Zero Emission Program

ANNUAL PROGRESS REPORT

Publication Date: June 26, 2024

Leading the way to a
ZERO EMISSION FUTURE.

Abstract

The Zero Emission Program Annual Progress Report expands on the two-year industry-leading Zero Emission Transit Bus Technology Analysis, known as the 5X5 Study. It includes the District's ZEB Program capital investment since inception and the financial forecast needed to deliver the complete fleet transition. Tracking and reporting on progress ensures that the District meets the Federal Transit Administration (FTA) requirements and the California Air Resources Board's (CARB's) Innovative Clean Transit (ICT) regulation. ZEB deployments follow the District's Clean Corridors Plan to prioritize the deployment of ZEBs into historically disadvantaged communities and improve air quality and public health while promoting social equity.

This report contains an integrated master schedule that incorporates existing projects in the District's current Capital Improvement Program (CIP) and the comprehensive analysis of the Transit Asset Management (TAM) to support the prioritization and programming of future projects. The TAM analysis examines the asset's age and condition used to determine the eligibility for replacement and is aligned with the District's Strategic Plan and its goals and objectives.

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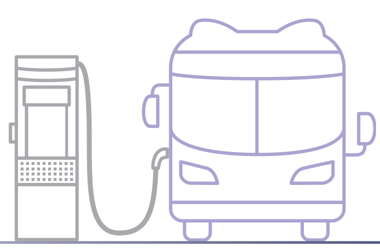
Executive Summary

AC Transit has built the most comprehensive Zero-Emission Program in the United States over the past two decades. The program has generated over 6.5 million miles and produced over 26,000 hours of workforce training to eliminate 15,000 metric tons of CO^2. The program's technology has expanded from a single hydrogen fuel-cell electric bus to a fleet of new-generation hydrogen fuel-cell and battery electric buses. Our ZEB infrastructure includes hydrogen fueling, electric charging, on-site fleet maintenance, and workforce development.

The District's ZEB Transition Plan will completely replace the existing diesel fleet with 100% ZEBs by 2040 to meet the California Air Resources Board (CARB) Innovative Clean Transit (ICT) regulation. The Plan envisions a fleet mix of 70% fuel cell electric buses (FCEB) and 30% battery electric buses (BEB) and estimates a current funding need of $2.0 billion. The ZEB transition has achieved 9% of its targeted goal and is expected to reach 16% by 2025. The plan includes early infrastructure build-out to allow flexibility with bus procurements. However, risks may impact the targeted annual goals as the flexibility is reduced from the transition schedule.

Zero Emission Program Risk Factors:

1. ZEB Transition funding needs $2.0 Billion
    a. Fleet cost – $1.7 Billion
    b. Infrastructure – $282 Million
2. BEB service range limitation (60% of Block Assignments)
3. BEB charging infrastructure delays (Switchgear Supply)
4. Hydrogen fuel cost ($10.60 per kg in 2024, a 44% increase since 2013. Noted that the report shows the 2023 pricing for Hydrogen was $9.42)
5. Hydrogen fueling station O&M cost ($440K Annually)
6. ZEB procurement cost increase (varies per market conditions)
7. BEB charging infrastructure reliability
8. Utility grid capacity and reliability to support BEB fleet charging needs
9. Resource constraints caused by fiscal cliff forecast
10. Cost escalations from inflation and supply chain issues
11. Potential ZEB thermal events caused by high-voltage battery design



ZEB Program Highlights:

First ZEB Pilot:
2002

Life-to-Date Miles:
6.5 Million

ZEB Workforce Training:
26,798
Hours

CO^2 Emissions Eliminated:
15,025
Metric Tons

Current Investment:
$294M
(2005-2026)

ZEB Fleet:
58 → 69
Actual **Planned**

Fueling/Charging Capacity
FCEB: 78 → 178
Actual **Planned**
BEB: 46 → 56
Actual **Planned**

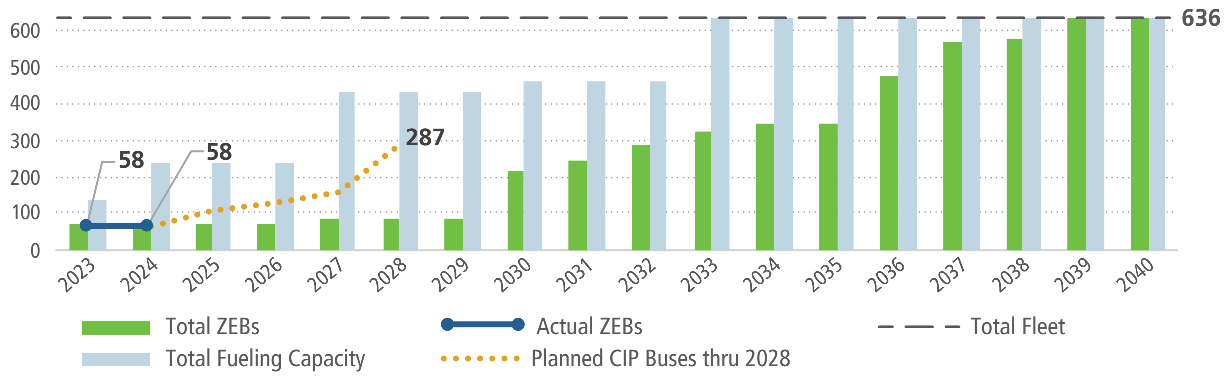
$25.5M
LoNo Grant Award to realize ZEBU and support ZEB purchases

Continue to deploy ZEBs per the Clean Corridors Plan.

ZEB Transition Progress

During the 2023 reporting period, the District had fifty-eight (58) ZEBs, of which thirty-seven (37) were deployed for service. Twenty-one (21) BEBs have been delayed for deployment along with the charging infrastructure project due to the public utility's inability to provide either electrical capacity or distribution capability adequate to support the deployment of the BEBs. Additional delays include the long lead time for the switchgear, which extended beyond one year. The District is initiating a project to secure on-site power generation technology as an alternative energy solution from grid power to provide the required energy for vehicle charging stations and resiliency needs. Based on our Capital Improvement Program (CIP) and the ability to secure funds, the District may have up to 287 ZEBs by 2028.

ZEB Transition Schedule



Financial Outlook (Cost vs. Funding)

The ZEB Program funding needs are anticipated through 2036 to contract the last phase of bus purchases and infrastructure projects to reach compliance with CARBs ICT regulation by 2040. Reasonable estimates have been made for grants to cover the ZEB transition forecast cost. As the transition plan progresses, updates to the funding forecast will be conducted. The Program Build Sheet Summary table below contains an estimated cost of $2.3 Billion and a funding shortfall of $658 million based on grants the District could secure. Cost estimates include bus price increases from actual ZEB purchase prices and current actual quotes. For future bus models not yet developed, estimates are created using the average cost per type noted in the ZEB Transition Plan. Infrastructure estimates now include an allowance amount for risk mitigations. Forecasts for fleet and infrastructure use annual escalations aligned with current market conditions for five years. Annual escalation beyond five years is decreased to align with the cost price index and will be evaluated against market conditions in the future to continue tracking program risk.

Program Build Sheet Summary

Investment Type	Investments	ZEB Transition Forecast (2024 Dollars)	Program Estimated Cost*	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	$183.20	$1,721.05	$1,904.25	$1,204.24	($516.81)
Infrastructure	$89.60	$242.96	$332.56	$121.69	($121.27)
Supporting Projects	$21.25	$38.56	$59.82	$18.10	($20.46)
ZEB Program Total	**$294.05**	**$2,002.58**	**$2,296.63**	**$1,344.03**	**($658.55)**

In 2024, the District received $2.65 million in "earmark" funding to further advance our ZEB program. $1.8 million will support safety compliance facility upgrades, including hydrogen sensing technology and equipment installation at our Central Maintenance Facility in East Oakland. The additional $850 thousand will help fund the architectural design needed for bid proposals to modernize the Training and Education Center in Hayward and proceed with the ZEBU construction project.

These investments will improve worker safety, support workforce development, and help place and keep zero-emission buses running in disadvantaged communities. All while promoting equity, improving quality of life in the communities we serve, and attracting more riders throughout our service area by introducing new clean and reliable zero-emission buses to the fleet; the District deeply appreciates Senator Alex Padilla and Representatives Barbara Lee and Eric Swalwell's advocacy to secure this much-needed funding.

Workforce Development

AC Transit understands that a critical dependency for success is the connection between investing in the physical rolling stock and infrastructure while aligning our commitment to invest in the workforce transformation needed to operate and maintain a ZEB fleet. In 2023, the District was awarded a $25.5 million federal grant to develop the nation's foremost clean transit training facility and program, coined "Zero-Emission Bus University (ZEBU)," and to support the purchase of 25 hydrogen fuel cell buses. $1.3 million is dedicated to workforce development, culminating in making ZEBU a reality by 2028. ZEBU will also provide a unique opportunity for area residents without advanced degrees to pursue a career in the green economy that pays a living wage and offers essential benefits, like healthcare. In addition, AC Transit's State of California Mechanic Apprenticeship is now a fully accredited college program as recognized by a post-secondary institution, Chabot College (Hayward, California).

ZEBU is central to our strategy to expand zero-emission bus service throughout the region. Over the next few years, AC Transit will seek $100 million in federal investments to deliver emission-free bus service that improves air quality, public health outcomes, and quality of life across the East Bay. A $100 million investment would include $5 million in federal funds to implement an innovative workforce training and development program that prepares transit workers to operate and maintain sophisticated ZEB fleets.

Bus Evaluation And Performance

All buses selected for this report are 40-foot buses spanning manufacturing years from 2016 through 2023. This includes a fleet mix of fuel cell, battery electric, diesel, and diesel-hybrid technologies. The performance evaluation table below provides an overview of the six (6) fleet groups with a summary of critical statistics during the 2023 calendar year. Key performance takeaways show that the BEB fleet produced the highest cost per mile due to some BEBs encountering battery pack replacements during 2023, so the cost-per-mile metric is high. Additionally, it's important to note that warranties are factored into the annual cost per mile (CPM) calculation. This is because the redemption time for each warranty claim varies, ranging from a couple of months to a year, posing challenges for consistent comparisons. However, warranties are gradually integrated into the CPM calculation over time and mileage. The cost for BEB buses was expensive initially but rapidly decreased over time when mileage increased (see the following graph).

Zeb Performance Evaluation (2023)

FLEET	DIESEL (BASELINE)	DIESEL HYBRID	FUEL CELL ELECTRIC (FCEB)	BATTERY ELECTRIC (BEB)
Bus Quantity	35	25	30	7
Life-to-Date Mileage (Per Bus Avg.)	258,835	301,373	70,579	63,113
2023 Mileage (Fleet Cumulative)	1,869,881	926,991	772,869	76,497
Cost/Mile (w/ credits)	2.03	2.16	2.78	3.30
Fleet Availability	88.26%	86.89%	63.26%	54.23%
Reliability (MBCRC)	14,840	8351	6,233	4,781
MPG (DGE)	4.78	5.15	7.93	15.11

The District added 21 BEBs into our fleet in 2023 (bus series BEB 8008), but they were not included in this analysis due to several factors. First, these buses were received in 2023; however, due to the limited availability of chargers at Division 4, many 8008 buses remained parked due to insufficient charging infrastructure. The situation improved somewhat when three portable chargers were installed as a temporary alternative solution in October 2023 at Division 2, allowing more buses to operate.

The ZEB fleet encountered issues during routine inspections that impacted its mileage, reducing it from the prior reporting year. The primary cause was issues with the high-voltage batteries, which resulted in long out-of-service periods. The HV battery power connections and current sensor module (CSM) were temporarily out of service until the OEMs completed the repairs. The battery packs were replaced under warranty for a cost ranging from $20K to $65K per bus, which can impact the accuracy of the cost/mile metric.

AC Transit Overview

The Alameda-Contra Costa Transit District (AC Transit) is California's most prominent public bus-only transit agency. Based in the San Francisco Bay Area's East Bay and headquartered in Oakland, AC Transit was formed in 1960, assuming the storied transit routes of the Key System and its predecessors, which, over the previous 100 years, carried passengers via horse-drawn rail streetcars, electric streetcars, ferries, and buses. AC Transit has an established commitment to preserving and improving the quality and quantity of transit service for 1.57 million East Bay residents that populate our 364 square mile service area, which includes Alameda and Contra Costa counties' 13 cities and adjacent unincorporated areas.

ZEB Program

As a recognized leader in zero-emission buses (ZEB) nationally and internationally, AC Transit has aggressively pursued opportunities and determined the feasibility of reduced and zero-emission technologies for over 20 years. The ZEB Program aligns with the District's strategic plan and the environmental improvement goal, which focuses on reducing carbon emissions from our buses and facilities, which will also directly benefit the neighborhoods in which we operate. AC Transit has improved the ZEB deployment process by enhancing project delivery methods and ongoing sustainable maintenance practices. Each development phase offered our internal subject matter experts an opportunity for improved best practices on procurement, project delivery, operations, ZEB technology performance, and workforce development innovation.

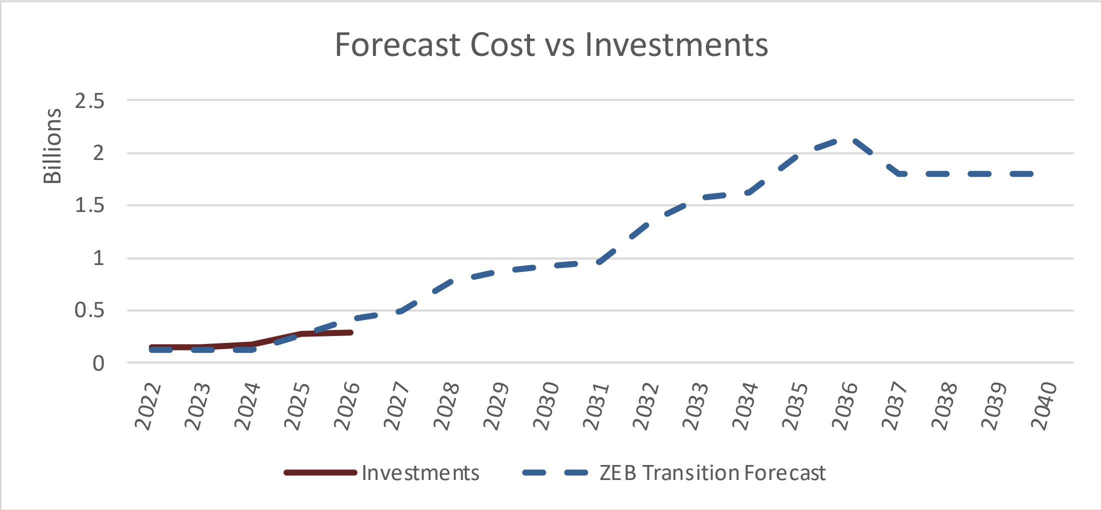
Service Profile

AC Transit operates 132 fixed routes, with two primary forms of service: East Bay local service and Transbay express service. East Bay's local service consists of regular routes, bus rapid transit routes, and supplemental school services. The service hours vary by line, with most local service operating every day from approximately 5:30 a.m. to midnight and All-Nighter lines operating from 1:00 a.m. to 5:00 a.m. Based on AC Transit's Clean Corridors Plan, the ZEB deployments are prioritized for disadvantaged communities that stretch from the northern-most point of the District to nearly the southern-most part of Alameda County and touch all operating Divisions (Richmond, Emeryville, East Oakland, and Hayward).

AC Transit Service Area

ZEB Program: Capital Investment

The District's ZEB Transition Plan is to replace the fleet with 100% ZEBs and build out supporting fueling and maintenance infrastructure by 2040 that will meet the ICT CARB regulation with an estimated mix fleet of 70% fuel cell buses (FCEB) and 30% battery electric buses (BEB) with a current funding need of $2.0 Billion. Other estimated ZEB Program costs include $23 Million to modernize the Training and Education Center, $14.8 Million to replace the non-revenue fleet, and $800 Thousand to enhance the data integration, management, and analytics platforms.



Actual Capital Investment against the projected forecast cost is shown in the chart below.

Zero Emission Technology Investment (Millions)

Project Type	Scope	Time Period					Total
		2002 - 2015	2016 - 2019	2017 - 2022	2018 - 2022	2023- 2026	
Bus	FCEB	$31	$12.9		$23	$86	$152.9
	BEB		$5.3	$3	$22		$30.3
Infrastructure	FCEB	$30.7	$3.2		$18	$33.8	$85.7
	BEB		$1.6	$.3	$2		$3.9
Supporting Projects						**$21.0**	**$21**
		$61.7	**$23**	**$3.3**	**$65**	**$140.8**	**$293.8**

AC Transit is deploying both ZEB technologies at our Oakland (Division 4) and Emeryville (Division 2) facilities. Constructed in 2014, the Oakland division's hydrogen station can fuel thirteen (13) buses in 24 hours. The six (6) depot DC-fast charging stations, installed in 2020, provide a maximum output of 125kW when two charging stations are configured in a daisy chain. Our transit district's future design plans include installing charging infrastructure for up to fifty (50) buses. At the Emeryville (Division 2) facility, AC Transit expanded hydrogen fueling capacity to sixty-five (65) buses and recently completed the installation of three (3) portable DC fast-charging stations that are operational and twenty-six (26) depot DC fast-charging stations that are pending PG&E power and commissioning.

AC Transit also participates in the California Low Carbon Fuel Standard (LCFS) market as a generator of credits based on green hydrogen production for bus use and through the deployment of ZEBs. As the District's ZEB fleet expands, our transit district will continue to capitalize on the sale of LCFS credits that can be used to offset the District's cost.

The Agency continues to explore funding opportunities that will expand the zero-emission program. Our transit district is securing purchasing support for an additional fifty-one (51) ZEBs, which includes a combination of forty-two (42) 40-foot and nine (9) 60-foot fuel-cell electric buses, which will have the latest advancements in zero-emission technology.

On October 13th, 2023, President Biden and Energy Secretary Jennifer Granholm announced seven regional clean hydrogen hubs selected to receive a collective $7 billion in Bipartisan Infrastructure Law funding to accelerate the domestic market for low-cost, clean hydrogen.

One of the seven selected regional hubs is the "California ARCHES Hydrogen Hub," proposed by the Alliance for Renewable Clean Hydrogen Systems (ARCHES). ARCHES plans to accelerate the development and deployment of renewable, clean H2 projects and infrastructure to reduce greenhouse gas emissions, improve local air quality, create good-paying jobs, and advance a zero-carbon economy. This California Hub proposal includes funding allocations to build thirteen hydrogen production plants throughout California and construct Hydrogen fueling infrastructure improvements as envisioned in AC Transit's ZEB Rollout Plan.

CALIFORNIA GOVERNOR'S OFFICE OF BUSINESS AND ECONOMIC DEVELOPMENT

AC Transit is proud to be one of the partners from across government, labor unions, national labs, NGOs, and more to contribute to the ARCHES proposal. This participation demonstrates our continued commitment to developing and deploying renewable, clean H2 projects and infrastructure to reduce greenhouse gas emissions, improve local air quality, create good-paying jobs, and advance a zero-carbon economy.

Zero Emission Transition

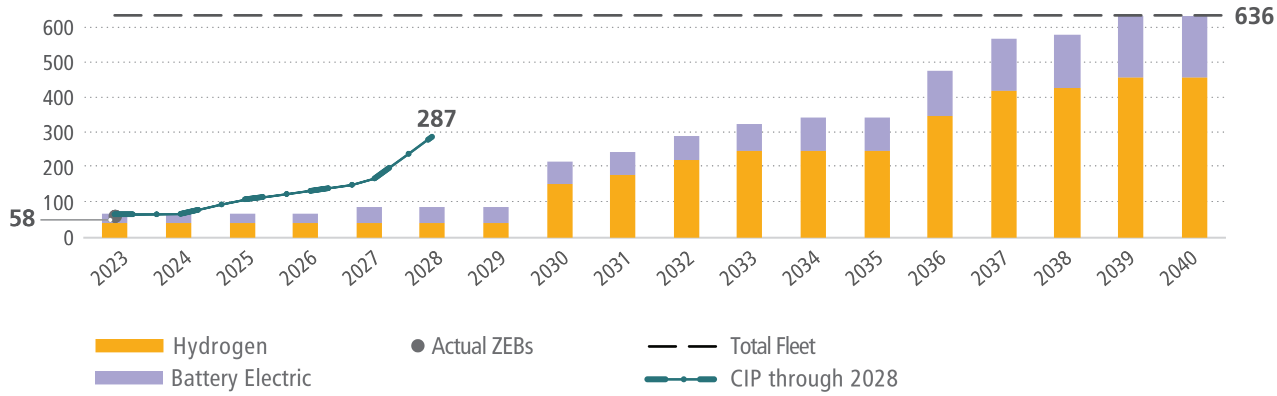
The scope of the ZEB Transition plan includes replacing all diesel buses with 70% FCEB and 30% BEB buses and upgrading infrastructure at all district division properties to support fueling and maintenance. Also included in the transition are projects to modernize the Training and Education Center, replace the non-revenue fleet, and enhance the data integration, management, and analytics platforms. The ZEB Program Investment Integrated Master Schedule in Appendix A displays the activities for the bus procurements and infrastructure projects.

The ZEB transition has achieved 9% of its targeted goal, and is expected to hit 16% by 2025.

Bus Procurement Schedule

The schedule for bus replacement is planned to be completed by 2039 and aligns with the District's Transit Asset Management (TAM) Plans useful life benchmarks for fleet replacement. ZEB Infrastructure projects are scheduled to be completed before the acceptance of the new ZEBs to support fueling/charging and maintenance for service operation deployments.

Planned Zero Emission Buses Accepted by Year



Bus Procurement Progress

The ZEB transition bus purchase project phases begin with authorization from the Board of Directors to secure funding. Once funding has been secured, the projects may be bundled as they move into procurement. The procurement includes technical specification, bid, award, production, delivery, inspection, and acceptance from the manufacturer. AC Transit staff prepares accepted buses for service and then deploys them directly into service or uses them for training. If required, they are then deployed into service.

Each bus procurement project is tracked in three categories: completed, current (in progress and upcoming), and future planned purchases needed to comply with regulations. The district has 58 ZEB buses, and the figure below shows completed bus purchase projects by technology type.

Completed Bus Projects 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**

Twelve bus purchase projects are included in our capital improvement program through 2028 and beyond, and the first projects within this set are anticipated to start in 2024. These projects replace 229 diesel buses with ZEBs by the expected completion of the last project, targeted for 2030, putting the district ahead of its transition schedule. Additionally, these bus purchases allow the district to maintain compliance with its Transit Asset Management performance targets. This early progress is feasible given that completed infrastructure projects allow capacity for fueling/charging and maintaining the ZEB buses. For more information on bus projects, see Appendix B.

Infrastructure Project Delivery

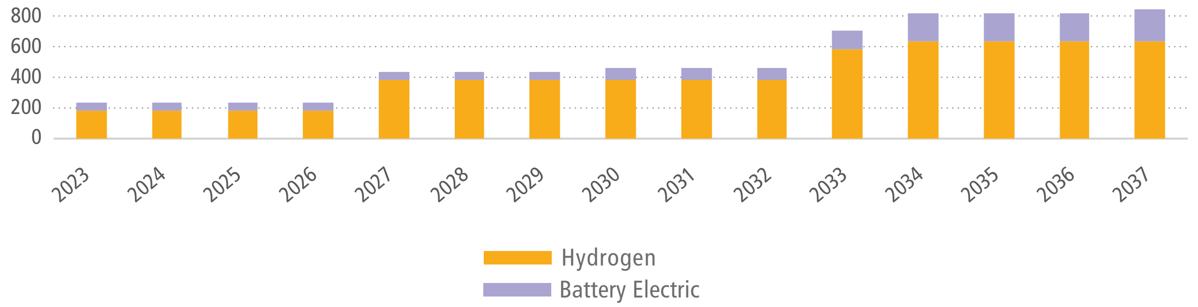
AC Transit operates zero-emission technology buses from its Oakland (Division 4) and Emeryville (Division 2) facilities. The Oakland Division has six stationary battery chargers for Battery Electric Buses (BEB) and a vapor compression hydrogen station for Fuel Cell Electric Buses (FCEB). Meanwhile, the Emeryville Division has a liquid compression hydrogen station.

Existing Facilities Technology

	BATTERY ELECTRIC BUS	FUEL CELL ELECTRIC BUS	
Facility	**Oakland Facility**	**Oakland Facility**	**Emeryville Facility**
Bus Energy Capacity	6	13	65
In Service Date	2020	2014	Rehab 2020
Type of Fuel	Electric	Hydrogen	Hydrogen
Technology	Stand-Alone Chargers	Vapor Compression	Liquid Compression
Capital Cost (Build)	$896,937	$6,300,308	$4,424,644
Core Hardware	(6) ChargePoint CPE250s	IC-50 Ionic Compressor	Dual ADC MP-100 Cryo Pumps
Related Hardware	(6) 100A/480V Circuits	Ambient Vaporizer	High Pressure Vaporizers
Dispenser Location	West Wall of Facility	Fuel Island	Fuel Island
Funding Source	Federal, Regional	Federal, State, Regional	State, Regional
Operating Statistics: January – December 2023			
Total O&M Cost	$0	$222,596	$220,812
Availability	63.20%	96.99%	98.63%

The transition schedule shows all buses being replaced by 2039, whereas the supporting infrastructure upgrades are planned to be completed in 2035 to ensure fueling capacities are established. Bus and infrastructure schedules are consistently monitored, and adjustments are made to consider TAM priorities, inflation, and technology advancements. Below is the schedule for the planned transition to 100% zero-emission fueling charging capacity based on planned infrastructure projects.

Planned Zero Emission Buses Fueling Charging Capacity by Year



Infrastructure Project Progress

Due to the public utility's inability to provide either electrical capacity or distribution capability adequate to support the deployment of AC Transit's BEBs anytime soon, the District is considering mitigations that will provide on-site power self-generation to support the BEB deployment plan. This on-site self-generation will support the division's operating facility load and adequate capacity to support BEB deployments under the District's approved ZEB Transition Plan. The District is planning an "islanded" microgrid approach, which will be implemented in a phased manner, matching the deployment timeline and related capital costs with the planned BEB fleet expansion.

Further, the District plans to fuel the on-site self-generation with a blended fuel approach using hydrogen and natural gas components in a variable mix. This provides an eventual pathway for the entire site and all supported rolling stock to be powered with 100% green and renewable fuel sources once green hydrogen becomes available. The blending capability will also allow the District to manage the fuel mix in a manner that can control the resulting costs.

This on-site self-generation approach will allow for scalable capacity generation and will result in significant operating cost savings compared to utility grid-supplied capacity. Further, this approach eliminates grid reliance, providing the security of increased assurance of energy availability without any instances of curtailment or unplanned shutdown. Finally, the increased energy efficiency of this approach will result in significant improvements in environmental benefits.

The District has planned infrastructure projects to increase the fueling capacity of hydrogen fuel cell buses and charging capacity of battery electric buses at each of its four divisions: Emeryville (D2), Richmond (D3), Oakland (D4), and Hayward (D6). Upgrades are planned for maintenance bays at each division and the Central Maintenance Facility (CMF). The infrastructure project phases begin with the Board of Directors' approval of the projects in the Capital Improvement Plan and then move through design and construction with procurement for each phase.

Completed Infrastructure by Technology

Project Description	Hydrogen Fueling Capacity (Buses)	Electric Charging Capacity (Buses)
D4 Hydrogen Infrastructure	13	
D2 Hydrogen Infrastructure	65	
D4 Battery Electric Infrastructure		6
Total	**78**	**6**

Infrastructure projects are being tracked in three categories: completed, current (in progress and upcoming), and future planned purchases needed to comply with regulations. The district can fuel/charge 84 ZEB buses because of its completed infrastructure projects using the technology type shown in the figure below. For more information on infrastructure projects, see Appendix C.

Other Supporting Projects

Other supporting projects for the ZEB Program include the ZEBU initiative and modernization of the Training and Education Center (TEC), enhancements to the ZEB Data Integration, Management, and Analytics Platform, and replacements of non-revenue vehicles. The workforce development section of the report provides additional information on ZEBU and TEC modernization.

Supporting Projects Cost

Project Title	Total Project Cost
Non-Revenue Fleet Replacement	$14,800,000
TEC Modernization	$23,000,000
Zeb Data Integrations, Management, Analytics Platform	$800,000

Non-Revenue Fleet Replacement

A zero-emission vehicle (ZEV) transition plan is in progress to complement the Zero Emissions Bus Transition plan on the District's non-revenue fleet. The ZEV transition will contain a mixed fleet of battery and fuel cell electric technology to meet the district's operating needs. The non-revenue vehicle transition will allow zero-emission service and admin vehicles to support our zero-emission buses that follow the following 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
- Target 100% ZEV Fleet Transition by 2040

Data Integration, Management

The ZEB Data Integration/Management project continues to improve the data ingestion and integration process from multiple applications. Sources include the Enterprise Asset Management System (EAMS), ChargePoint, PG&E, weather systems, CADAVL, scheduling and asset management databases (SQL), and other platforms like Online Transaction Processing (OLTP) and Azure VMWare Service (AVS). The District continues its activity to improve the Data Integration and Management Environment (DIME) infrastructure, which includes the transition from Azure VMWare Service (AVS) servers to the Azure Cloud Application Platform as a Service (PaaS) to enhance security, scalability, and efficiencies.

Program Risk

AC Transit's purpose is to provide a transit service that is both convenient and reliable. Our service and all the supporting functions in the District must be funded adequately to create convenient and reliable service. Risks have been identified for the overall zero emission program that may impact delivering AC Transit's Board direction on revenue fleet, infrastructure, and supporting projects. The table below summarizes the program risks by the District's ZEB transition guiding principles, categorized by TAM replacement targets, vehicle and infrastructure capabilities, operational efficiencies and sustainability, and safety management hazards. Each risk has an identified action that is continually monitored as impacts to the program change.

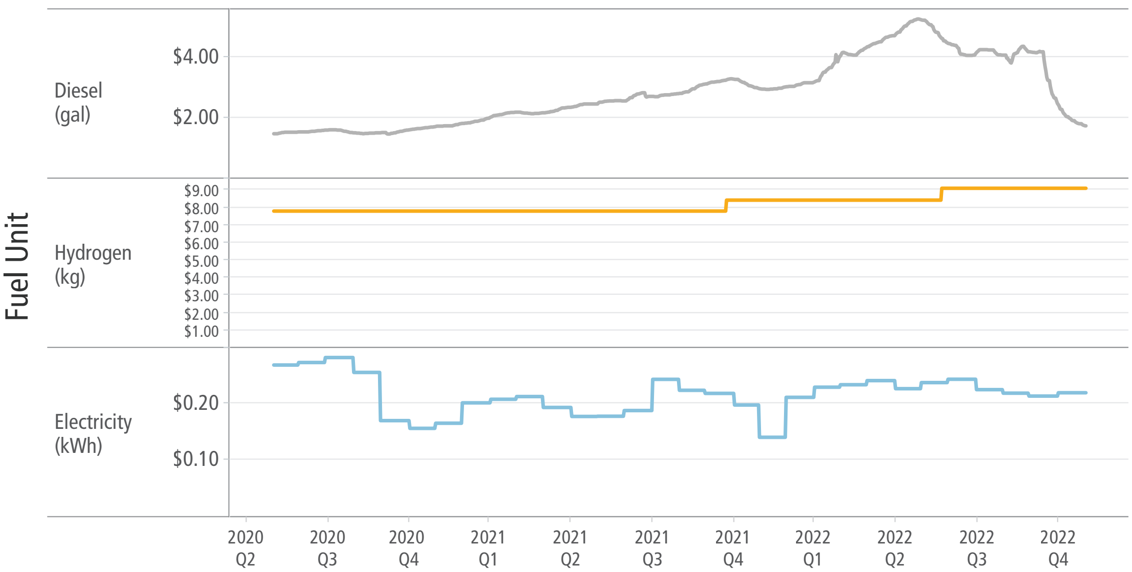
Program Risk Matrix by Guiding Principle

Category	Risk Description	Risk Action
TAM Replacement Target	ZEB Transition funding need of $2.0 Billion	Monitor
	Fleet cost - $1.7 Billion	
	Infrastructure - $282 Million	
Vehicle & Infrastructure Capabilities	Cost escalations from inflation and supply chain issues	Monitor
	Cost increases due to Project labor agreements	Monitor
	BEB Service Range Limitation (60% of Block Assignments)	Accept
	BEB Charging Infrastructure Delays (Switchgear Supply)	Accept
	BEB Charging Equipment Reliability	Monitor
	Utility Grid Capacity to Support BEB Fleet Charging Needs	Mitigate
Efficient & Sustainable to Operate	Resource constraints caused by fiscal cliff forecast	Monitor
	Inability to charge BEBs due to utility power safety shutoffs	Monitor
	Utility kWh cost escalation (14% Increase)	Monitor
	Hydrogen Cost Increase ($9.09 per kg)	Monitor
	Hydrogen Station Maintenance Cost ($440K Annually)	Monitor
Safety Management Hazards	Potential ZEB thermal events caused by high voltage battery design	Monitor

Energy Trends

The figure below provides the current trend of energy sources. Compared to 2022, the price of diesel dropped significantly by more than 20% from $3.86 to $3.07, while prices increased for Hydrogen by 8% (from $8.72 to $9.42) and Electricity by 14.2% (from $0.22 to $0.25). This change in energy cost contributes to the cost-per-mile metric when examining operational performance.

Energy Price Trend (3 Year)



Financial Plan

Program Estimated Cost

Funding needs are anticipated through 2036 to contract the last phase of bus purchases and infrastructure projects to reach compliance with ICT/CARB regulations by 2040. Reasonable estimates have been made for grants to cover the ZEB transition forecast cost. As the transition plan progresses, updates to the funding forecast will be conducted. The Program Build Sheet in Appendix D provides a breakdown of the $2.3 Billion estimated cost with a funding shortfall of $658 Million based on the potential funding available to secure.

Program Build Sheet Summary

Investment Type	Pre-2023 Expenditures	ZEB Transition Forecast (2022 Dollars)	Program Estimated Cost	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	$183.20	$1,721.05	$1,904.25	$1,204.24	($516.81)
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*Includes some pending investments to be reconciled in the upcoming fiscal year

Cost estimates for the ZEB Transition Plan are rough order of magnitude based on existing zero-emissions bus purchases with applied escalation as outlined in the MTC Regional Bus/Van Pricelists. Where technology is still in development for certain vehicle types, a rough order of magnitude cost is developed based on a percentage of the cost difference of the same diesel vehicle type. Estimates for fleet and infrastructure use annual escalations aligned with current market conditions for five years. Annual escalation beyond five years is decreased to align with the cost price index and will be evaluated against market conditions to continue tracking program risk.

Funding Requests

The District is pursuing over $100 million in state and federal investment to take the industry-leading zero-emission program to the next level. This funding will support the bus manufacturing industry by purchasing dozens of new ZEBs, constructing essential infrastructure, and delivering robust workforce training through ZEBU.

ZEB Program: Workforce Development

AC Transit achieved a significant milestone when the Federal Transit Administration (FTA) awarded a prestigious 2023 Bus and Low-and No-Emission Grant Award (Low-No Grant) of $25.5 million. Of the total, $16.0 million is for the design and construction to modernize the current Training and Education Center facility, located in Hayward, California, and $1.3 million is for workforce development, culminating in making Zero Emission Bus University, ZEBU, a reality by 2028.

Educational Eco-System- Zero-Emission Bus University

At its core, ZEBU is a pioneering sustainable public transportation education. ZEBU engages AC Transit's skilled and unskilled workforce in rigorous ZEB programs, connecting employees to life-changing careers. What makes ZEBU bold is its vision to implement an educational ecosystem where learning is designed as transformative, granting open access to skills required to maintain ZEB deployments. This, in turn, creates career pathways without barriers that may have previously limited opportunities. In so doing, AC Transit can attract a future workforce from communities in its service area to consider a career in public transit. Investing 5% of the Low-No grant or $1.275M into this eco-system ensures that designing the workforce development plan supports upscaling career initiatives and ZEB deployment.

Workforce development funding will position ZEBU to deliver:

1. World-class, advanced technological skills training for District employees,
2. Innovative training methods creating active, immersive learning environments, enhancing worker safety and efficacy,
3. Transformative career and academic opportunities and;
4. Provide ZEB training to any transit agency interested in implementing, maintaining, and sustaining zero-emission buses.

Sustaining Career Ladder Initiatives

Building ZEBU requires transitioning from a conventional approach to training to more diverse workforce development programs. It starts with AC Transit's labor and management partnership, Progress in Action (PIA). PIA is a leadership team of District and Amalgamated Transit Union, Local 192 executives. The focus is to work together to build career ladder initiatives. PIA activities are intrinsically linked to transforming employees into a ZEB workforce. Each program is a career- and skill-building requisite necessary for ZEB deployments. AC Transit doesn't hope to find talent; it works to build up from the frontlines employed within.

Career ladder initiatives that upskill frontline employees include:

- **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 combines fundamental bus mechanic training with in-shop, real-world maintenance experiences. Upon completion, employees successfully enroll as State of California mechanic apprentices.

- **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.

- **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.

- **Master Journey Level Mechanic:**
  This award is given to 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.

- **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 to develop sustainable transit careers in transportation or maintenance.

Career ladder initiatives that upscale include:

- 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).

- The eight-course, four-year apprenticeship is now a 26-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.

- 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.

- 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).

- 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 as rooted in employee transformation as it is in upscaling training approaches and methodologies. ZEBU covers all propulsion systems, from designing a ZEB core curriculum to varying asynchronous and synchronous delivery methods to an immersive two-week, hands-on course, embracing experiential and pragmatic applications to inspect, maintain, and repair ZEB buses. Core programming includes everything... from orientation and PPE/high voltage to high-pressure hydrogen, operational start-up/shutdown and emergency procedures, familiarization with the location and functions of significant fuel cell and battery electric components, fueling and charging of battery electric buses, energy storage systems, and power train technologies.

Training also includes many innovative training modules allowing new, up-close-and-personal insights into the inner workings of significant sub-components such as a Ballard fuel cell complete with its air and cooling sub-systems. Plans are to incorporate more modules, especially at the lithium-ion cell level or the inner workings of battery modules/packs. The future may soon be at the cell level, repairing bad cells versus replacing battery packs, saving time and money, and the cost of buses down, not in service.

With mixed reality systems, learning takes on a new dimension of encyclopedic knowledge without being overwhelmed by too much information. ZEBU's mixed reality: Re-invent and re-invigorate workforce training by engaging staff in the learning process in real-time. Learning-by-doing, a ZEBU pedagogy, takes on new meaning as employees are immersed in actual work tasks and guided by virtual demonstrations. Mixed reality systems provide a virtual "live assist" for on-the-job learning, making complex or multi-layered tasks less intimidating and cumbersome. It transforms traditional, one-dimensional training-by-slide (decks) into a three-dimensional knowledge experience wherein learning becomes interactive with the object that is the focus of training.

ZEBU embraces two systems: augmented reality (AR) and virtual reality (VR). AR technology overlays virtual objects onto a physical world, whereas virtual reality (VR) is entirely in a non-physical or virtual space. With AR, ZEBU completed two pilot programs supporting the bookends, if you will, of ZEB maintenance: performing a preventive maintenance inspection and replacing an air compressor or critical sub-component to an efficiently performing fuel cell.

With AR, mechanics are hands-free in a live-lab environment (i.e., the maintenance shop floor), guided by virtual displays (action videos or holograms) showing how to perform actual work tasks. Learning and repairing exist concurrently: As the mechanic knows, the required work is done. With VR, ZEBU plans to immerse learners into the safe practices of high-voltage settings. VR provides a secure, virtual environment to practice and test without fear or harm of a life-threatening arc flash. Practicing safety habits and allowing one to experience consequences in a virtual environment validates standard operating practices for real-world applications, reduces fear, and instills confidence when performing tasks in high-voltage areas.

ZEBU and Industry: A National Resource for ZEBs

Building a future to meet the District's ZEB deployment also means that the District will create an asset library. This knowledge experience platform can be shared with transit agencies interested in implementing, maintaining, and sustaining zero-emission buses. Whether sharing how to develop career ladder initiatives to create talent to sustain a ZEB future or working directly with frontline staff ready for upskilling, funding will help ensure ZEBU is positioned to offer ZEB training within our core programming.

ZEB Program: Operational Performance

ZEB Fleet Evaluation

The Capital and Operational Report expands the evaluation of the ZEB technologies beyond the initial 5X5 control fleet of the ZETBTA reports. The primary analysis will focus on evaluating zero-emission buses, but additional control buses and fleets have been added to complement the study. The buses included are all 40-foot units spanning manufacturing years 2016 through 2023. The mix includes fuel cell, battery electric, diesel, and diesel-hybrid technology. Unless otherwise noted, this analysis covers various propulsion technologies and buses for calendar year 2023 (Jan 1, 2023, through December 31, 2023).

The matrix below provides additional specifications of the report's bus fleet. It includes the service activation dates, the study's cumulative life-to-date miles, and the design specification types of the ninety-seven (97) buses. It is important to note that AC Transit uses a typical lead time of eighteen (18) months from order date to service activation, based on the average bus order, delivery, and acceptance timeline experienced during recent procurements.

Fleets Included in the 2023 Annual Report

FLEET	DIESEL (BASELINE)	DIESEL HYBRID	FUEL CELL ELECTRIC (FCEB)		BATTERY ELECTRIC (BEB)	
			7000	7030	8000	8006
Series Grouping	1600	1550	7000	7030	8000	8006
Year Model	2018	2016	2018	2022	2018	2021
Manufacturer	Gillig	Gillig	New Flyer	New Flyer	New Flyer	Gillig
Bus Purchase Cost	$488,247	$699,060	$1,156,044	$1,212,161	$938,184	$963,009
Energy/Fuel Capacity	120 gal	120 gal	38 kg	38 kg	466 kw	444 kW
Range Specification	450 miles	500 miles	300 miles	300 miles	180 miles	130 miles
Propulsion Design	Conventional Diesel	Diesel/ Battery	Battery Dominant	Battery Dominant	Battery	Battery
Battery Design	N/A	Lithium-Ion	Lithium-Ion	Lithium-Ion	Lithium-Ion	Lithium-Ion
Engine/Powerplant	Cummins	Cummins	Ballard/A123	A123	Xalt Energy	Cummins
Transmission/Propulsion	Voith	BAE	Siemens	Siemens	Siemens	Cummins
In Service Date	Jan 2019	Aug 2016	Jan 2020	Dec 2021	May 2020	Sep 2021
Life-to-Date Mileage (Per Bus Avg.)	258,835	301,373	116,043	47,847	77,161	27,993
Funding Source	Federal, Regional, Local	Federal, Regional, Local	State, Regional, Local	Federal, State, Local	Federal, Regional	Federal, State, Local

ZEB Technology Environmental Impacts

In recent years, there has been a growing concern about the impact of greenhouse gas emissions on the environment, and transportation has been identified as a significant contributor to this problem. As a result, there has been a concerted effort to develop and deploy zero-emission buses (ZEBs) as a more sustainable and environmentally friendly alternative. ZEBs are powered by electricity or hydrogen fuel cells, which produce zero greenhouse gas emissions during operation. In this section, we will examine the environmental impact of ZEBs compared to traditional buses that run on diesel or hybrid diesel technology. We will explore various metrics, such as greenhouse gas emissions, carbon emissions, and energy rates, to assess the environmental benefits of ZEBs and the potential impact of their adoption on the environment.

While ZEBs have zero tailpipe emissions (Scope 1), it is essential to acknowledge that they are not entirely emission-free when considering Scope 2 and Scope 3 emissions. Scope 2 emissions refer to the indirect emissions from producing the electricity or hydrogen fuel that powers ZEBs. In contrast, Scope 3 emissions refer to the indirect emissions associated with producing materials, parts, and components that go into building ZEBs and their disposal.

The exact number of emissions ZEBs produce through these indirect sources varies depending on the fuel source used and the production processes involved. Therefore, while ZEBs offer a promising avenue for reducing greenhouse gas emissions in the transportation sector, it is essential to carefully evaluate the entire life cycle of the bus, including both direct and indirect emissions, when assessing their environmental impact.

AC Transit launched a Sustainability Program in 2022 to measure the baseline life cycle emissions of all the District's operations, including the ZEB fleet. For this report, we are only concerned with Scope 1 diesel fuel emissions.

The figure to the right shows the total CO^2 emissions offset from operating the District's ZEB fleet in 2023. In total, ZEBs in this study offset emissions by 1,082 metric tons. This is approximately the equivalent of burning 1.21 million pounds of coal or supplying 136 homes with energy for a year. FCEB 7030 was the largest offset source due primarily to the number of buses and miles operated in the reporting period.

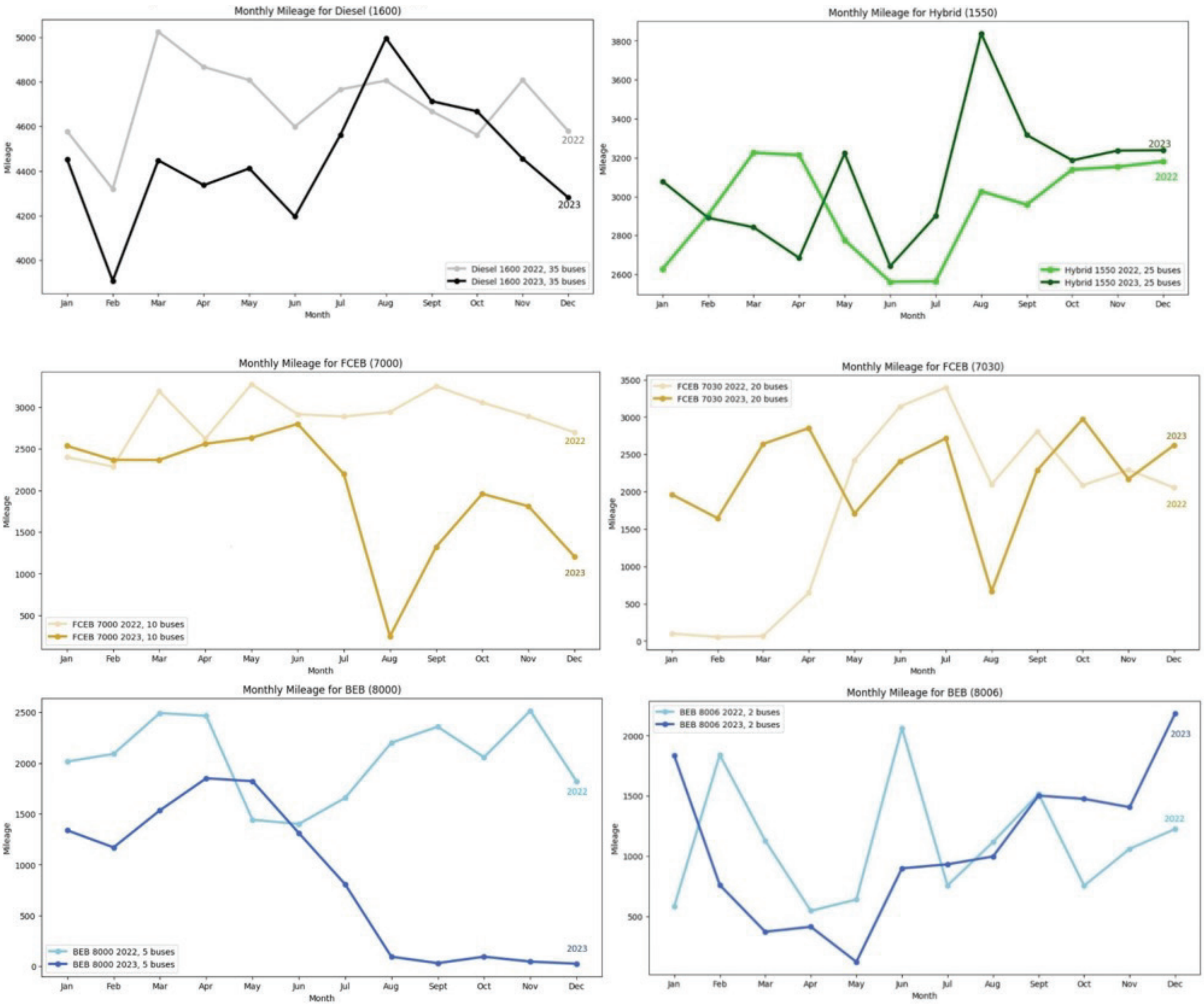
ZEB Greenhouse Gas Equivalents, January 2023 – December 2023

Gallons of gasoline **121,742**	Pounds of coal **1,211,917**
BBQ propane cylinders **49,702**	Barrels of oil **2,502**
1 year of Home Electricity **211**	1 Year of Home Energy **136**
Smartphones charged **131.61M**	Tanker trucks of gasoline **14.30**

Bus Mileage

For zero-emission buses to be a viable alternative to traditional fossil fuel-powered buses, they must have a lower environmental impact and be efficient and cost-effective. This section focuses on the performance and efficiency of different ZEB technologies, including their mileage, fuel efficiencies, and energy rates. We can better understand each technology's strengths and weaknesses by comparing these metrics. Over the next several years, the performance will inform purchasing decisions and our ZEB transition plan as we make our fleet 100% zero emissions by 2040.

Fuel Monthly Mileage by Technology



The figure 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, with a total of 53,425 miles per bus, 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)- experienced a sharp mileage reduction due to issues found on the ESS HV power connections and current sensor module (CSM) found during inspections. All the buses were temporarily held out of service until all repairs were completed.
- BEB (8000)- experienced battery pack issues in the latter half of the year, resulting in long out-of-service periods

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	4.78	Miles/Gal	4.78	M/DGE
HYBRID		Diesel	5.15	Miles/Gal	5.15	M/DGE
FCEB	**7000**	Hydrogen	7.50	Miles/Kg	8.33	M/DGE
	7030	Hydrogen	6.99	Miles/Kg	7.77	M/DGE
BEB	**8000**	Electricity	0.40	Mile/kWh	15.21	M/DGE
	8006	Electricity	0.39	Mile/kWh	15.02	M/DGE

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

- BEB 8000 has the highest fuel efficiency, with 15.21 miles per diesel gallon equivalency, followed closely by BEB 8006, which has 15.02.
- 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
2023	$3.07 / Gal	$9.42 / KG	$0.25 / kWh
2022	$3.86 / Gal	$8.72 / KG	$0.219 / kWh
% Changes	-20.5%	8%	14.2%

The figure on the previous page shows the average annual cost of energy in 2023. Energy prices are difficult to compare because of the inherent differences in energy efficiencies between the specific propulsion technologies that use the fuels. Compared to the prices in 2022, we noticed that the diesel price dropped significantly by more than 20% from $3.86 to $3.07, while prices increased for Hydrogen by 8.5% (from $8.72 to $9.46) and Electricity by 14.2% (from $0.22 to $0.25). 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 2023)

METRIC	DIESEL	HYBRID	FCEB		BEB	
	1600	1550	7000	7030	8000	8006
Total Costs (Fleet-Wide)						
Maintenance	$2,586,082	$1,444,334	$380,690	$712,600	$152,921	$51,066
Labor Hours	$15,929	$7,694	$2,115	$4,102	$772	$347
Energy (Fuel)	$1,202,242	$553,618	$302,664	$720,913	$32,110	$16,535
Total	**$3,804,253**	**$2,005,646**	**$685,469**	**$1,437,615**	**$185,803**	**$67,948**
Costs per Mile						
Maintenance	$1.38	$1.56	$1.59	$1.34	$3.02	$1.98
Energy (Fuel)	$0.64	$0.60	$1.26	$1.35	$0.63	$0.64
Total	**$2.03**	**$2.16**	**$2.85**	**$2.69**	**$3.65**	**$2.62**
Bus Count	35	25	10	20	5	2
Avg Daily Bus Count	24.96	15.89	4.42	9.49	2.02	1.31
Total Mileage	**1,869,881**	**926,991**	**239,896**	**532,973**	**50,702**	**25,795**

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 2023 compared to 2022. The primary disparity in Cost per Mile between 2022 and 2023 stems from a substantial cost increase for BEB usage. For BEB 8000, the CPM increased by 150% for maintenance costs and 37.67% for energy costs, while for BEB 8006, the CPM increased by 95% for maintenance costs and 64.7% for energy costs. This escalation is primarily attributed to the elevated maintenance expenses associated with BEBs. There were multiple incidents in 2023 where we needed to replace the battery packs on BEBs, resulting in significantly higher maintenance costs. Moreover, the fuel price dynamics in 2023 did not favor electricity, as diesel prices experienced a notable decrease while electricity prices rose.

Operational Cost/Mile year-over-year percent changes from 2022 to 2023

METRIC	DIESEL	HYBRID	FCEB		BEB	
	1600	1550	7000	7030	8000	8006
Total Costs (Fleet-Wide)						
Maintenance	28.63%	7.63%	-9.45%	10.22%	3.47%	90.47%
Labor Hours	26.84%	0.41%	-15.23%	-15.82%	-18.70%	66.77%
Energy (Fuel)	-23.28%	-15.35%	-24.69%	38.92%	-43.07%	60.63%
Total	**5.97%**	**0.10%**	**-16.90%**	**22.84%**	**-9.43%**	**82.10%**
Cost per Mile						
Maintenance	35.75%	2.56%	29.81%	-12.48%	150.21%	95.30%
Energy (Fuel)	-19.03%	-19.33%	7.96%	10.30%	37.67%	64.71%
Total	**11.75%**	**-4.61%**	**19.13%**	**-2.34%**	**119.12%**	**86.81%**
Bus Count	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Avg Daily Bus Count	1.07%	2.54%	-25.15%	11.69%	-4.05%	19.25%
Total Mileage	**-5.24%**	**4.94%**	**-30.24%**	**25.94%**	**-58.65%**	**-2.48%**

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 FCEB, which was more than $181,000.

ZEB Recovery Total: Warranties and LCFS Credits

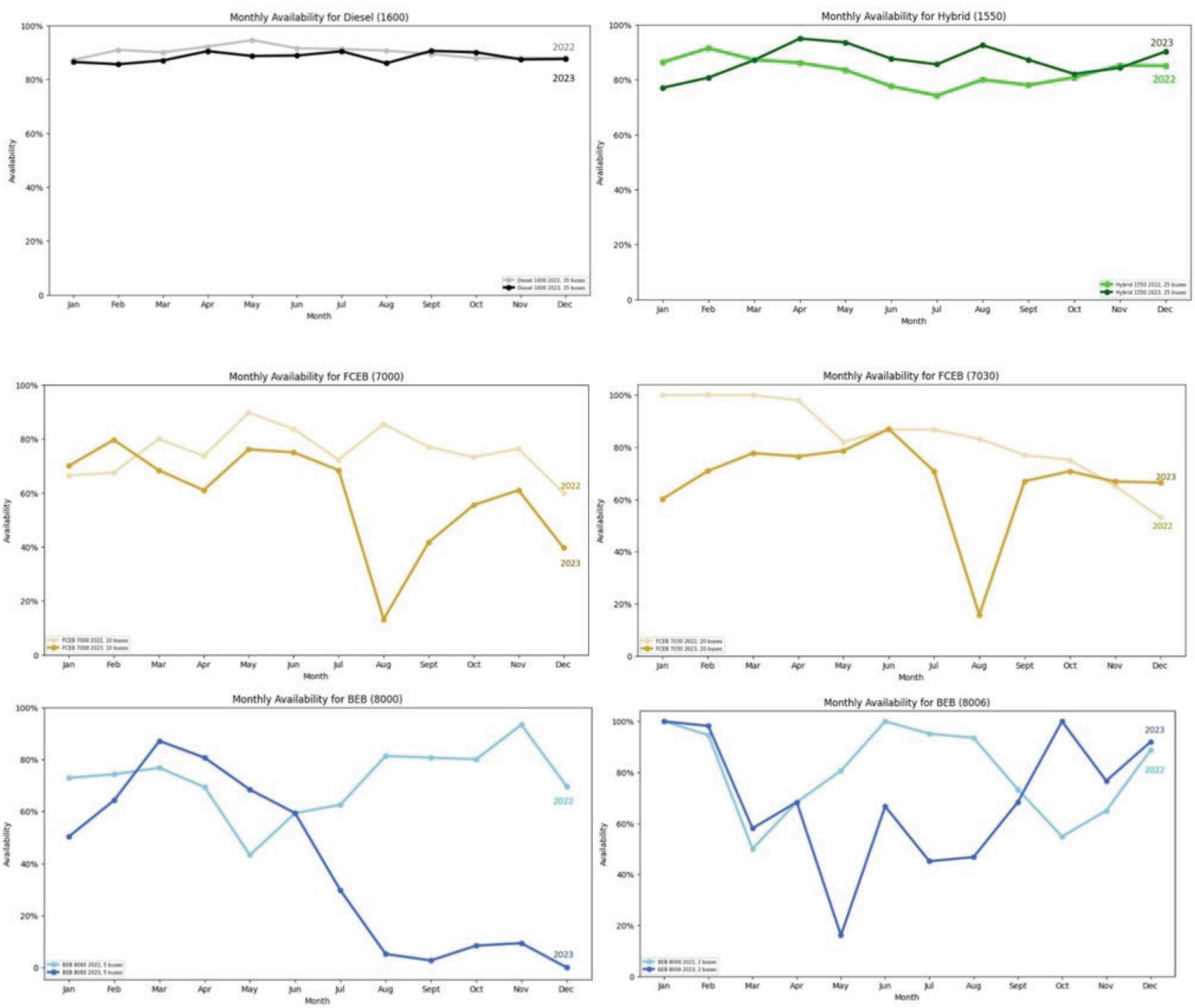
TECHNOLOGY		WARRANTY CLAIMS	WARRANTIES	NET CREDITS	TOTAL RECOVERY
DIESEL	1600	26	$42,828	$0.00	**$42,828**
HYBRID	1550	2	$2,486	$0.00	**$2,486**
FCEB	7000	53	$152,219	$249.85	**$152,468**
	7030	176	$181,232	$555.10	**$181,788**
BEB	8000	18	$79,905	$11,330.08	**$91,235**
	8006	13	$7,117	$5,764.24	**$12,881**

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



The figure on the previous page 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 88% and hybrid at 87% for 2023.
- FCEB 7000 and 7030 have lower monthly availability rates than diesel and hybrid buses, with FCEB 7000 averaging 59% and FCEB 7030 at 67%. They both experienced a significant decrease in availability starting in June due to the current sensor module (CSM) issue and corrosion on some of the ESS HV power connections found during the PMI inspections.
- Battery electric buses (BEBs) have the lowest monthly availability rates and the most variability, with BEB 8000 averaging 38% and BEB 8006 at 69%. BEBs experienced a shutdown due to maintenance issues related to battery packs on these buses in the latter half of the year.

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 2023)

TECHNOLOGY		Major	Minor	Total	Mileage	MBCRC
DIESEL		11	115	126	1,869,881	14,840
HYBRID		45	66	111	926,991	8,351
FCEB	7000	13	30	43	239,896	5,579
	7030	18	63	81	532,973	6,580
BEB	8000	4	8	12	50,702	4,225
	8006	2	2	4	25,795	6,449

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

- Diesel buses perform the highest, at about 14,840 miles between chargeable road calls.
- The electric buses (BEB) have the least number of road calls, but the MBCRC number is not very high because most buses are new.
- The hydrogen-powered buses perform the lowest, traveling approximately 5,500 to 6,500 miles between road calls.

Road Calls By System (January – December 2023)

SYSTEM	DIESEL	HYBRID	FCEB		BEB		TOTAL
			7000	7030	8000	8006	
Common System Failures	94	56	17	44	7	3	221
Engine/Fuel Cell System	31	38	11	20	0	0	100
Fuel System	0	1	6	3	0	0	10
High Voltage System	0	9	8	11	5	1	34
Transmission/Electric Drive	1	7	1	3	0	0	12
Total	**126**	**111**	**43**	**81**	**12**	**4**	**377**

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
- Fumes in Bus have problems and need to be replaced

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 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.
- Zero-emission technology systems are not less reliable than conventional technology.

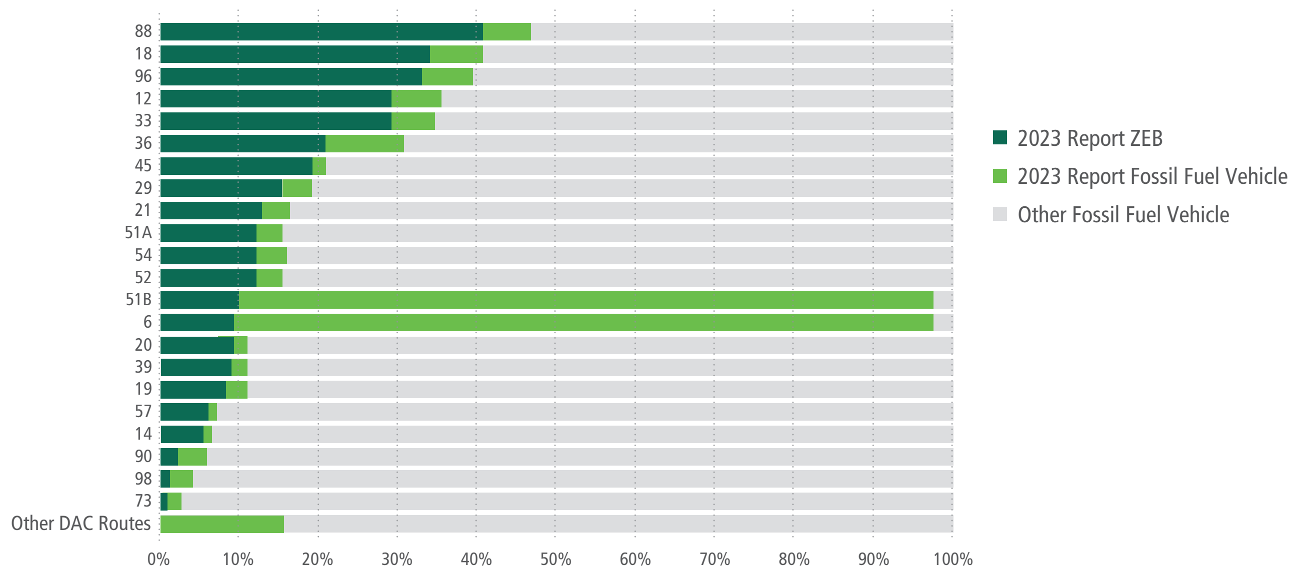
Clean Corridors ZEB Deployments

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 pollution that causes climate change.

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 while promoting social equity. The figure below illustrates which lines had buses from this program deployed between January 1 and June 30, 2023. The results indicate that Lines 88, 18, 96, 12, and 33 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. Except for Line 40, they are typically assigned 40-foot buses.
4. They are generally flat, with only one line–54–heading into the Oakland hills. All other lines go no higher than the Macarthur/580 corridor.

DAC Corridors Distribution of Zeb Trip Deployments



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.

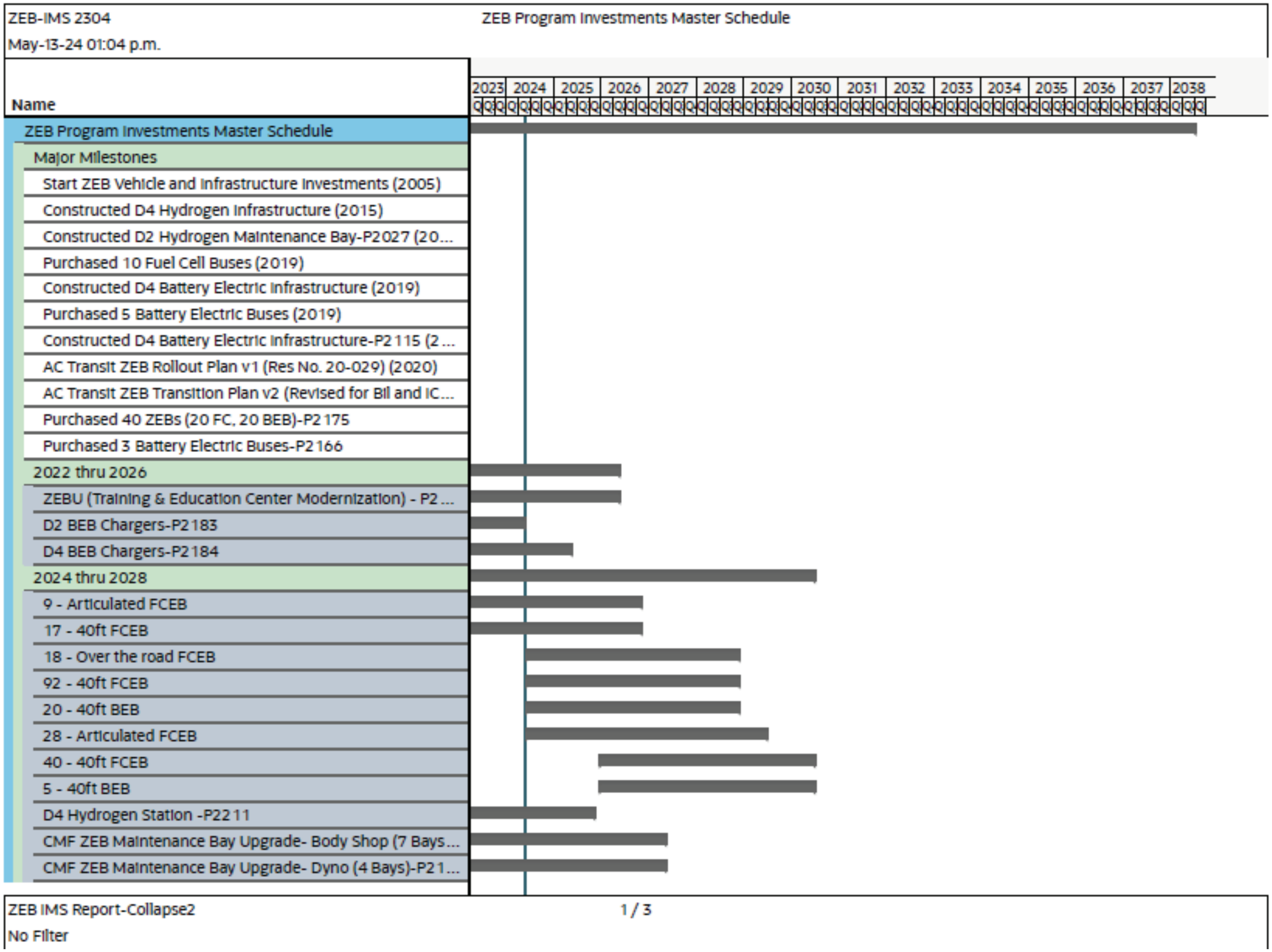
The chart below tracks how the ZEBs were deployed in 2023. Each route was classified as serving a DAC or another route, and the proportion of trips on a DAC or another route was calculated. The results show that over 91% to 99% of ZEB deployments occurred on DAC routes. This means we meet the goal of utilizing ZEBs in Disadvantaged Communities as outlined in the Clean Corridor Plan.

Zeb Deployment by Route Type (January – December 2023)

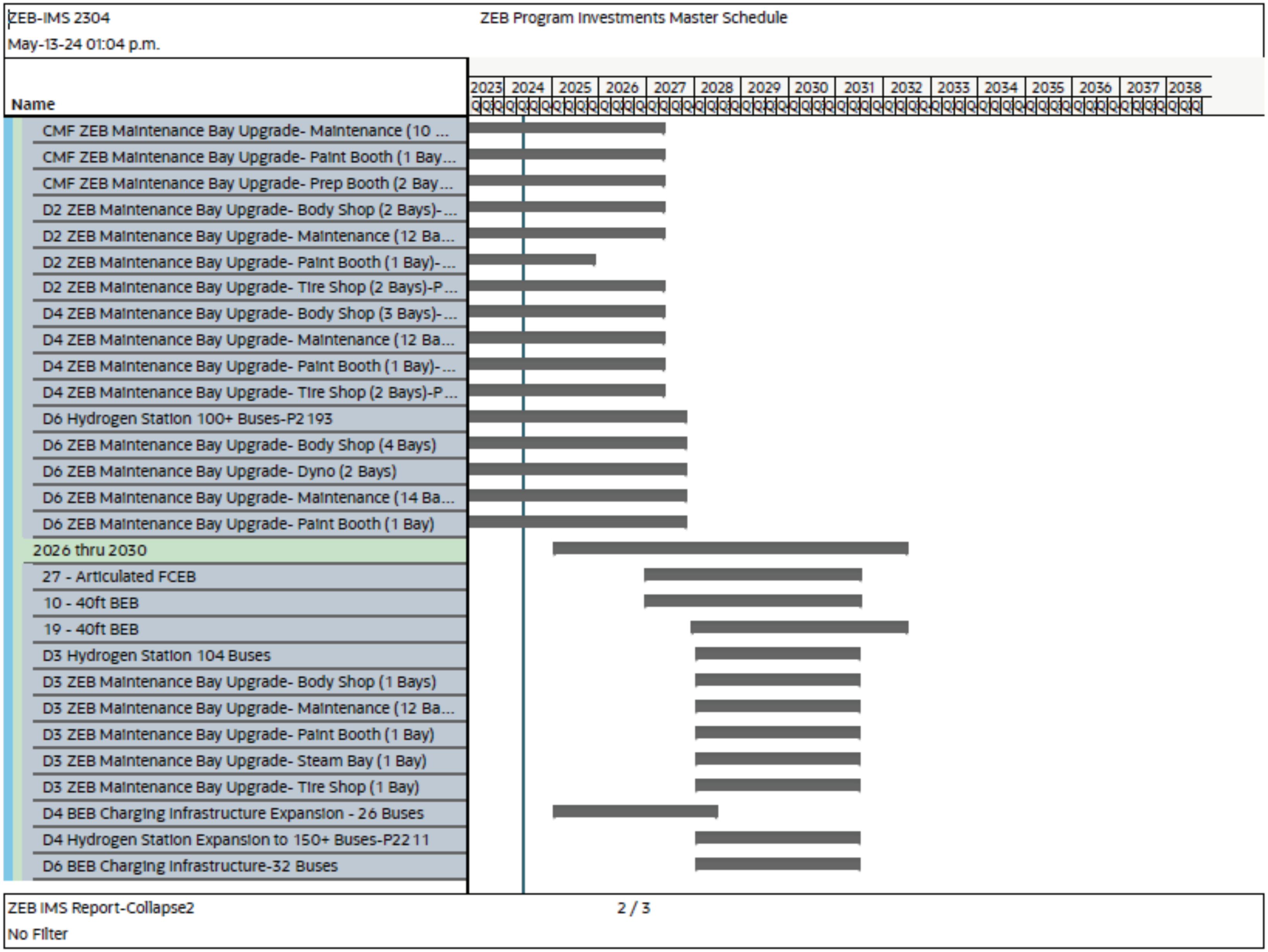
		DAC Route	Other Routes
DIESEL		48.02%	51.98%
HYBRID		94.67%	5.33%
FCEB	**7000**	97.30%	2.70%
	7030	91.89%	8.11%
BEB	**8000**	99.89%	0.11%
	8006	99.05%	0.95%

The deployment of buses to the DAC routes answers how we use the available resources. The chart above demonstrates the trip distribution of the ZEB fleets on our DAC routes, where routes 88, 16, and 96 experienced more than 30% of the trips assigned to a zero-emission bus.

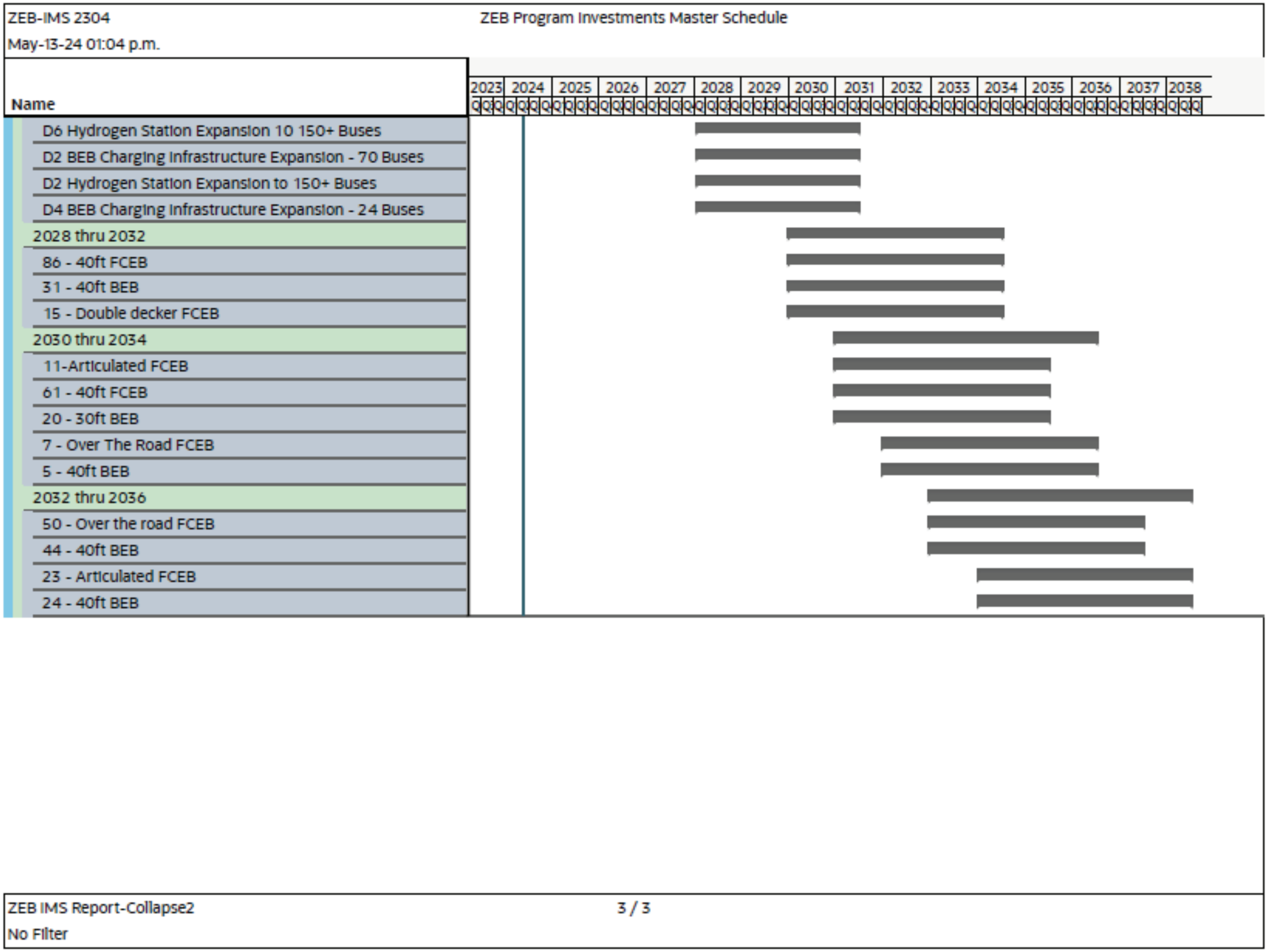
Appendix A: ZEB Program Integrated Master Schedule (pg 1 of 3)



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



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



Appendix B: Bus Procurement Projects

Current Bus Projects by Phase

Phase	Project Description	CIP Funding Year	CIP Estimate
Board Approval Process	Purchase (9) Articulated Fuel Cell Buses	2024	$19,829,724
	Purchase (42) 40ft Fuel Cell Buses	2025	$65,272,599
	Purchase (23) Articulated Fuel Cell Buses	2026	$57,233,684
	Purchase (25) 40ft Fuel Cell Buses	2027	$41,196,094
	Purchase (18) Over-the-road Fuel Cell Buses	2028	$61,280,026
	Purchase (20) 40ft Fuel Cell Buses	2028	$34,934,288
	Purchase (92) 40ft Fuel Cell Buses	2028	$160,697,723

Future Bus Procurement Projects Required for 2040 ICT Carb Compliance

Project Description	Projected CIP Funding Year	Cost Estimate
Purchase 24 BEBs	2026	$38,132,917
Purchase 10 BEBs	2029	$17,852,561
Purchase 27 FCEBs	2029	$75,491,726
Purchase 19 BEBs	2030	$35,955,057
Purchase 15 FCEBs	2032	$102,380,556
Purchase 31 BEBs	2032	$65,914,325
Purchase 86 FCEBs	2032	$189,646,052
Purchase 11 FCEBs	2033	$38,828,601
Purchase 20 BEBs	2033	$45,076,893
Purchase 61 FCEBs	2033	$142,587,369
Purchase 5 BEBs	2034	$11,945,377
Purchase 7 FCEBs	2034	$33,804,901
Purchase 44 BEBs	2035	$111,426,474
Purchase 50 FCEBs	2035	$255,951,391
Purchase 23 FCEBs	2036	$96,695,104
Purchase 24 BEBs	2036	$64,424,762

Appendix C: Infrastructure Projects

Current Infrastructure Projects by Phase

Phase	Project Description	CIP Funding Year	CIP Estimate*
Construction	D2 BEB Charging Infrastructure (26 Buses)	2021	$6,145,106
	D4 BEB Charging Infrastructure & Microgrid **	2022	$32,393,200
	D4 Hydrogen Station Upgrade (+100 Buses)	2023	$9,101,230
Planning	CMF ZEB Maintenance Bay Upgrade - Maintenance - 10 Bays	2024	$9,197,179
	D6 Hydrogen Station - 100+ Buses	2024	$15,502,000
Design	TEC Modernization	2025	$23,000,000

* 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 C: Infrastructure Projects

Future Infrastructure Projects Required for 2040 ICT Carb Compliance

Project Description	Projected CIP Year	Cost Estimate
CMF ZEB Maint Bay Upgrade - Body Shop - 7 Bays	2025	$1,932,000
CMF ZEB Maint Bay Upgrade - Dyno - 4 Bays	2025	$1,288,000
CMF ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$644,000
CMF ZEB Maint Bay Upgrade - Prep Booth - 2 Bay	2025	$966,000
D2 ZEB Maint Bay Upgrade - Body Shop - 2 Bays	2025	$966,000
D2 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$644,000
D2 ZEB Maint Bay Upgrade - Tire Shop - 2 Bays	2025	$966,000
D4 ZEB Maint Bay Upgrade - Body Shop - 3 Bays	2025	$1,288,000
D4 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$644,000
D4 ZEB Maint Bay Upgrade - Tire Shop - 2 Bays	2025	$966,000
D6 ZEB Maint Bay Upgrade - Body Shop - 4 Bays	2025	$1,288,000
D6 ZEB Maint Bay Upgrade - Dyno - 2 Bays	2025	$966,000
D6 ZEB Maint Bay Upgrade - Maintenance - 14 Bays	2025	$2,392,000
D6 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$644,000
D4 BEB Charging Infrastructure Expansion - 26 Buses	2027	$19,734,001
D3 Hydrogen Station - 104 Buses	2025	$14,697,000
D3 ZEB Maint Bay Upgrade - Body Shop - 1 Bay	2025	$644,000
D3 ZEB Maint Bay Upgrade - Maintenance 12 Buses	2025	$2,576,000
D3 ZEB Maint Bay Upgrade - Paint Booth - 1 Bay	2025	$ 644,000
D3 ZEB Maint Bay Upgrade - Steam Bay - 1 Bay	2025	$644,000
D3 ZEB Maint Bay Upgrade - Tire Shop - 1 Bay	2025	$644,000
D4 Hydrogen Station Expansion - to 150+ Buses	2030	$11,776,000
D6 BEB Charging Infrastructure - 32 Buses	2030	$33,506,400
D6 Hydrogen Station Expansion - to 150+ Buses	2030	$11,776,000
D2 BEB Charging Infrastructure Expansion - 70 Buses	2031	$16,640,000
D2 Hydrogen Station Expansion - to 150+ Buses)	2031	$10,672,000
D4 BEB Charging Infrastructure Expansion - 24 Buses	2034	$11,385,920

Appendix D: ZEB Investment Build Sheet

Investment Type	Pre-2023 Expenditures	ZEB Transition Forecast Cost (2022 Dollars)	Program Estimated Cost	Potential Grant Funding	Funding Gap (Shortfall)
Revenue Bus	**$183,200,000**	**$1,721,053,276**	**$1,904,253,276**	**$1,204,238,628**	**($516,814,648)**
Existing FCEB	$66,900,000	$0	$66,900,000	$0	$0
Existing BEB	$30,300,000	$0	$30,300,000	$0	$0
Diesel Bus Replacement with ZEB	$0	$1,721,053,276	$0	$1,204,238,628	
Infrastructure	**$89,600,000**	**$242,960,037**	**$332,560,037**	**$121,688,146**	**($121,271,891)**
Division 2	$36,866,667	$36,033,106	$72,899,773	$0	($36,033,106)
Charging Stations	$2,300,000	$22,785,106	$25,085,106	$0	($22,785,106)
Hydrogen Stations	$31,500,000	$10,672,000	$42,172,000	$0	($10,672,000)
Maintenance Bays	$3,066,667	$2,576,000	$5,642,667	$0	($2,576,000)
Division 3	$0	$19,849,000	$19,849,000	$0	($19,849,000)
Hydrogen Stations	$0	$14,697,000	$14,697,000	$0	($14,697,000)
Maintenance Bays	$0	$5,152,000	$5,152,000	$0	($5,152,000)
Division 4	$34,166,667	$107,022,352	$141,189,019	$0	($107,022,352)
Charging Stations	$1,600,000	$83,247,122	$84,847,122	$0	($83,247,122)
Hydrogen Stations	$29,500,000	$20,877,230	$50,377,230	$0	($20,877,230)
Maintenance Bays	$3,066,667	$2,898,000	$5,964,667	$0	($2,898,000)
Division 6	$15,500,000	$70,858,400	$86,358,400	$0	($70,858,400)
Charging Stations	$0	$33,506,400	$33,506,400	$0	($33,506,400)
Hydrogen Stations	$15,500,000	$32,062,000	$47,562,000	$0	($32,062,000)
Maintenance Bays	$0	$5,290,000	$5,290,000	$0	($5,290,000)
CMF	$3,066,667	$9,197,179	$12,263,846	$0	($9,197,179)
Maintenance Bays	$3,066,667	$9,197,179	$12,263,846	$0	($9,197,179)
Supporting Projects	**$21,253,708**	**$38,562,606**	**$59,816,314**	**$18,100,684**	**($20,461,922)**
Non-Revenue Fleet Replacement	$0	$11,794,897	$11,794,897	$0	($11,794,897)
Non-Revenue Charging /Fueling Infrastructure	$0	$3,010,782	$3,010,782	$0	($3,010,782)
TEC Modernization- ZEBU	$21,210,635	$23,000,000	$44,210,635	$18,100,684	($4,899,316)
ZEB Data Integr, Mgmt, Analytics Platform	**$43,073**	**$756,927**	**$800,000**	**$0**	**($756,927)**
Program Total	**$294,053,708**	**$2,002,575,919**	**$2,296,629,627**	**$1,344,027,458**	**($658,548,461)**

Appendix E: ZEB Performance Datasets (CY2023)

Bus Mileage by Technology (Average)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
DIESEL		4,451	3,908	4,448	4,337	4,412	4,196	4,562	4,995	4,713	4,667	4,455	4,281	**53,425**
HYBRID		3,079	2,891	2,842	2,685	3,222	2,642	2,900	3,839	3,317	3,187	3,236	3,238	**37,080**
FCEB	7000	2,533	2,366	2,365	2,560	2,630	2,797	2,195	249	1,322	1,958	1,810	1,204	**23,990**
	7030	1,963	1,645	2,640	2,851	1,707	2,408	2,715	662	2,287	2,975	2,170	2,624	**26,649**
BEB	8000	1,339	1,171	1,535	1,851	1,823	1,313	809	96	33	96	48	27	**10,140**
	8006	1,835	760	372	413	122	898	932	997	1,502	1,475	1,406	2,185	**12,897**

Availability Rate By Technology (Average)

		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
DIESEL		86%	86%	87%	90%	89%	89%	90%	86%	91%	90%	87%	88%	**88%**
HYBRID		77%	81%	87%	95%	94%	88%	86%	93%	87%	82%	84%	90%	**87%**
FCEB	7000	70%	80%	68%	61%	76%	75%	68%	13%	42%	55%	61%	40%	**59%**
	7030	60%	71%	78%	77%	79%	87%	71%	16%	67%	71%	67%	66%	**67%**
BEB	8000	50%	64%	87%	81%	68%	59%	30%	5%	3%	8%	9%	0%	**39%**
	8006	100%	98%	58%	68%	16%	67%	45%	47%	68%	100%	77%	92%	**70%**

1600 Franklin Street
Oakland, CA 94612

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