	Battery	Battery
Battery Design	N/A	Lithium-Ion	Lithium-Ion	Lithium-Ion	Lithium-Ion	Lithium-Ion	Lithium-Ion
Engine/Powerplant	Cummins	Cummins	Ballard/A123	A123	Xalt Energy	Cummins	Cummins
Transmission/ Propulsion	Voith	BAE	Siemens	Siemens	Siemens	Cummins	Cummins
In Service Date	Jan 2019	Aug 2016	Jan 2020	Dec 2021	May 2020	Sep 2021	Aug 2024
Life-to-Date Mileage (Per Bus Avg.)	313,066	343,665	135,989	78,345	81,194	46,456	20,939
Funding Source	Federal, Regional, Local	Federal, Regional, Local	State, Regional, Local	Federal, State, Local	Federal, Regional	Federal, State, Local	Federal, Regional

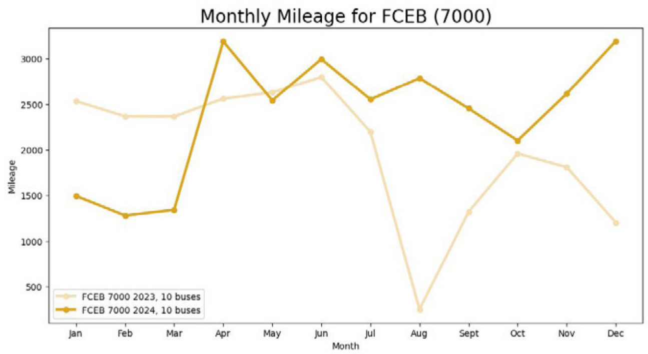
Bus Mileage

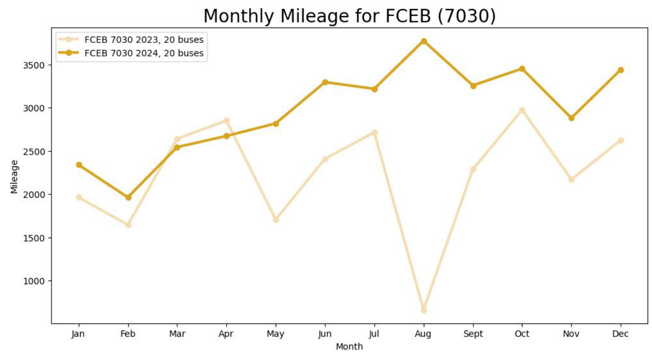
Zero Emission buses need to effectively reduce environmental impacts while being efficient and cost-effective to serve as a viable alternative to traditional fossil fuel-powered buses. This section delves into the performance and efficiency of various ZEB technologies, examining aspects such as mileage, fuel efficiency, and energy consumption rates. By comparing these metrics, we can gain a clearer understanding of the strengths and shortcomings of each technology. In the coming years, this performance data will guide our purchasing decisions and shape our plan for transitioning to a 100% Zero Emission fleet by 2040.

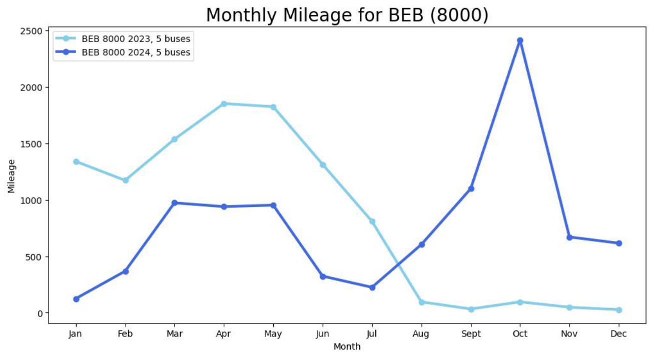
Fuel Monthly Mileage by Technology

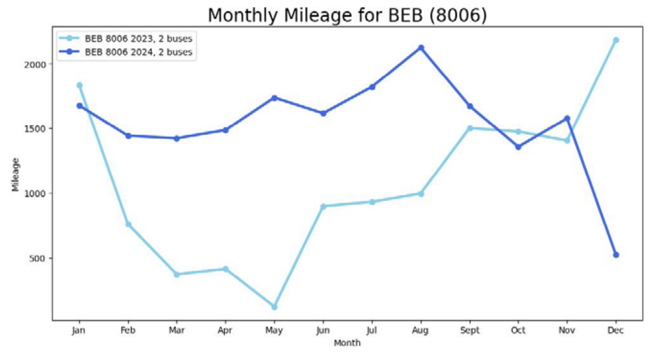


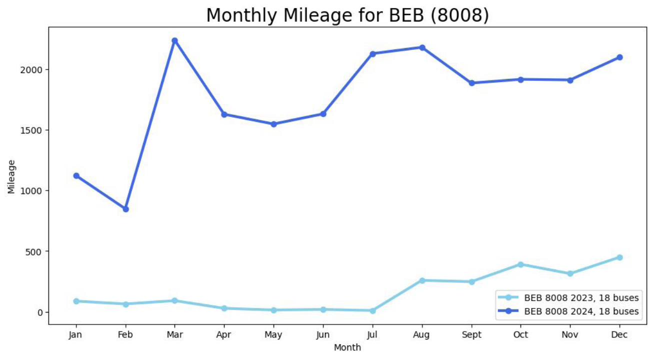












The figures above provides the average monthly bus mileage by technology. Based on this information, the following observations were noted:

- Diesel (1600)- accumulated the most miles during the period, and this bus type has the highest mileage for most months.
- Hybrid (1550)- mileage remained consistent, ranging from 3,000 to 4,000 miles per month per bus.
- FCEB (7000 and 7030)- has a stable monthly mileage between 2000 to 3000 miles, which is a great improvement from 2023 where they experienced a sharp mileage reduction due to issues found on the ESS HV power connections and current sensor module (CSM) found during inspections.
- BEB (8008)- starting to become steadily operational since 2023, with all buses fully deployed in October 2024.

Fuel and Energy Efficiency

Regarding relative performance differences, diesel buses traveled the most miles throughout the year, while the other bus types show variability in their mileage trends. Hybrid and FCEB (7000) bus types show stable mileage growth over the year, while FCEB (7030) and BEB (8006) types show the most variability in mileage.

Fuel Efficiencies and Equivalent Comparison

		Energy/Fuel	Fuel Efficiency	Efficiency Metric	Equivalent Efficiency	Equivalent Metric
DIESEL		Diesel	4.69	Miles/Gal	4.69	M/DGE
HYBRID		Diesel	5.24	Miles/Gal	5.24	M/DGE
FCEB	**7000**	Hydrogen	6.68	Miles/Kg	7.42	M/DGE
	7030	Hydrogen	6.99	Miles/Kg	7.77	M/DGE
BEB	**8000**	Electricity	0.33	Mile/kWh	12.45	M/DGE
	8006	Electricity	0.40	Mile/kWh	15.30	M/DGE
	8008	Electricity	0.37	Mile/kWh	14.26	M/DGE

The chart above compares the native fuel efficiency and equivalent efficiency of the various bus propulsion technologies.

- BEB 8006 has the highest fuel efficiency, with 15.3 miles per diesel gallon equivalency, followed closely by BEB 8008, which has 14.26.
- FCEB 7000 and 7030 series buses have higher fuel efficiency than diesel and hybrid buses but lower than the BEB types.
- The diesel buses have the lowest fuel efficiency among the bus types listed.

Zero Emission buses, particularly BEB buses, have significantly higher energy efficiencies than diesel-powered buses.

Energy Rate Comparison (Annual Average)

	DIESEL	HYDROGEN	ELECTRICITY
2024	$3.01 / Gal	$10.58 / KG	$0.26 / kWh
2023	$3.07 / Gal	$9.81 / KG	$0.25/ kWh
% Changes	-2.0%	8%	3.6%

The figure above shows the average annual cost of energy in 2024. Energy prices are difficult to compare because of the inherent differences in energy efficiency between the specific propulsion technologies that use the fuels. Compared to the prices in 2023, we noticed that the diesel price dropped by about 2% from $3.07 to $3.01, while prices increased for Hydrogen by 8% (from $9.81 to $10.58) and Electricity by 3.6% (from $0.25 to $0.26). This change in energy cost partly contributes to the cost-per-mile calculation changes in the next section.

Maintenance and Operational Cost Analysis

Zero Emission buses must also be cost-effective and environmentally friendly. This section will focus on the cost analysis of different ZEB technologies, including their ongoing maintenance and operational costs. Moreover, we will examine the available energy credits for ZEBs, which could significantly reduce their operational costs. By comparing these metrics, we can better understand the economic feasibility of adopting different ZEB technologies, identify which technologies have the lowest operational costs, and provide the best value for public resources.

Operational Cost/Mile Totals (January – December 2024)

METRIC	DIESEL	HYBRID	FCEB		BEB		
	1600	1550	7000	7030	8000	8006	8008
Total Costs (Fleet-Wide)							
Maintenance	$2,832,719	$1,799,587	$318,892	$697,154	$85,703	$46,244	$500,209
Labor Hours	16,280	7,486	1,403	3,133	471	316	3,534
Energy (Fuel)	$1,217,163	$606,930	$306,000	$896,360	$15,988	$23,812	$273,121
Total	**$4,066,162**	**$2,414,003**	**$626,295**	**$1,596,647**	**$102,162**	**$70,372**	**$776,863**
Costs per Mile							
Maintenance	$1.49	$1.70	$1.60	$1.14	$4.25	$1.25	$1.27
Energy (Fuel)	$0.64	$0.57	$1.53	$1.47	$0.79	$0.64	$0.69
Total	**$2.13**	**$2.28**	**$3.13**	**$2.61**	**$5.04**	**$1.90**	**$1.96**
Bus Count	35	25	10	20	5	2	21
Avg Daily Bus Count	25.62	17.55	3.23	9.32	1.58	1.45	6.62
Total Mileage	1,898,100	1,057,301	199,456	609,972	20,168	36,927	394,700

The chart above shows a detailed list of bus fleet cost averages, CPM performance, and daily bus availability in service. Based on this information, the District observed the following:

- The Hybrid 1550 has the lowest energy (fuel) cost per mile, followed by the Diesel 1600 and BEB 8000 buses. The FCEB 7030 has the highest fuel cost per mile.
- The FCEB 7030 has the lowest maintenance cost per mile, followed by the Diesel 1600 and Hybrid 1550. The highest maintenance cost is BEB 8000.
- The total cost per mile is lowest for the Diesel 1600, followed by the Hybrid 1550.

The table below shows the percentage change in 2024 compared to 2023. The primary disparity in Cost per Mile between 2023 and 2024 stems from a substantial cost increase for BEB usage. For BEB 8008, the CPM decreased by 84.9%. This drop in cost is primarily attributed to the gradually maturing BEBs that enter service in 2023. These buses initially did not have sufficient supporting facilities to be operational, and now they can go into service in 2024. There were multiple incidents in 2023 where we needed to replace the battery packs on BEBs, resulting in significantly higher maintenance costs.

Operational Cost/Mile year-over-year percent changes from 2023 to 2024

METRICS	Diesel (BASELINE)	Diesel Hybrid	Fuel Cell Electric (FCEB)		Battery Electric (BEB)		
	1600	1550	7000	7030	8000	8006	8008
Total Costs (Fleet-Wide)							
Maintenance	9.5%	24.6%	-16.2%	-2.2%	-44.0%	-9.4%	-0.2%
Labor Hours	2.2%	-2.7%	-33.6%	-23.6%	-39.0%	-9.0%	-6.6%
Energy (Fuel)	1.2%	9.6%	1.1%	24.3%	-50.2%	44.0%	644.0%
Total	**6.9%**	**20.4%**	**-8.6%**	**11.1%**	**-45.0%**	**3.6%**	**43.4%**
Costs per Mile							
Maintenance	7.9%	9.2%	0.8%	-14.5%	40.9%	-36.7%	-89.5%
Energy (Fuel)	-0.3%	-3.9%	21.6%	8.6%	25.2%	0.6%	-21.8%
Total	**5.3%**	**5.6%**	**10.0%**	**-2.9%**	**38.2%**	**-27.6%**	**-84.9%**
Bus Count	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Avg Daily Bus Count	2.6%	10.5%	-26.9%	-1.8%	-21.5%	10.5%	259.2%
Total Mileage	1.5%	14.1%	-16.9%	14.4%	-60.2%	43.2%	850.8%

Warranties and Energy Credits

An essential factor to adjust when calculating and comparing costs is the recovered costs through warranty claims and low-carbon fuel standard (LCFS) credits. The chart below shows the warranties and credits recovered for each propulsion technology.

- Top 40 warranties claim all come from BEB or FCEB and involve systems ranging from electronics, fuel systems, and power plants.
- Overall, cost recovery was most significant for BEB, which was more than $599,000.

ZEB Recovery Total: Warranties and LCFS Credits

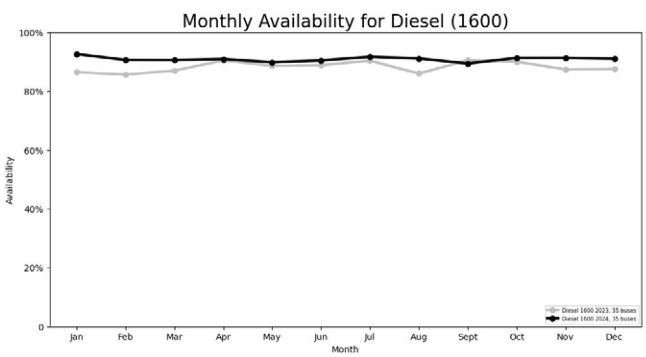
TECHNOLOGY		WARRANTY CLAIMS	WARRANTIES	LCFS NET CREDITS	TOTAL RECOVERY
DIESEL	1600	11	$18,590	$0.00	**$18,590**
HYBRID	1550	5	$7,834	$0.00	**$7,834**
FCEB	7000	42	$202,347	$593.63	**$202,940**
	7030	81	$153,221	$1,815.42	**$155,036**
BEB	8000	12	$148,519	$3,522.99	**$152,042**
	8006	12	$20,915	$6,450.65	**$27,366**
	8008	176	$576,825	$68,947.97	**$645,773**

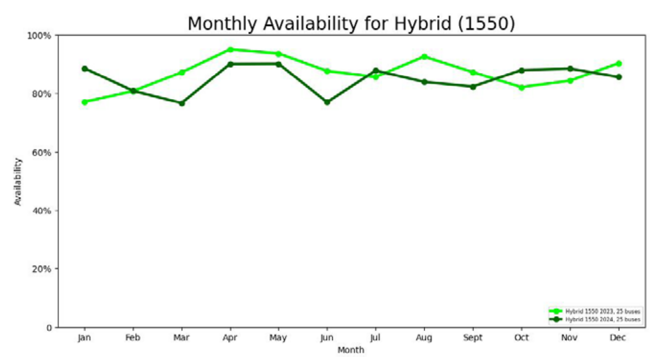
Bus Availability

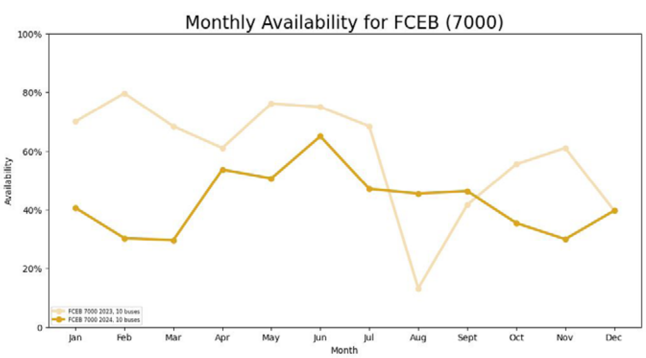
In addition to environmental considerations, the reliability and availability of Zero Emission buses (ZEBs) are critical when evaluating their potential as a replacement for traditional and hybrid diesel buses. ZEBs are a relatively new technology and are still undergoing development and refinement, which can affect their reliability and availability in various ways.

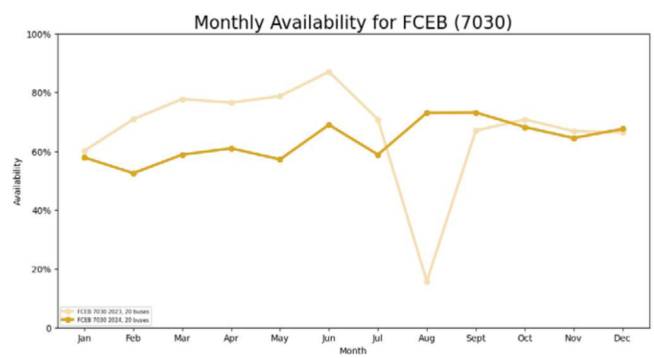
In this section, we will examine the reliability and availability of ZEBs based on data from existing deployments. We will evaluate their performance in terms of their ability to operate consistently and meet their required schedules and examine the factors contributing to their reliability and availability. By analyzing the data, we can gain insight into the challenges and opportunities of using ZEBs and identify areas for improvement to make ZEBs a more reliable and available option for sustainable transportation.

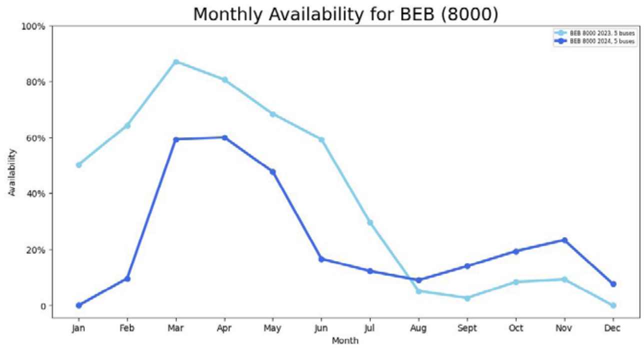
Monthly Bus Availability by Technology (2024)

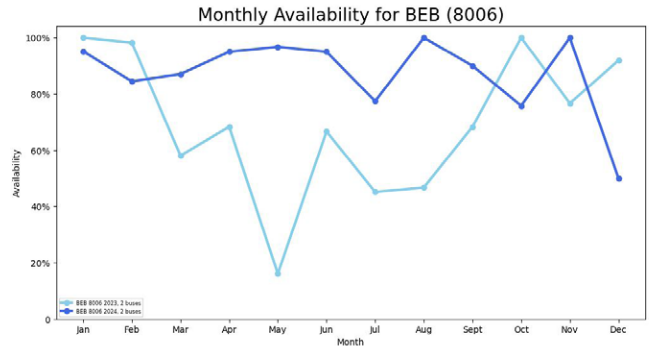


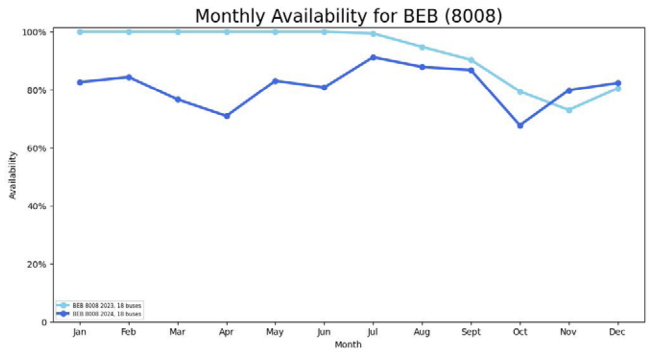












The figure above provides the availability by bus technology, where the District observed the following:

- Diesel and hybrid buses have the highest monthly availability rates among all the fleet types, with diesel averaging 90.93% and hybrid at 84.89% for 2024.
- FCEB 7000 and 7030 have lower monthly availability rates than diesel and hybrid buses, with FCEB 7000 averaging 42.84% and FCEB 7030 at 63.5%.
- Battery electric buses (BEBs) have variable availability, with BEB 8000 averaging 23.26%, BEB 8006 at 87.23% and BEB 8008 at 81.2%.

One of the most critical indicators of reliability is the availability of service, which is whether a bus can make a morning pull-out. Morning pull-out refers to the first bus trip of the day, which is often the busiest and most critical regarding meeting schedules and ensuring that passengers can get to their destinations on time. If a bus cannot make the morning pull-out, it can cause delays and disruptions that can have ripple effects throughout the day. Therefore, it is essential to ensure that ZEBs are reliable enough to make morning pull-out consistently. This can be affected by various factors, such as charging infrastructure, routine maintenance, and unscheduled repairs. By analyzing data on ZEB reliability and availability, we can identify patterns and trends that can help us better understand the factors contributing to reliable performance and develop strategies to improve ZEB reliability.

Bus Reliability

Another critical reliability indicator is the number of chargeable road calls a bus experiences throughout the year. Chargeable road calls refer to situations where a bus cannot continue or experiences a malfunction while in service and needs to be taken off the road for repairs. While some road calls are unavoidable, road calls can result in service disruptions and inconvenience for passengers, as well as increased Maintenance and repair costs for transit agencies. In addition to identifying the number of road calls a ZEB experiences, tracking the cause of each road call is essential, as this can help pinpoint any underlying issues or trends that need to be addressed. By understanding the factors contributing to road calls, the District can develop initiative-taking strategies to reduce the number of road calls, increase reliability, and improve the overall performance of ZEBs.

Because road calls are typically normalized with mileage, this metric should be reported as the miles between chargeable road calls (MBCRC). The higher the MBCRC, the better, as it implies that a bus remains operational longer before an issue occurs. The chart below shows the total road calls and MBCRC across the study fleets.

Miles Between Chargeable Road Calls (January – December 2024)

TECHNOLOGY		Major	Minor	Total	Mileage	MBCRC
DIESEL		11	69	80	1,898,100	23,726
HYBRID		53	84	137	1,057,301	7,774
FCEB	7000	8	18	26	199,456	7,671
	7030	30	47	77	609,972	7,922
BEB	8000	0	2	2	20,168	10,084
	8006	0	1	1	36,927	36,927
	8008	7	25	33	394,700	11,961

Based on the road call information, the District observed the following:

- Diesel buses perform great, at about 23,726 miles between chargeable road calls.
- The electric buses (BEB) have the least number of road calls, but the MBCRC number is also high because most buses are new, with the 8000 and 8006 fleets consisting of only a few buses.
- The hydrogen-powered buses perform the lowest, traveling approximately 7,500 to 8,000 miles between road calls.
- Zero Emission technology systems are not less reliable than conventional technology.

Road Calls By System (January – December 2024)

SYSTEM	DIESEL	HYBRID	FCEB		BEB			TOTAL
			7000	7030	8000	8006	8008	
Common System Failures	37	51	16	50	0	1	24	181
Engine/Fuel Cell System	34	64	1	19	0	0	8	118
Fuel System	5	5	0	1	0	0	0	10
High Voltage System	0	16	9	7	2	0	0	39
Transmission/Electric Drive	4	0	0	0	0	0	0	4
Total	**80**	**136**	**26**	**77**	**2**	**1**	**32**	**354**

These are some examples of failures for different buses:

For **diesel buses**, the most common failure includes:

- Brakes
- Engine problem (check engine light on)
- Air conditioning
- Air leak/pressure

For **hybrid buses**, the most common failure includes:

- Engine problem (check engine light on)
- Coolant System

For **FCEBs**, the most common failure includes:

- Hydrogen fuel system (including high pressure, filter problem, circulation blower, etc)
- Engine problem (check engine light on)
- Battery (mostly warranty repair)

For **BEBs**, the most common failure includes:

- Electrical system problem
- Battery related problem

The chart above groups the road calls into five major systems, which allows us to evaluate the reliability of the Zero Emission technology systems on the buses. This is a simple method to see how these new systems compare, where the District observed the following:

- Common system failures found on conventional and Zero Emission buses are among the most significant contributors to road calls.
- Zero Emission propulsion system failures on the FCEB and BEB were lower than the Diesel propulsion system failures.

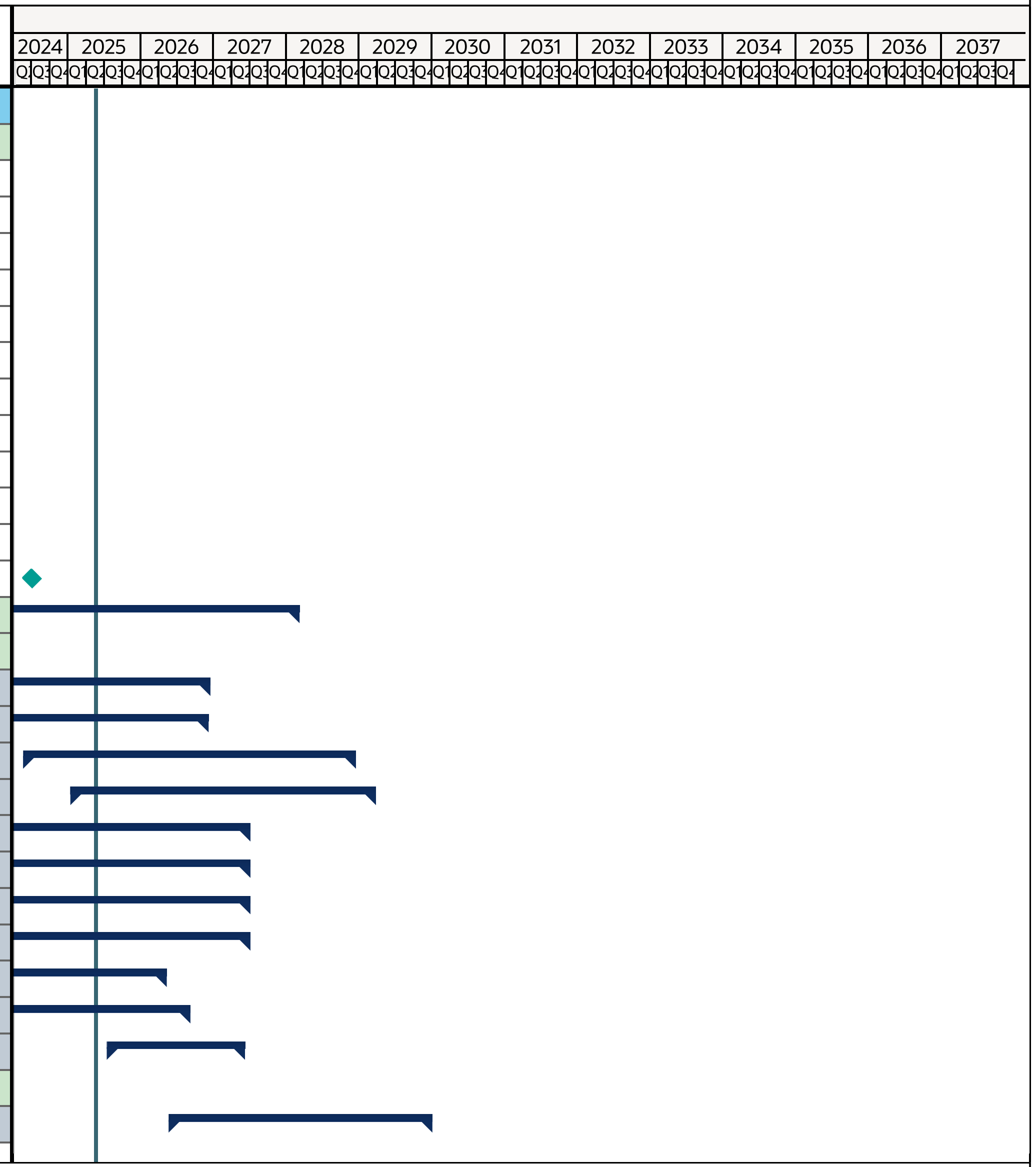
Appendix A: ZEB Program Integrated Master Schedule (pg 1 of 3)

ZEB-IMS 2505 | Zero Emissions Program

May-28-25 10:50 a.m. | Investment Master Schedule

Name

- ZEP Investment Master Schedule
  - Major Milestones
    - Start ZEB Vehicle and Infrastructure Investments (2005)
    - Constructed D4 Hydrogen Infrastructure (2015)
    - Constructed D2 Hydrogen Maintenance Bay-P2027 (2018)
    - Purchased 10 Fuel Cell Buses (2019)
    - Constructed D4 Battery Electric Infrastructure (2019)
    - Purchased 5 Battery Electric Buses (2019)
    - Constructed D4 Battery Electric Infrastructure-P2115 (2020)
    - AC Transit ZEB Rollout Plan v1 (Res No. 20-029) (2020)
    - AC Transit ZEB Transition Plan v2 (Revised for Bil and ICT require…
    - Purchased 40 ZEBs (20 FC, 20 BEB)-P2175
    - Purchased 3 Battery Electric Buses-P2166
    - Constructed D2 Battery Bus Infrastructure-P2183 (2024)
  - 2022 thru 2026
  - 2024 thru 2028
    - 9 - Articulated FCEB-P2235
    - 47 - 40ft FCEB-P2234
    - 23 - Articulated FCEB-0721
    - 10 - 35ft BEB -0692
    - CMF ZEB Maintenance Bay Upgrade- Prep Booth (2 Bays)-P2198…
    - D2 ZEB Maintenance Bay Upgrade- Maintenance (10 Bays)-P2198
    - D4 ZEB Maintenance Bay Upgrade- Maintenance (12 Bays)-P2198
    - D6 ZEB Maintenance Bay Upgrade- Maintenance (14 Bays)-P21…
    - D4 BEB Chargers-P2184
    - D4 Hydrogen Station Upgrade-P2211
    - D6 Hydrogen Station 120+ Buses-P2193
  - 2026 thru 2030
    - 102 - 40ft FCEB-0720 & 0722



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Appendix A: ZEB Program Integrated Master Schedule (pg 2 of 3)

ZEB-IMS 2505 | Zero Emissions Program

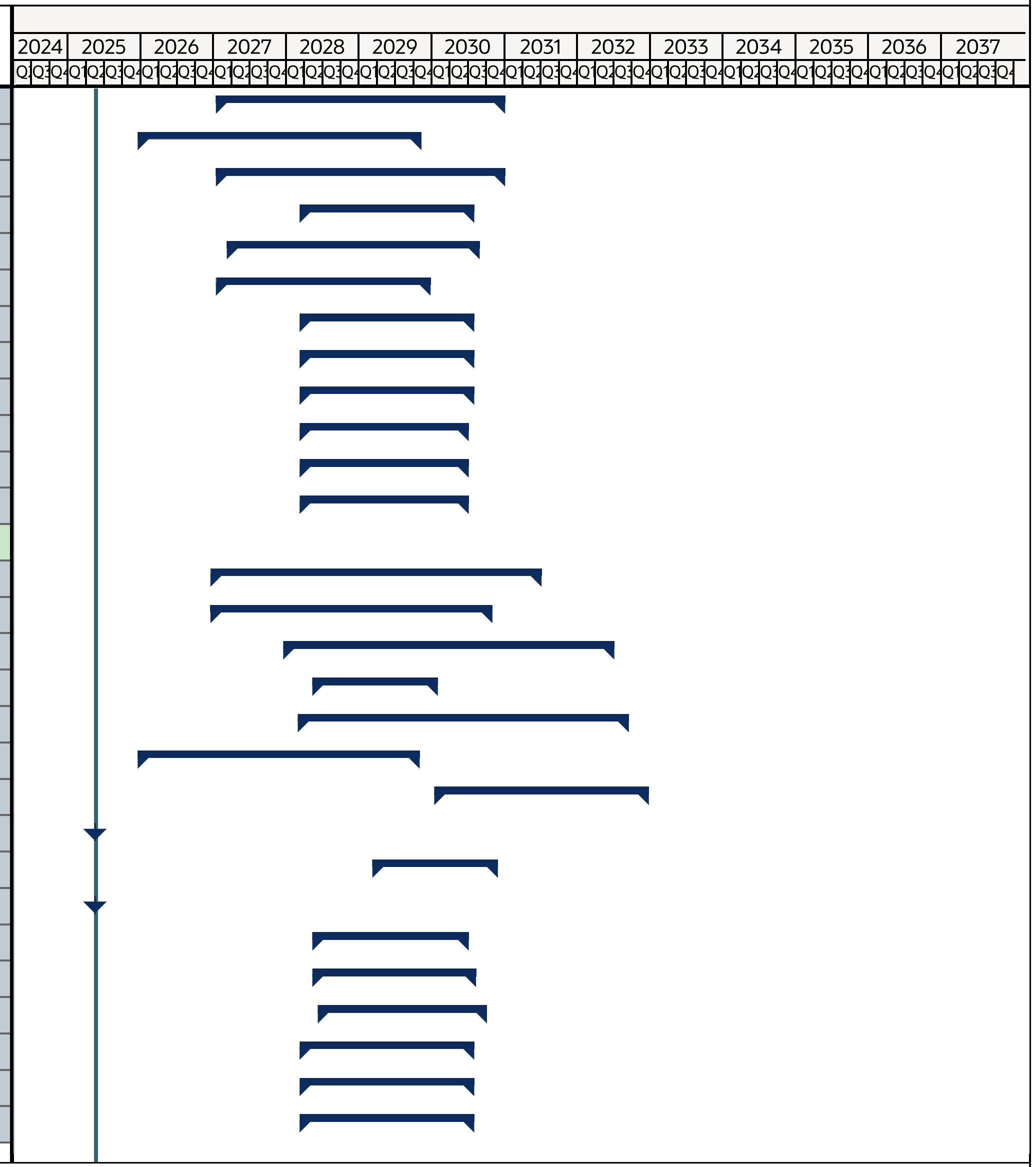
May-28-25 10:50 a.m. | Investment Master Schedule

Name

- 25 - 40ft FCEB-0724
- 55 - 40ft FCEB-0723
- 10 - 40ft FCEB-0725
- D3 Hydrogen Station 104 Buses-0733
- D2 Hydrogen Station Expansion to 150+ Buses-0731
- D6 BEB Charging Infrastructure-30 Buses-0736
- D6 ZEB Maintenance Bay Upgrade- Body Shop (4 Bays)-0737
- D6 ZEB Maintenance Bay Upgrade- Dyno (2 Bays)-0737
- D6 ZEB Maintenance Bay Upgrade- Paint Booth (1 Bay)-0737
- D4 ZEB Maintenance Bay Upgrade- Body Shop (3 Bays)-0735
- D4 ZEB Maintenance Bay Upgrade- Paint Booth (1 Bay)-0735
- D4 ZEB Maintenance Bay Upgrade- Tire Shop (2 Bays)-0735

2028 thru 2032

- 27 - Articulated FCEB
- 10 - 40ft BEB
- 20 - 40ft BEB
- CMF ZEB Maintenance Bay Upgrade- Body Shop (7 Bays)
- 28 - Articulated FCEB
- 5 - 40ft BEB
- D4 BEB Charging Infrastructure Expansion - 29 Buses
- CMF ZEB Maintenance Bay Upgrade- Body Shop (4 of 7 Bays)
- CMF ZEB Maintenance Bay Upgrade- Dyno (4 Bays)
- CMF ZEB Maintenance Bay Upgrade- Maintenance (4 Bays)
- CMF ZEB Maintenance Bay Upgrade- Paint Booth (1 Bay)
- D2 ZEB Maintenance Bay Upgrade- Body Shop (2 Bays)-0732
- D2 ZEB Maintenance Bay Upgrade- Tire Shop (2 Bays)-0732
- D3 ZEB Maintenance Bay Upgrade- Body Shop (1 Bay)-0734
- D3 ZEB Maintenance Bay Upgrade- Tire Shop (1 Bay)-0734
- D3 ZEB Maintenance Bay Upgrade- Paint Booth (1 Bay)-0734



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Appendix A: ZEB Program Integrated Master Schedule (pg 3 of 3)

ZEB-IMS 2505 | Zero Emissions Program

May-28-25 10:50 a.m. | Investment Master Schedule

Name

- D3 ZEB Maintenance Bay Upgrade- Steam Bay (1 Bay)-0734
- D2 ZEB Maintenance Bay Upgrade- Paint Booth (1 Bay)-0732
- D3 ZEB Maintenance Bay Upgrade- Maintenance (12 Bays)-0734
- D4 Hydrogen Station Expansion to 150+ Buses

2030 thru 2034

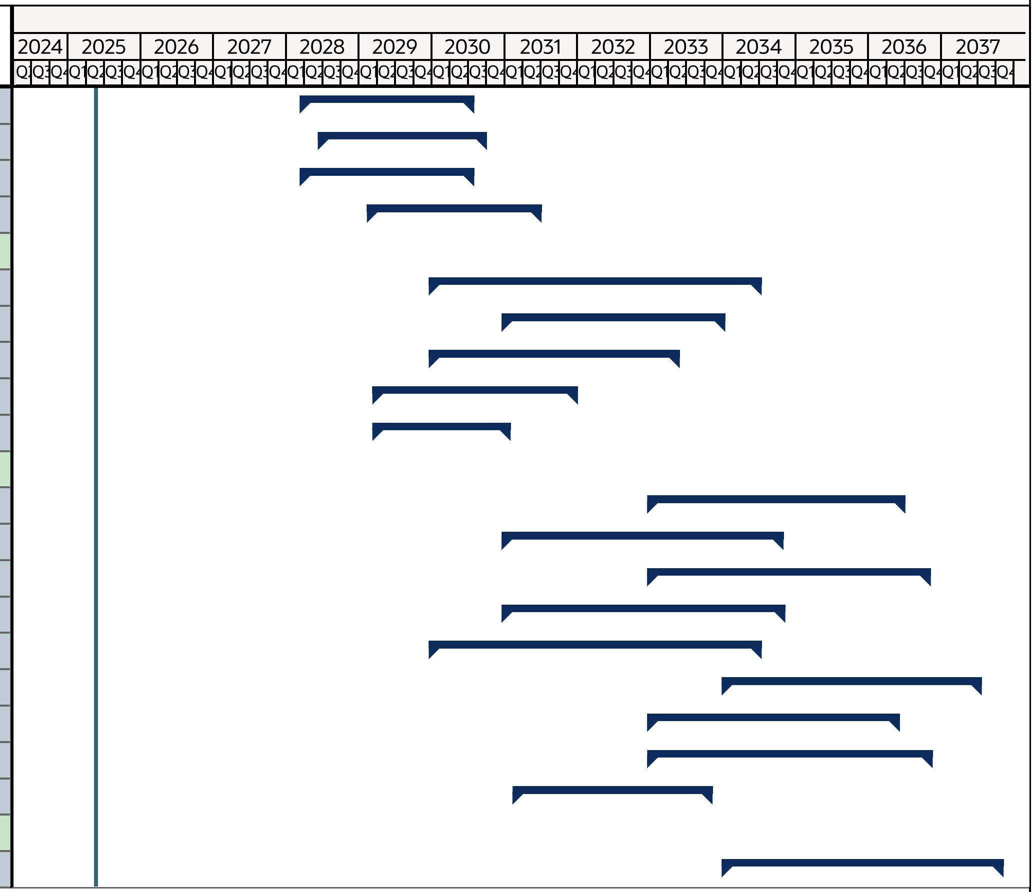
- 86 - 40ft FCEB
- 11-Articulated FCEB
- 31 - 40ft BEB
- D2 BEB Charging Infrastructure Expansion - 70 Buses
- D6 Hydrogen Station Expansion 120+ Buses

2032 thru 2036

- 50 - Over the road FCEB
- 61 - 40ft FCEB
- 44 - 40ft BEB
- 20 - 30ft BEB
- 15 - Double decker FCEB
- 23 - Articulated FCEB
- 7 - Over The Road FCEB
- 5 - 40ft BEB
- D4 BEB Charging Infrastructure Expansion - 24 Buses

2034 thru 2038

- 24 - 40ft BEB



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Appendix B: Bus Procurement Projects by Phase*

**Note that some projects may be combined in the CIP for effective implementation*

Phase	Project Description	Projected CIP Funding Year	Cost Estimate
Board Approval Process	Purchase 55 FCEBs	2027	$99,694,547
	Purchase 54 FCEBs	2027	$88,983,563
	Purchase 48 FCEBs	2026	$79,096,500
	Purchase 47 FCEBs	2025	$73,043,146
	Purchase 27 FCEBs	2028	$81,296,715
	Purchase 25 FCEBs	2028	$45,315,703
	Purchase 23 Articulated FCEBs	2026	$52,030,622
	Purchase 10 FCEBs	2028	$18,126,281
Procurement	Purchase 9 Articulated FCEBs	2024	$19,829,724
Future	Purchase 7 FCEBs	2033	$26,897,341
	Purchase 61 FCEBs	2032	$127,187,930
	Purchase 50 FCEBs	2029	$96,387,206
	Purchase 50 DD FCEBs	2034	$199,808,821
	Purchase 5 BEBs	2033	$9,687,285
	Purchase 44 BEBs	2034	$88,658,030
	Purchase 36 FCEBs	2029	$72,174,740
	Purchase 35 BEBs	2028	$57,965,121
	Purchase 31 BEBs	2030	$55,529,924
	Purchase 28 Articulated FCEBs	2026	$84,307,705
	Purchase 24 BEBs	2035	$50,293,283
	Purchase 23 FCEBs	2035	$81,461,378
	Purchase 20 BEBs	2033	$37,258,788
	Purchase 15 FCEBs	2032	$79,923,528
	Purchase 11 Articulated FCEBs	2032	$34,635,111

Appendix C: Infrastructure Projects*

**Note that some projects may be combined in the CIP for effective implementation*

Phase	Project Description	Projected CIP Funding Year	Cost Estimate (ROM)***
Planning (these are all in design)	CMF ZEB Maint Bay Upgrade - Maintenance - 10 Bays	2024	$2,392,000
	CMF ZEB Maint Bay Upgrade - Prep Booth - 2 Bay	2025	$1,000,500
	D2 ZEB Maint Bay Upgrade - Maintenance - 12 Bays	2025	$2,392,000
	D4 ZEB Maint Bay Upgrade - Maintenance - 12 Bays	2025	$2,392,000
	D6 Hydrogen Station - 100+ Buses	2024	$16,054,000
	D6 ZEB Maint Bay Upgrade - Maintenance - 14 Bays	2025	$2,392,000
Design	TEC Modernization	2025	$23,000,000
Construction	D4 BEB Charging Infrastructure	2022	$14,876,400
	D4 Hydrogen Station Upgrade	2023	$6,145,106
Future**	CMF ZEB Maint Bay Upgrade - Body Shop - 7 Bays	2025	$2,001,000
	CMF ZEB Maint Bay Upgrade - Dyno - 4 Bays	2025	$1,334,000
	CMF ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$667,000
	D2 ZEB Maint Bay Upgrade - Body Shop - 2 Bays	2025	$1,000,500
	D2 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$667,000
	D2 ZEB Maint Bay Upgrade - Tire Shop - 2 Bays	2025	$1,000,500
	D4 ZEB Maint Bay Upgrade - Body Shop - 3 Bays	2025	$1,334,000
	D4 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$667,000
	D4 ZEB Maint Bay Upgrade - Tire Shop - 2 Bays	2025	$1,000,500
	D6 ZEB Maint Bay Upgrade - Body Shop - 4 Bays	2025	$1,334,000
	D6 ZEB Maint Bay Upgrade - Dyno - 2 Bays	2025	$1,000,500
	D6 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$667,000
	D4 BEB Charging Infrastructure Expansion - 26 Buses	2027	$19,136,001
	D3 Hydrogen Station - 104 Buses	2025	$14,260,000
	D3 ZEB Maint Bay Upgrade - Body Shop - 1 Bay	2025	$667,000
	D3 ZEB Maint Bay Upgrade - Maintenance 12 Buses	2025	$2,668,000
	D3 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$667,000
	D3 ZEB Maint Bay Upgrade - Steam Bay - 1 Bay	2025	$667,000
	D3 ZEB Maint Bay Upgrade - Tire Shop - 1 Bay	2025	$667,000
	D4 Hydrogen Station Expansion - to 150+ Buses	2030	$11,408,000
	D6 BEB Charging Infrastructure - 32 Buses	2030	$35,732,800
	D6 Hydrogen Station Expansion - to 150+ Buses	2030	$11,408,000
	D2 BEB Charging Infrastructure Expansion - 70 Buses	2031	$16,120,000
	D2 Hydrogen Station Expansion - to 150+ Buses)	2031	$10,672,000
	D4 BEB Charging Infrastructure Expansion - 24 Buses	2034	$11,051,040
	D6 Microgrid to Support BEB Charging Infrastructure****	2029	$20,010,000

*** Future Infrastructure Projects Required for 2040 ICT Carb Compliance*
****Estimates may be updated since the last approved CIP*
***** Microgrid projects are part of risk mitigation, and an allowance has been added to project cost estimates to address risk, which will require further approval.*

Appendix D: ZEB Investment Build Sheet

Investment Type	Investments	ZEB Transition Forecast Cost (2025)	Program Estimated Cost	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	**$292,200,000**	**$1,721,482,376**	**$2,013,682,376**	**$1,397,525,169**	**($323,957,207)**
Existing FCEB	$248,900,000	$0	$66,900,000	$0	$0
Existing BEB	$43,300,000	$0	$30,300,000	$0	$0
Diesel Bus Replacement with ZEB	$0	$1,721,482,376	$0	$1,397,525,169	
Infrastructure	**$103,200,000**	**$233,934,836**	**$337,134,836**	**$131,194,728**	**($102,740,108)**
Division 2	$36,100,000	$37,045,106	$73,145,106	$0	($37,045,106)
Charging Stations	$2,300,000	$22,785,106	$25,085,106	$0	($22,785,106)
Hydrogen Stations	$31,500,000	$11,408,000	$42,908,000	$0	($11,408,000)
Maintenance Bays	$2,300,000	$2,852,000	$5,152,000	$0	($2,852,000)
Division 3	$0	$20,401,000	$20,401,000	$0	($20,401,000)
Hydrogen Stations		$14,697,000	$14,697,000	$0	($14,697,000)
Maintenance Bays	$0	$5,704,000	$5,704,000	$0	($5,704,000)
Division 4	$48,500,000	$87,598,851	$136,098,851	$0	($87,598,851)
Charging Stations	$15,000,000	$63,513,121	$78,513,121	$0	($63,513,121)
Hydrogen Stations	$31,200,000	$20,877,230	$52,077,230	$0	($20,877,230)
Maintenance Bays	$2,300,000	$3,208,500	$5,508,500	$0	($3,208,500)
Division 6	$16,300,000	$74,517,700	$90,817,700	$0	($74,517,700)
Charging Stations	$0	$37,959,200	$37,959,200	$0	($37,959,200)
Hydrogen Stations	$14,000,000	$33,350,000	$47,350,000	$0	($33,350,000)
Maintenance Bays	$2,300,000	$3,208,500	$5,508,500	$0	($3,208,500)
CMF	$2,300,000	$14,372,179	$16,672,179	$0	($14,372,179)
Maintenance Bays	$2,300,000	$14,372,179	$16,672,179	$0	($14,372,179)
Supporting Projects	**$21,240,000**	**$35,819,373**	**$57,059,373**	**$0**	**($35,819,373)**
Non-Revenue Fleet Replacement	$0	$10,230,838	$10,230,838	$0	($10,230,838)
Non-Revenue Charging /Fueling Infrastructure	$0	$2,588,535	$2,588,535	$0	($2,588,535)
TEC Modernization- ZEBU	$21,240,000	$23,000,000	$44,240,000	$0	($23,000,000)
Program Total	**$416,640,000**	**$1,991,236,585**	**$2,407,876,585**	**$1,528,719,897**	**($462,516,688)**

Appendix E: ZEB Performance Datasets (CY2024)

Bus Mileage by Technology (Average)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
DIESEL		4,744	4,366	4,737	4,478	4,589	4,239	4,437	4,691	4,504	4,640	4,492	4,450	**54,367**
HYBRID		3,636	2,887	3,196	3,504	3,816	3,545	3,817	3,762	3,830	4,019	3,697	3,607	**43,316**
FCEB	7000	1,495	1,280	1,343	3,190	2,542	2,995	2,553	2,786	2,453	2,101	2,615	3,193	**28,547**
	7030	2,340	1,963	2,544	2,673	2,818	3,296	3,219	3,775	3,258	3,453	2,881	3,440	**35,659**
BEB	8000	124	367	972	939	952	324	225	603	1,097	2,415	670	615	**9,303**
	8006	1,678	1,443	1,423	1,487	1,738	1,617	1,821	2,124	1,674	1,358	1,578	523	**18,464**
	8008	1,124	849	2,240	1,628	1,548	1,631	2,128	2,180	1,885	1,916	1,911	2,098	**21,139**

Availability Rate By Technology (Average)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
DIESEL		93%	91%	91%	91%	90%	90%	92%	91%	89%	91%	91%	91%	**91%**
HYBRID		89%	81%	77%	90%	90%	77%	88%	84%	82%	88%	88%	86%	**85%**
FCEB	7000	41%	30%	30%	54%	51%	65%	47%	45%	46%	35%	30%	40%	**43%**
	7030	58%	53%	59%	61%	57%	69%	59%	73%	73%	68%	65%	68%	**64%**
BEB	8000	0%	10%	59%	60%	48%	17%	12%	9%	14%	19%	23%	8%	**23%**
	8006	95%	84%	87%	95%	97%	95%	77%	100%	90%	76%	100%	50%	**87%**
	8008	83%	84%	77%	71%	83%	81%	91%	88%	87%	68%	80%	82%	**81%**

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