Zero Emission Bus Transition Plan

ALAMEDA CONTRA COSTA TRANSIT DISTRICT

OAKLAND, CA

Leading the way to a **ZERO EMISSION FUTURE.**

DOCUMENT CONTROL HISTORY

Version	Document Title	Date	Comments
1	Zero Emission Bus Transition Plan	6/22/22	Meet BIL and ICT requirements

AUTHORITY ACCEPTANCE

Recipient Name	Title	Signature
Salvador Llamas	Chief Operating Officer	

Table of Contents

Figure References

Acronyms

AC Transit	Alameda-Contra Costa Transit District
API	Applications Program Interface
BAAQMD	Bay Area Quality Management District
BEB	Battery Electric Bus
BEB FCEB	Mixed Fleet
BIL	Bipartisan Infrastructure Law
BTW	Behind the Wheel
CARB	California Air Resource Board
CMF	Central Maintenance Facility
CNG	Compressed Natural Gas
CTE	Center for Transportation & the Environment
D2	Division 2, Emeryville CA
D3	Division 3, Richmond, CA
D4	Division 4, Oakland, CA
D6	Division 6, Hayward, CA
DOE	Department of Energy
ESS	Energy Storage System
FCEB	Full Cell Electric Bus
FTA	Federal Transit Administration
GO	General Office
HVIP	Hybrid & Zero Emissions Truck & Bus Voucher Incentive Project
ICT	Innovative Clean Transit
O&M	Operations and Maintenance
OEMs	Original Equipment Manufactures
TAM	Transit Asset Management
TCP	Transit Capital Priorities
TEC	Training and Education Center
ZEB	Zero-Emissions Bus

SECTION A

A History of Transition

The Alameda-Contra Costa Transit District (AC Transit) is the largest public bus-only transit agency in California. AC Transit is headquartered in Oakland, California, and 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. In more than 60 years of operation, AC Transit has established a commitment to preserving the quality and advancing the quantity of transit service for 1.5 million East Bay passengers that populate our 364 square mile service areas, including 13 cities and adjacent unincorporated areas of Alameda and Contra Costa counties.

AC Transit is a recognized leader in zero emission buses (ZEB), both nationally and internationally. For more than 20 years, our transit district has aggressively pursued opportunities and determined the feasibility of reduced emission and zero emission technologies. In that time, AC Transit has fine-tuned the ZEB deployment process through enhanced project delivery methods. Our subject matter experts have improved or established best practices for procurement, project delivery, operations, and ZEB technology performance. AC Transit has also authored training manuals and launched the first in-house training modules for sustainable ZEB maintenance practices.

Today, AC Transit is at the vanguard of testing an array of conventional and zero emission fuel technologies in a public transit environment. The Zero Emission Transit Bus Technology Analysis report is euphemistically known as the 5X5 Study because it represents real-time testing of 25 bus propulsion systems in the same service environment while also testing the same ZEB bus manufacturers.

The 5X5 study, currently in its third iteration, collects data on energy, capital and operating costs, performance metrics, mileage, and coach reliability. This open-source report is AC Transit's contribution to the transit industry, offering an invaluable roadmap for agencies seeking to transition fleets to 100% zero emission.

AC Transit is not only committed to a transition to clean energy but equally evolving our organizational processes. Our transit district adopted a Strategic Plan, which consists of Core Values, Vision and Mission Statements, Goals, and Initiatives. The Strategic Plan is nimble by design and used to prioritize initiatives, effectively allocate resources, and educate employees and the communities we serve.

AC Transit Core Values

Safety

Service

Environmental Sustainability

Equity

Innovation

Integrity

Trust

Mission Statement

We deliver safe, reliable, sustainable transit service that responds to the needs of our customers and communities.

Vision Statement

AC Transit is valued as a leader that helps the Bay Area thrive by connecting East Bay communities to each other and to regional destinations.

Strategic Goals and Initiatives

GOALS:

Safe and Secure Operations
Convenient and Reliable Service
Financial Stability and Resiliency
High-Performing Workforce
Strong Public and Policymaker Support
Environmental Improvement

INITIATIVES:

Service Quality
Infrastructure Modernization
Employee Recruitment, Training and Retention
Zero Emission Programs
Financial Efficiency and Revenue Maximization
Internal and External Diversity, Equity, Inclusion and Accessibility Programs and Priorities

SECTION B

Transition Plan: General Information

ZEB Rollout Plan Executive Leadership Contact Information

Name	Title	Phone	Email
Michael A. Hursh	General Manager	(510) 891-4753	mhursh@actransit.org
Salvador Llamas	Chief Operating Officer	(510) 891-7215	sllamas@actransit.org

Bipartisan Infrastructure Law

The Bipartisan Infrastructure Law (BIL), Pub. L. 117-58, signed by President Biden on November 15, 2021, amended the statutory provisions for the Grants for Buses & Bus Facilities Competitive Program (49 USC § 5339(b)) and the Low or No Emission Vehicle Program (49 USC § 5339(c)) to include the requirement that any application for projects related to zero emission vehicles include a Zero emission Transition Plan. On December 1, 2021, the Federal Transit Administration (FTA) issued a Dear Colleague letter providing information regarding the minimum requirements of a Zero emission Transition Plan. FTA will rate more highly zero emission projects where the applicant is able to demonstrate how the proposed project and fleet transition plan support the conversion of the agency's overall fleet to zero emissions.

Innovative Clean Transit Regulation

The Innovative Clean Transit (ICT) regulation was adopted by the California Air Resources Board (CARB) in December of 2018 and became effective October 1, 2019. Title 13 California Code of Regulations §2023 (13 CCR § 2023.1 through 2023.11) requires all public transit agencies to gradually transition their bus fleets to zero emission technologies. The ICT regulation applies to all transit agencies that own, operate, or lease buses with a gross vehicle weight rating (GVWR) greater than 14,000 pounds. The ICT regulation requires a percentage of new bus purchases to be zero emission buses (ZEBs). The ZEB purchase requirements begin in 2023 for large transit agencies (200 buses or more) and 2026 for small transit agencies. Starting 2029, 100 percent of all transit agencies' new bus purchases must be ZEBs, with a goal of complete transition to ZEBs by 2040. Each transit agency must adopt and submit to the California Air Resources Board (CARB) a Zero Emission Bus Rollout Plan describing how the agency will transition to a zero emission fleet.

Accordingly, on June 10, 2020, AC Transit's Board of Directors adopted a Resolution which outlines the District's goal of full transition to zero emission technologies by 2040. To meet the FTA requirements, the new Zero Emission Bus Transition Plan is compliant with the Bipartisan Infrastructure Law and incorporates what was already implemented to comply with the California Air Resources Board's (CARB's) Innovative Clean Transit (ICT) Regulation. The ZEB Transition Plan is specific to AC Transit and is not part of a Joint Group.

BIL and ICT Requirements

Per ICT Regulation a ZEB Rollout Plan must meet the following requirements:

a) A goal of full transition to zero-emission buses by 2040 with careful planning that avoids early retirement of conventional internal combustion engine buses

b) Identification of the types of zero-emission bus technologies a transit agency is planning to deploy, such as battery electric or fuel cell electric bus

c) A schedule for construction of facilities and infrastructure modifications or upgrades, including charging, fueling, and maintenance facilities, to deploy and maintain zero-emission buses. This schedule must specify the general location of each facility, type of infrastructure, service capacity of infrastructure, and a timeline for construction

d) A schedule for zero-emission and conventional internal combustion engine buses purchases and lease options. This schedule for bus purchases must identify the bus types, fuel types, and number of buses

e) A schedule for conversion of conventional internal combustion engine buses to zero-emission buses, if any. This schedule for bus conversion must identify number of buses, bus types, the propulsion systems being removed and converted to

f) A description on how a transit agency plans to deploy zero-emission buses in disadvantaged communities as listed in the latest version of "CalEnviroScreen"

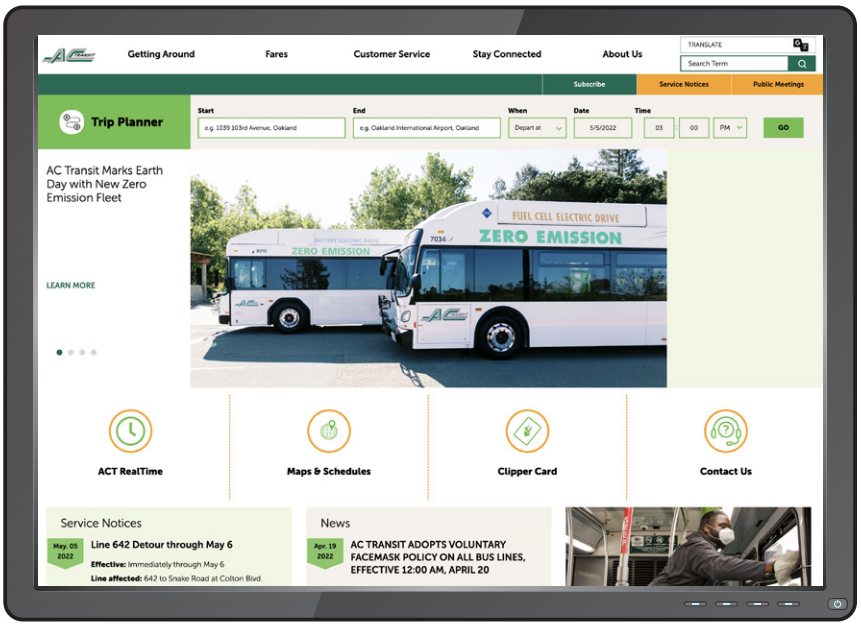
g) A training plan and schedule for zero-emission bus operators and maintenance and repair staff.

h) Identification of potential funding sources

i) Start-up and Scale-up Challenges

AC Transit's Board of Directors has approved a Strategic Plan, Clean Corridors Plan, Capital Improvement Program, Facilities Utilization Study, and Zero-Emissions Bus Study as the guiding documents to comply with the ICT Regulation requirements. The guiding documents can be found on the District's website.

AC Transit Website: www.actransit.org



SECTION C:

Technology Portfolio

Transition Goals and Technology Replacement

A state mandated 100% zero emission fleet by 2040 is well underway at AC Transit. In addition to real-time operational experience as the region's earliest adopter of zero emission bus technology, AC Transit codified our zero emission fleet transition planning through a strategic plan developed in 2017. The effort was in concert with the Center for Transportation and the Environment (CTE) to assist with assessing the zero emission technology for AC Transit's service demands.

The District is deploying both BEB's and FCEB's as we continue industry leading testing of the Zero Emissions Transit Bus Technology Analysis Study (ZETBTA), which is designed to evaluate the most reliable long-term operational range, financial efficiency, and sustainability of ZEBs. The ZETBTA study permits staff to report to the AC Transit Board of Directors an all-encompassing update on ZEB performance, operations and maintenance (O&M) costs including the cost of fuel/energy, and infrastructure O&M costs. The nimble study permits modifications to our transition plan.

Additionally, operating both technologies offers some resiliency advantages during public safety power shut-off events or when hydrogen fuel might be unavailable.

BATTERY ELECTRIC BUS

FUEL CELL ELECTRIC BUS

Transition Plan Timeline

AC Transit's Board of Directors approved a Strategic Plan, Clean Corridors Plan, Capital Improvement Plan, Facilities Utilization Plan, and Zero Emission Bus Study as a blueprint for achieving a full zero emission transition. The plan considers the minimum useful life of buses, BIL requirements, and ICT Regulation compliance.

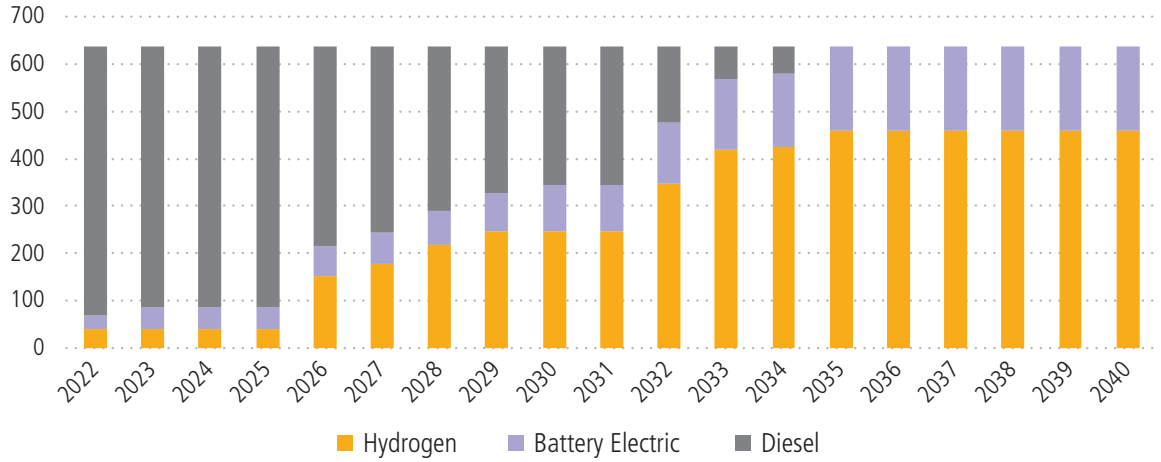
It is imperative that all transit agencies build in contingencies for unexpected challenges. Both battery electric and fuel cell electric bus technologies have start-up and scale-up challenges, identified in Section I of the Plan. In order to successfully transition our fleet, AC Transit will need policy makers, original equipment manufacturers (OEMs), and energy providers to help navigate challenges and risks. As with any living document, the ZEB Transition Plan is not binding and can be updated. Adjustments will be made to the Plan as technology advances and solutions are realized.

Fleet Transition Schedule and Cost

Based on AC Transit's current fleet replacement schedule and planned procurements, the following chart depicts the annual mixed fleet composition to achieve a goal of 100% zero emission buses by 2040. The replacement schedule is based on the District's Transit Asset Management (TAM) Plan,

mandated by the Federal Transit Administration (FTA). ZEB technology mix is based on existing range capability, route block pairing, operating cost, and performance data.

Figure 1: ZEB Fleet Transition Schedule



Using cost estimates based on the District's current 45 ZEB deployment project, which assumes a 2020 year-of-expenditure, the total cost to successfully transition to a 100% ZEB fleet will reach $1.3 billion. Based on earlier studies, an incremental cost of $696 million over a standard diesel bus fleet is expected however, this may change as the technologies and equipment become further commercialized. Summarized on the chart below is the bus procurement and large-scale infrastructure cost to support each technology type. Infrastructure cost uses the current estimate of $23.9 million to deploy 50 battery electric buses (BEB) and $7.1 million to deploy 50 fuel cell electric buses (FCEB) as a scalable baseline.

This cost estimate has been developed using the District's cost of procuring standard 40' battery electric and fuel cell buses in 2019. The actual purchase cost during each procurement phase is expected to fluctuate depending on market conditions. Cost for supporting infrastructure is rough order of magnitude estimate based on adjusting District capital project cost for each technology. Expected project packages are forecasted based on the quantity of accepted buses of each technology per year. The cost for this supporting infrastructure is expected to fluctuate with any changes to the bus procurement schedule. These costs are summarized in the chart below by bus technology.

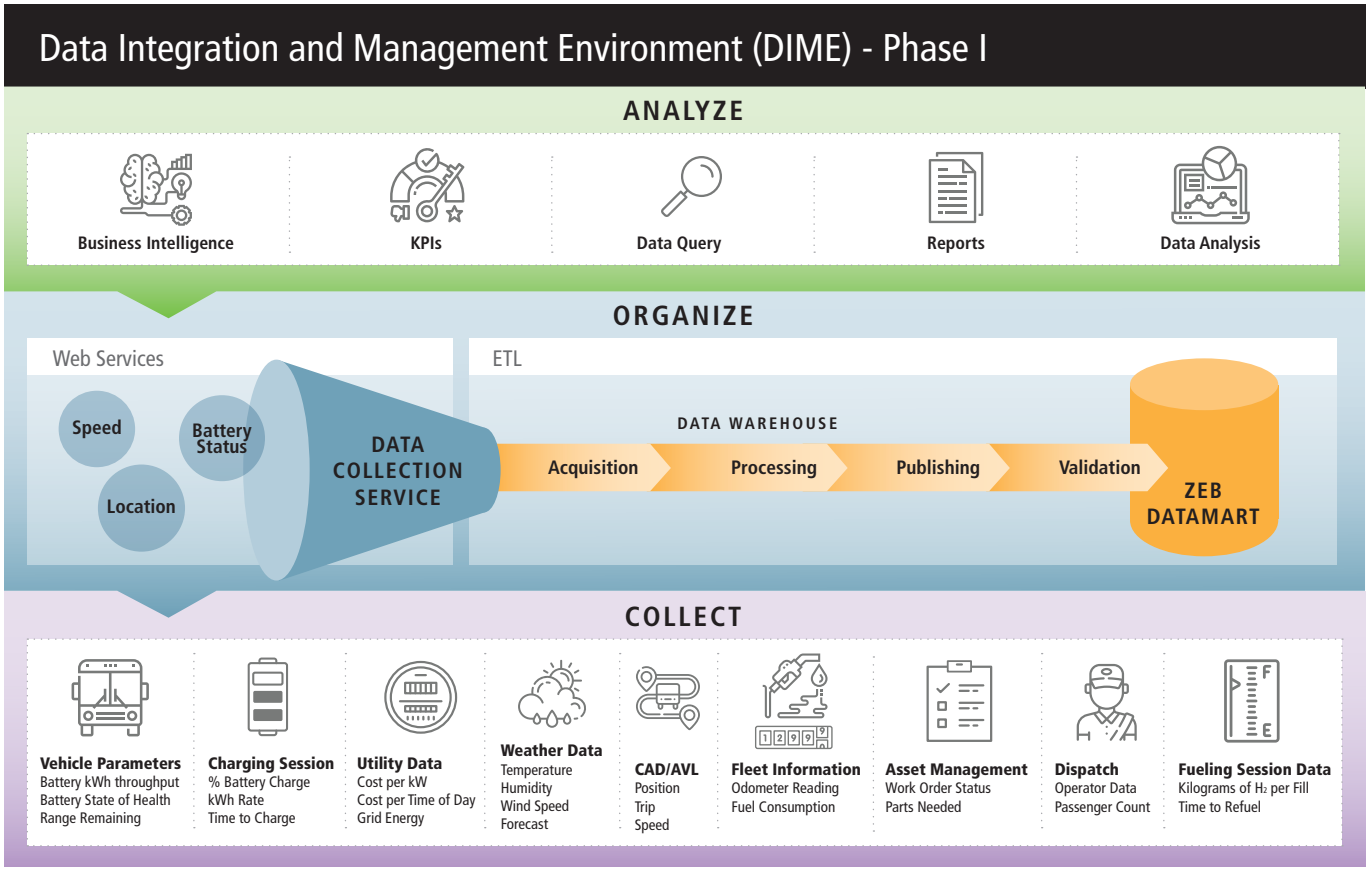
Figure 2: ZEB Technology Cost

ZEB Technology	Fleet Qty	Bus Cost	Infrastructure Cost	Technology Total
Battery Electric Bus	178	$255,000,000	$152,000,000	$407,000,000
Fuel Cell Bus	458	$740,000,000	$120,400,000	$860,400,000
	636	$995,000,000	$272,400,000	$1,267,400,000

Information Technology Infrastructure and Data Analytics Platform

AC Transit has invested in the Data Integration and Management Environment (DIME) that includes cloud infrastructure to collect, integrate, transform, and visualize ZEB energy and performance data real-time. The goal is to minimize manual data collection processes from various operations systems while optimizing the energy consumption of vehicles and operation costs.

Figure 3: DIME – Phase I



1. **Analyze:** Views to support data-driven, informed decisions for strategic and critical assets, with reliable Business Intelligence (BI) and visualization tools that provide essential features and data feeds.

2. **Organize:** Extracting important information from master data sources, without compromising quality or availability that encompass business requirements.

3. **Collect:** A collection of authenticated data from vendors, partners, and internal data sources to ensure transfers are protected, efficient, scalable and error-free.

Robust, reliable, and real-time connectivity will be a critical sub-system in assuring timeliness and quality data collection. All ZEB equipment will be connected to our Local Area Network (LAN) or Wireless Local Area Network (WLAN). Any data transmission outside our network will utilize our secure Wide Area Network (WAN) infrastructure and point to point secure VPN technology.

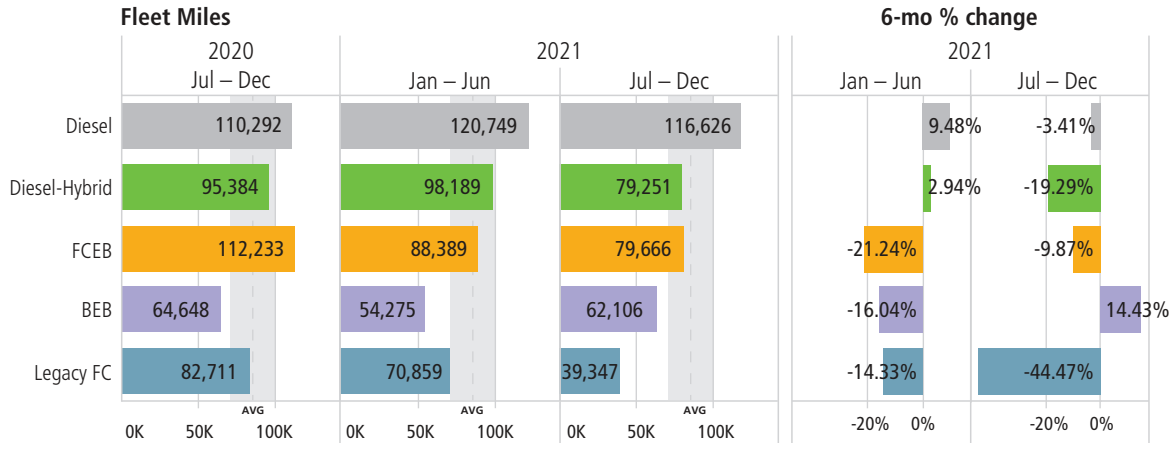
DIME: Phase II

AC Transit will utilize new computational methods and machine learning models for using the Zero Emission Bus Data for energy maximization and route performance in phase II. The latest data models created in various scenarios could be utilized in the DIME platform for predictive analytics or as part of an energy management platform to optimize charging infrastructure cost and usage. These data models will also enable the District to make data-driven decisions to optimize the operating efficiency in the current fleet's utilization and make accurate predictions informing future transitions. The goal is to improve the operational performance of our zero emission bus rollout through service optimization. Staff anticipates benefitting by learning more about sophisticated simulation and analysis tools, using advanced machine learning methods to provide practical insights for operating zero emission buses. These various simulation models will take vehicle data, infrastructure data, and fleet ops data and provide information to allow fleets to reduce their operating costs and increase ZEB utilization. Phase II will include developing a real-time Web User interface dashboard for ZEB fleet operations to support scheduling, dispatch, and charging/refueling decisions. The platform will allow optimized ZEB fleet operation evaluation through enhanced KPIs, leading to maximized ZEB utilization and lower operating costs.

Zero Emission Transit Bus Technology Analysis (ZETBTA)

The District runs the industry's most diverse bus propulsion systems, consisting of conventional diesel, diesel-hybrid, fuel cell electric buses, battery-electric buses, and legacy fuel cell technologies. To inform staff, guide future planning, and decision-making AC Transit developed a comprehensive study, the Zero Emission Transit Bus Technology Analysis (ZETBTA). The analysis is the first ever true, side-by-side evaluation of ZEB technologies operated by the same agency, in the same service environment, with ZEBs from the same bus manufacturer that compares performance and cost data among the fleets. The figure below provides an example of the mileage data comparison and reporting period percentage change from the previous report period.

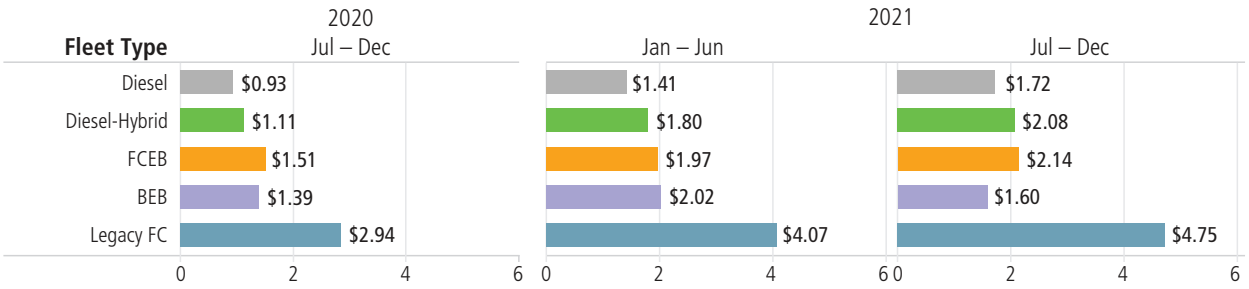
Figure 4: Vehicle Mileage Comparison



ZETBTA includes the integration of lessons learned and best practices gleaned from the agency's extensive experience in deploying ZEB technologies, including developing innovative workforce training programs, data integration and management, and transit deployment viability. When selecting cost and performance data to include in this analysis, AC Transit carefully considered key performance indicators (KPI) that align with our Strategic Plan and ZEB Transition Plan to guide the implementation of ZEB fleets. This approach provides data results that helped assess which ZEB technology can best

meet the operational requirements of the District while being financially efficient and sustainable. An example of this data is represented in the Cost/Mile figures:

Figure 5: Cost/Mile Comparison



To conduct an independent review of our data, analysis, and performance results, AC Transit partnered with Stanford University's Precourt Institute for Energy. Precourt is world renowned for its more than 200 faculty members and staff scientists working on energy-related challenges.

SECTION D

Current Fleet & Future Bus Purchases

Current Bus Fleet

AC Transit has over 630 active revenue vehicles that are comprised of 24, 30, 40, 42, 45, and 60-foot buses. These vehicles are distributed throughout the system based on capacity requirements of routes and trips with the busiest service using the 60-foot articulated buses. Individual routes often use a combination of bus types due to route interlining and the varying nature. The following table identifies the quantity of buses in the current fleet based on the service type.

Figure 6: Current Fleet Matrix

Type	Length	Year	Bus Technology	Bus Quantity
Cutaway	24	2014	Gasoline	10
Standard 30'	30	2006	Diesel	51
		2009	Diesel	39
Standard 40'	40	2003	Diesel	36
		2008	Diesel	27
		2010	FCEB (Depot fueling)	13
		2012	Diesel	65
		2014	Diesel	68
		2016	Diesel	55
		2016	Hybrid	25
		2017	Diesel	10
		2018	Diesel	35
		2019	FCEB (Depot fueling)	10
		2019	BEB (Depot fueling)	5
		2019	Hybrid	1
		2020	BEB (Depot fueling)	2
Transbay	40	2013	Diesel	54
	42	2018	Diesel	15
	45	2002	Diesel	36
Articulated	60	2006	Diesel	5
		2009	Diesel	9
		2013	Diesel	23
		2017	Diesel	28
		2019	Hybrid	27

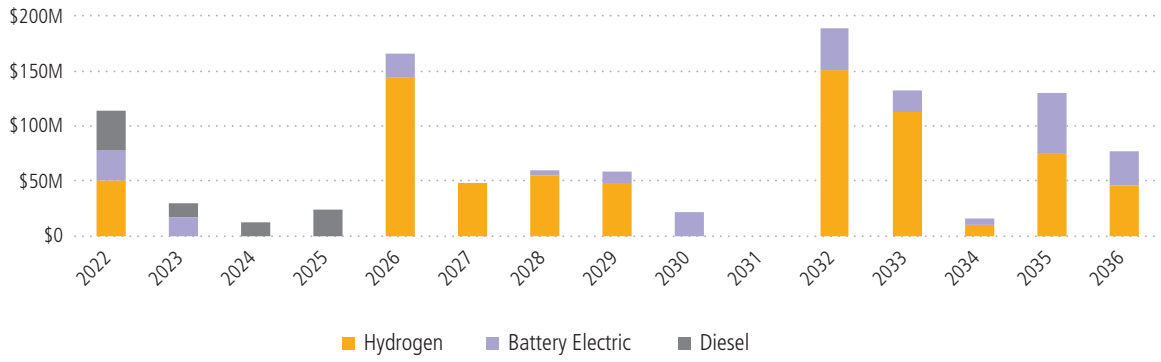
Bus Replacement Schedule

It is important to note AC Transit's priority is to deliver safe, reliable, sustainable transit service that responds to the needs of our customers and communities, as stated in our Mission Statement. Providing transit service that is both convenient and reliable is AC Transit's purpose. Our service and all the supporting functions in the District must be funded adequately to create convenient and reliable service. In order to comply with federal and state regulation while delivering AC Transit Board direction, the following ZEB transition guiding principles have been established.

1. Replace the fleet per Federal Transit Administration (FTA) mandated Transit Asset Management (TAM) Plan Performance Targets
2. Prioritize ZEB deployment per the AC Transit Board adopted Clean Corridors Plan
3. Procure ZEB's based on vehicle and infrastructure technology capabilities to meet service requirements
4. Deploy ZEB technology that is most efficient and sustainable to operate
5. Meet the 2040 ICT Goal

AC Transit's goal is to replace vehicles at the end of their useful life as defined in the Transit Asset Management (TAM) Plan. Based on the District's current fleet replacement schedule and currently planned procurements, the following chart reflects the annual cost to purchase buses to achieve a 100-percent zero-emission bus fleet by 2040. The schedule is dependent upon funding and zero-emissions technology becoming available on more fleet types, to advance deployment on blocks that operate 300 or more daily miles, in order to move completely away from conventional diesel.

Figure 7: Fleet Replacement Cost



AC Transit is currently working on the purchase of 45 ZEBs and supporting infrastructure, funded by various state and federal sources. With the current committed funding, AC Transit will be able to deliver the first phase including: the purchase of 20 FCEBs and 20 BEBs; BEB charging infrastructure for 26 buses at D2 utilizing pedestal mounted dispensers and distributed charging technology; and design of an additional BEB charging infrastructure for 24 buses at D4.

AC Transit is also planning the construction of new hydrogen fueling infrastructure at the Hayward (D6) facility with commissioning planned in late 2026.

The District is able to save considerable time and effort in the procurement process for Zero Emission Buses through the use of State Cooperative Purchasing Agreements. This is essentially a method of the District "piggybacking" off contracts developed by State Purchasing Agencies without having to engage in the highly complex and time-consuming effort of conducting its own solicitation in advance of a properly vetted contract award. The District has recently utilized such a cooperative purchasing agreement awarded by the State of Virginia to purchase 2 BEBs and plans to purchase at least 38 more under that contract. The State of California has also recently awarded contracts to a range of BEB and FCEB manufacturers that can be used the same way. While the District engages in these types of cooperative purchases, it still conducts due diligence to ensure fair and reasonable pricing and proper contracting procedures have been undertaken during the original contract process.

Figure 8: Fleet Replacement Plan

Replacement Year	ZEB Buses				
	Qty	Type	Technology	Division	Req. Range (mi)
2026	36	Standard 40'	Fuel Cell	6	300
	24	Standard 40'	Fuel Cell	2	300
	20	Standard 40'	Battery - Depot	4	200
	32	Standard 40'	Fuel Cell	4	300
	18	Over-the-road	Fuel Cell	2	300
2027	28	Articulated	Fuel Cell	4	300
2028	40	Standard 40'	Fuel Cell	6	300
	5	Standard 40'	Battery - Depot	2	300
2029	10	Standard 40'	Battery - Depot	4	200
	27	Articulated - BRT	Fuel Cell	4	300
2030	19	Standard 40'	Battery - Depot	4	200
2032	36	Standard 40'	Fuel Cell	6	300
	18	Standard 40'	Fuel Cell	3	300
	32	Standard 40'	Fuel Cell	3	300
	31	Standard 40'	Battery - Depot	6	200
	15	Double-decker	Fuel Cell	3	300
2033	20	Standard 30'	Battery - Depot	2	200
	22	Standard 40'	Fuel Cell	2	300
	39	Standard 40'	Fuel Cell	3	300
	11	Articulated	Fuel Cell	6	300

Replacement Year	ZEB Buses				
	Qty	Type	Technology	Division	Req. Range (mi)
2034	5	Standard 40'	Battery - Depot	2	200
	7	Over-the-road	Fuel Cell	4	300
2035	18	Over-the-road	Fuel Cell	2	300
	14	Over-the-road	Fuel Cell	4	300
	18	Over-the-road	Fuel Cell	3	300
	44	Standard 40'	Battery - Depot	2	200
2036	24	Standard 40'	Battery - Depot	4	200
	23	Articulated	Fuel Cell	2	300

SECTION E

Facilities and Infrastructure

AC Transit has four operating Divisions supported by a Central Maintenance Facility (CMF) and a General Office (GO). CMF, located in Oakland, provides administration, warehouse and maintenance functions that support all four Divisions.

Figure 9: AC Transit Facilities

Name	Address	Year Built	Size (sq. ft.)
General Office	1600 Franklin St, Oakland, CA 94612	1989	100,000
Central Maintenance Facility	10626 E. 14th St, Oakland, CA 94603	1984	517,000
D2 - Emeryville Division	1177 47th St, Emeryville, CA 94608	1987	392,000
D3 - Richmond Division	2016 MacDonald Ave, Richmond, CA 94801	1989	266,000
D4 - East Oakland Division	1100 Seminary Ave, Oakland, CA 94621	1987	579,500
D6 - Hayward Division	1758 Sabre St, Hayward, CA 94545	1987	833,500
Training and Educational Center	20234 Mack St, Hayward, CA 94545	1987	29,000

To accommodate projected operational needs and address current deficiencies the District has developed a Facilities Utilization Plan that acts as a master plan that outlines a road map to meet near and long-term needs. The Plan also provides a strategy for funding and financing that is coordinated with a detailed implementation plan. The Facilities Utilization Plan assumes that the District will operate a certain percentage of battery electric buses (BEBs) and fuel cell electric buses (FCEBs) based on current technology performance and District needs but can be adapted to accommodate any zero emission bus technology distribution. The plan incorporates the footprint required for fueling or charging infrastructure, maintenance capacity for FCEBs and BEBs, and bus parking reconfiguration to allow for needed BEB charging infrastructure.

With an initial BEB deployments, charging requirements are met relatively easily with a handful of plug-in pedestal chargers and small infrastructure investment. Scaling to a large BEB deployment requires a significantly different approach to charging and substantial infrastructure upgrade and smart charging software. Plug-in charging would not be practical for a large deployment as dispensers installed in the yard creates a hazard. Instead a preferred approach is to use overhead pantograph or dispensers attached to overhead structures, such as gantries and deck, installed across the yard. This would require reconfiguration of bus circulation and parking configurations at Divisions.

As our ZEB fleet grows, so does the infrastructure required to energize the fleet. We recently expanded our hydrogen fueling capacity for up to 78 buses between our Oakland & Emeryville divisions. We have plans to construct BEB charging infrastructure for up to 50 buses at Oakland and 26 buses at Emeryville. We have also secured funding to expand hydrogen fueling capacity to 130 buses at the Oakland division and have Board approval to seek funding for a hydrogen fueling station at our Hayward division. When these projects are completed, we will be able to operate ZEB technologies from three Divisions increasing our charging capacity for up to 82 BEBs and hydrogen fueling capacity for up to 325 FCEB.

Utility Partnership

AC Transit is actively working on the utility partnership by participating in Pacific Gas and Electric's (PG&E's) Electric Vehicle Fleet program. This partnership ensures that proper design standards for fleet electrification infrastructure are leveraged into each of our BEB infrastructure installations. Participation in the program ensures that adequate grid capacity will be available and interconnected to our site prior to the planned commissioning dates of our systems. Participation in PG&E's EV Fleet program also makes incentive rebates available to AC Transit from the utility for EV supply infrastructure and EV charger installations. Additionally, the District has worked in partnership with a variety of state agencies to ensure their incentive programs and regulations can maximize leverage of federal funds and ensure that these programs and regulations are in alignment with the needs of the industry.

ZEB Technology Cost Estimate

ZEB technology estimated costs were developed based on the year-of-expenditure using the Zero Emission Transit Bus Technology Analysis (ZETBTA) bus procurements and infrastructure project deliveries. The infrastructure costs were based on the ZEB technology using historic actual costs as engineered estimates at the maximum vehicle deployment quantities.

Figure 10: Bus and Infrastructure Estimated Capital Cost (in 2022 dollars)

ZEB Technology	Bus Procurement/ Avg per Unit	Infrastructure
Battery Electric Bus	$1.4M	$24.9M for 50 BEB Deployment
Fuel Cell Electric Bus	$1.6M	$7.2M for 50 FCEB Deployment

Construction Implementation

The District has four operating division sites and one central maintenance facility within its 364 square mile service area. Infrastructure modernization is planned at each of these facilities in alignment with the transition schedule for Hydrogen and Battery bus purchases. Project delivery methods will be evaluated by the District's internal project management teams and stakeholders as required to deliver hydrogen and battery electric capacity, Provisions for closure of the existing diesel infrastructure is not factored with the ZEB transition. Figure 11 (next page) specifies the location of each facility, and construction timeline. AC Transit is seeking funding for a large and scalable ZEB infrastructure; timing for delivering the infrastructure is aligned with the delivery of ZEBs and will adjust accordingly.

In addition to the existing charging capacity of 6 BEBs and fueling 78 FCEBs, AC Transit is planning to add charging capacity for 26 BEBs at D2 in 2022. AC Transit plans to place a scalable BEB charging for 24 BEBs with capacity to expand to 50 BEBs at D4 in 2023. Beyond the planned implementation, AC Transit will delivery infrastructure improvements strategically to meet the proposed vehicle replacement schedule as well as redeveloping Divisions per the Facilities Utilization Plan.

Figure 11: ZEB Technology Capacity by Division

	FCEB→516 | BEBs→206							
Location	**Division 2 Emeryville**		**Division 3 Richmond**		**Division 4 Oakland**		**Division 6 Hayward**	
ZEB Technology	BEB Chargers	FCEB Fueling	BEB Chargers	FCEB Fueling	BEB Chargers	FCEB Fueling	BEB Chargers	FCEB Fueling
Existing		75			7	13		
2022-2023	26				31	75		
2024-2025								75
2028-2029					50			
2030-2031		146		104		143	31	123
2032-2034	97				78			
Capacity	**97**	**146**	**0**	**104**	**78**	**143**	**31**	**123**

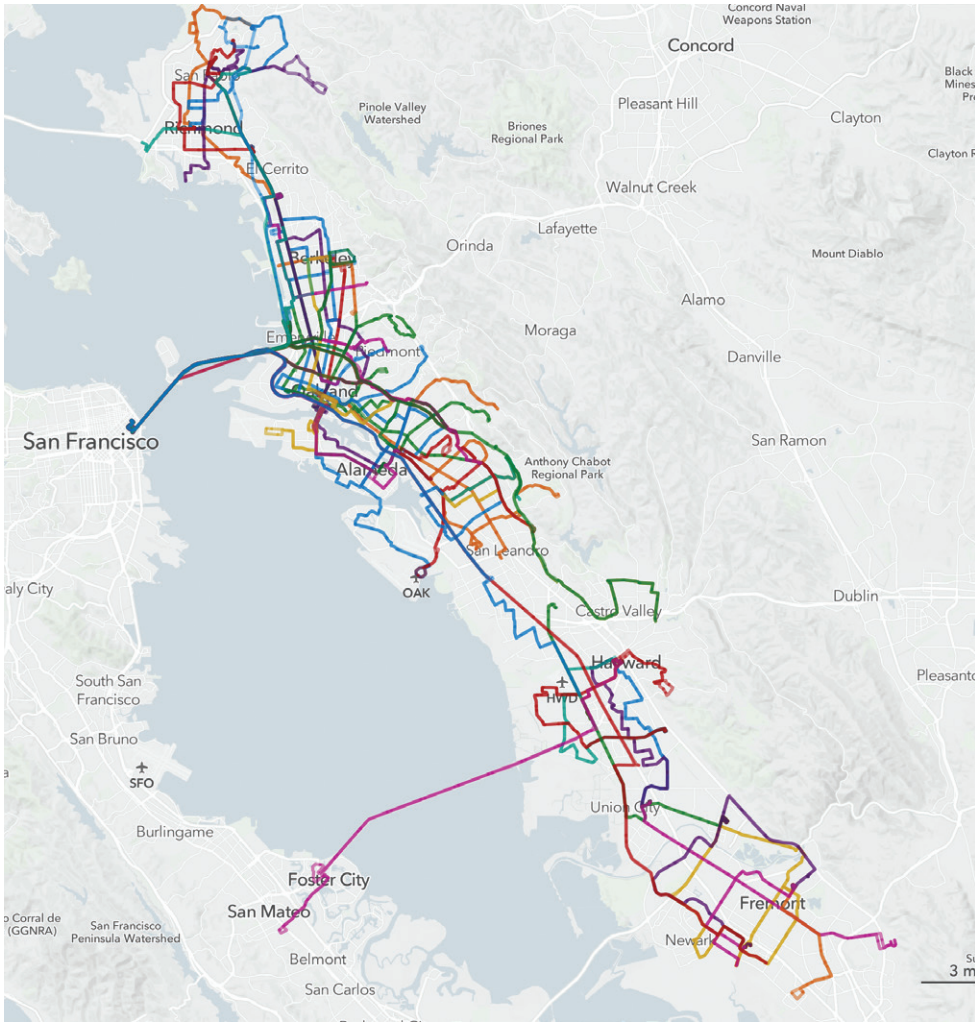
SECTION F

Disadvantaged Communities

The District's Clean Corridors Plan identifies a series of corridors and communities to be prioritized for ZEB deployment. The overall goal of the plan is to have vehicles used on all lines serving these corridors and communities be completely zero emission (whether battery-electric bus or hydrogen fuel-cell electric bus). The methodology for identifying and prioritizing the corridors and communities in that plan was as follows:

1) Evaluate existing conditions
2) Review areas identified as Disadvantaged Communities in the service area
3) Rank lines based on ridership and productivity to ensure maximum impact of the ZEB deployment
4) Consider constraints such as capacity/capability of divisions to accommodate ZEB growth
5) Scope out the number of vehicles and supporting infrastructure required to convert entire corridors/communities into Clean Corridors
6) Forecast operating and capital costs associated with conversion to Clean Corridors

Clean Corridor Lines



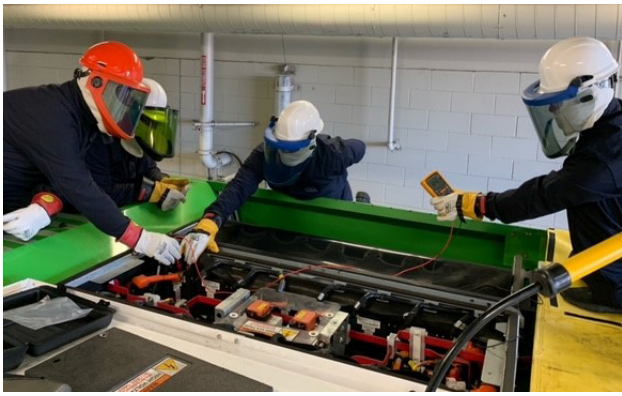
The clean corridor lines are grouped into their respective service area and community ridership rankings. The number of peak vehicles per line is a key factor to determine the relative impact of converting a line or service area into a purely zero emission Clean Corridor. The average weekday ridership is divided by the number of peak vehicles required to operate that grouping of lines. Doing so allows the District to prioritize lines where the greatest number of customers can benefit from the new lines with the fewest number of buses being converted to zero emission.

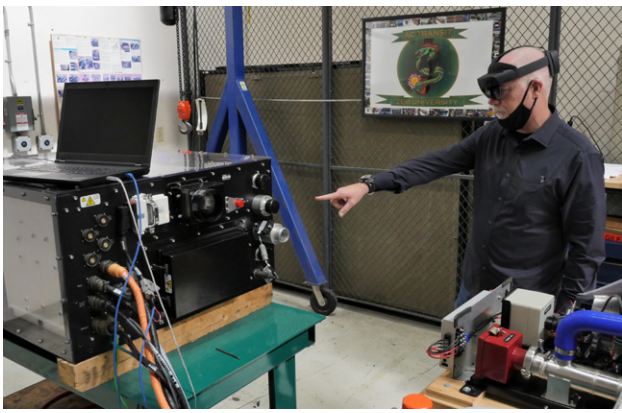
Figure 12: Clean Corridor Line Group

Area	Lines	Division(s)	Weekday Ridership	Peak Vehicles	Buses/ Hour/ Direction	Riders per Vehicle
Fruitvale	19, 20, 21, 39, 47, 51A, 54, O	D2, D4	19,012	41	27	704
Macarthur-Grand	57, NL, NXs	D2, D4	11,042	34	26	425
West Berkeley	51B, 52, 80, C, F, J, Z	D2, D3	16,615	38	21	791
Richmond	70, 71, 74, 76, L, LA	D3	7,400	31	20	370
West Oakland	14, 29, 36, 62, 88	D2, D4	13,503	35	17	794
Hayward	41, 56, 60, 83, 86, 97, M, S	D6	8,859	38	16	554
Coliseum	45, 46, 46L, 73, 90, 98	D4	7,758	19	14	554
North Oakland	6, 12, 18	D2	13,282	30	13	1,022
Downtown Oakland	33, 96, BS	D2, D4	6,663	18	13	513
Fremont	200, 212, 216, 232, 251, SB	D6	3,440	24	11	313
San Pablo Ave	72, 72M, 72R	D3	12,674	31	9	1,408
International	1	D4	11,469	18	8	1,434
Foothill	40	D4	8,951	13	5	1,790

SECTION G

Workforce Training





TMoving to a ZEB fleet required changes to the District's multiple operating functions. Transitioning requires training employees to keep pace with changing technologies. AC Transit provides operational training for its bus operators, mechanics, and other support employees. The following describes the process for the planning and scheduling of training and the inter-agency cooperation with Original Equipment Manufacturers (OEMs). Emphasis herein is primarily focused on mechanic training. The shift from internal combustion engines and propulsion technologies to zero emission systems is more complicated for mechanics than it is for bus operators.

It is important to note however that every bus operator at a District ZEB bus location is trained prior to the fleet being deployed into revenue service. Training provides each employee with both academic and behind-the-wheel drive time experiences. Topics covered include awareness of high-voltage systems, dash controls and indicator lights, specific start-up and shut-down procedures, and defensive driving safety. Training meets regulatory requirements per California Highway Patrol, Motor Carrier Specialist inspections as is also defined in the California Code of Regulations (Title 13 CCR, § 1229, Driver Proficiency).

In alignment with its strategic goals, AC Transit is seeking state and federal advocacy programs to secure funding to support the planning, design, construction, and operation of a training center that will provide zero emission technological skills for operations and maintenance transit workers to serve as a career gateway and support a workforce development center for disadvantaged communities.

Total ZEB Workforce Development Production

To date, the District has successfully scheduled and produced over 23,634 hours of training in one or more of the nineteen (19) courses listed in the table below on the following page.

The courses are listed alphabetically by title in the first column. The second column (Hours) represents the duration of each class. The third column lists the fleet for which the course content has been developed.

Figure 13: ZEB-Based Course Offerings

Course	Hours	Fleet
A123 Battery Training (Vendor)	8	Gillig Hybrid New Flyer FCEB
Ballard Fuel Cell - ZEB (Vendor)	24	New Flyer FCEB
Ballard Fuel Cell 10k miles PMI - ZEB (Vendor)	32	New Flyer FCEB
Fuel Cell Power Plant - ZEB	8	New Flyer FCEB Van Hool FCEB
High Voltage Electrical Safety - ZEB (Vendor)	8	FECB/BEB
Hydrogen FC Safety and Familiarization - ZEB	8	Van Hool FCEB
Hydrogen Fuel Cell Bus Hands-On - ZEB	240	Van Hool FCEB
Lithium Ion Battery Familiarization - ZEB	8	ZEBs
New Flyer BEB Orientation - ZEB (Vendor)	3	New Flyer BEB
New Flyer BEB Srv/Maintenance - ZEB (Vendor)	24	New Flyer BEB
New Flyer FC Orientation - ZEB (Vendor)	3	New Flyer FCEB
New Flyer FCEB Maintenance - ZEB (Vendor)	32	New Flyer FCEB
New Flyer FCEB Safety & PM - ZEB (Vendor)	8	New Flyer FCEB
New Flyer Safety/Familiarization FCEB/BEB - ZEB	24	New Flyer Safety
Siemens ELFA - ZEB (Vendor)	8	VH/New Flyer FCEB and BEBs

Learning Management System

All training is planned and scheduled via a learning management system (LMS) located on the District's intranet site known as MyACT. This site serves as the main portal for transportation and maintenance department management to access available courseware, class schedules, and enroll staff. Moreover, the LMS provides users the functionality to query data, from researching staff attendance to classes completed per employee (including details related to bus types, routes, and/or by topics). This functionality is critical in being able to track training progress and to identify skill-set gaps that may warrant training campaigns as needed to ameliorate specific key performance indicators.

Maintenance Training Plan

Procuring fuel cell electric (FCEB) or battery electric (BEB) ZEBs requires coordination with internal stakeholders and OEMs, as well as prioritizing classes for specific employees based on high voltage exposure levels. The following outlines a general maintenance training plan.

Basic Courses: Familiarization and Safety

Training coordinates with OEMs and internal stakeholders to schedule staff to attend OEM bus familiarization and safety orientations. This is a standard, scheduled first-step practice when receiving any new bus (not just ZEBs). This training is foundational and impacts all mechanics and service employees (i.e., those who clean, fuel, and park).

Familiarization/safety orientation is an OEM-led class and content typically includes high voltage safety awareness, personal protective equipment (PPE), safety measures, and preventive maintenance. This course is presented to each shift at each affected operating division upon delivery of the bus. As this course is an overview, or high-level review, it is approximately three hours per session. In addition to mechanics and service employees, maintenance supervisory staff and maintenance trainers are required to attend.

Bus Component Courses

Additional OEM classes, beyond that of familiarization and safety include, but are not limited to, air systems, brakes, steering/suspension, door operations, electrical/multiplex systems (from schematics to ladder logics), computer and diagnostic systems, to include troubleshooting pathways. These bus component-based courses are scheduled for all mechanics at those locations where ZEB infrastructure and support exists. Courses entail moderate-to-high voltage level of exposure and therefore also, include maintenance trainers and maintenance supervisors. Often courses are scheduled quarterly and repeat as necessary. While these course topics are not specifically ZEB technologies, they are pertinent in that these are not static products/components. Performing preventive maintenance inspections and diagnostics on these products may impact or adversely affect ZEB functionality if not done correctly.

Advanced Courses

More advanced courses are initially taught by sub-component suppliers and scheduling is often coordinated through the OEM. For example, an OEM will work with staff to schedule the fuel cell manufacturer to teach the specifics of their product(s). Courses taught by sub-component suppliers usually address energy storage systems, electric-propulsion and/or fuel cell systems to name a few. Sub-component, supplier-led courses often include topics from safety and high voltage awareness to component functionality and troubleshooting diagnostics. As with Bus Component Courses the same operational staff are scheduled for these classes and training schedules are quarterly and repeat as necessary.

In-House Production

New technology requires strong partnerships with both OEM and sub-component suppliers. The learning curve is steep at first but flattens with practice and experience. The District's goal is for maintenance trainers to teach classes with less reliance on OEMs in the long run. To that end, some ZEB-based courses are now taught by staff and include the following topics: safety awareness for high-voltage systems and high-pressure hydrogen, operational start-up/shut-down and emergency procedures, familiarization with location and functions of major fuel cell and battery electric components, fueling of fuel cell and charging of battery electric buses.

Working partnerships with OEMs has helped tremendously in gaining knowledge experience. These partnerships are structured pedagogically as well. OEMs often rely on training staff to learn how to translate engineering processes into mechanical procedures. The District has a rich history of acquiring training aides or modules used specifically to diminish these gaps between theoretical constructs and praxis.

The newest evolution in this effort is an actual OEM fuel cell module complete with air and coolant kits, poster training aids, related tool and diagnostic accessories as well. This resource was funded by a California Air Resources Board grant and has literally been turned into one of the first-ever fully functioning fuel cell power plant training systems. This innovation in curriculum development engages mechanics, for example, to perform required preventive maintenance in 1,000 and 5,000-hour inspections. Mechanics can practice all the required steps on this training aid first, make mistakes safely, and turn each challenge into a teaching moment. And that's just the beginning, we anticipate developing fault code troubleshooting exercises as well. These innovations in teaching establish new skills and confidence, and dramatically decrease learning curves when performing the same tasks on live ZEBs. Future curriculum development will focus on creating similar training modules for energy storage, electric low floor axle, and hydrogen storage systems.

5-Week Technical Training Program

Another great example of in-house training can be found in the experiential, five-week technical (hands-on) fuel cell training program. This training is perhaps the most in-depth and notable course staff developed and helps mechanics' understanding and retention of the training as the individual learns by working alongside a zero emission trainer. Mechanics learn how to practice safety measures, perform preventative maintenance, advanced diagnostics, and troubleshooting. What makes this course unique is that it mimics the advantages of an apprenticeship model in that the mechanic learns by doing alongside an expert, repeatedly.

Synchronous Learning

Staff has successfully developed courseware designed for synchronous learning environments or online interactivity to deliver training. These live, interactive online classes enable maintenance trainers and mechanics from all operating divisions to engage together, virtually, and safely (especially during the current pandemic). Equally significant, mechanics can attend classes without having to leave their respective shops for the entire day. Training times are shorter, normally two to three hours, compared to more traditional in-person eight-hour classes. It should be noted that not all topics are well suited for this environment. Current courses (as identified in the table below) include the following: Digital Multimeter; High Voltage: Awareness and Safety; and Hydrogen: Safety, Fueling, and Storage. More courses are in development.

Mixed Reality Systems

Moving ahead, AC Transit will introduce a new, innovative learning methodology in implementing virtual and augmented reality systems (also known herein as mixed reality systems). Mixed reality systems will re-invent and re-invigorate workforce training by engaging staff in the learning process, in real-time. Learning-by-doing takes on new meaning as employees are immersed in actual work tasks, guided along the way 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. Teaching becomes a live environment as the learner actively performs the tasks taught, at the same time. Mixed reality will transform traditional, one-dimensional, train-by-slide (decks) into a three-dimension, knowledge experience wherein learning becomes interactive to the object that is the focus of the training.

Virtual reality, for example, is ideal in preparing a new workforce to engage more frequently with high voltage systems. The application of a virtual reality headset offers the mechanic a chance to learn how to apply PPE, work on specific inspection steps (within an energy storage system) and make mistakes without consequence of injury to self, others, or damaging equipment. Implementing this mixed reality as a learning tool will reduce fear of shock, arch flash and other hazards as the process is practiced in a virtual, and completely safe, world first. It's the perfect application to troubleshoot, test, and practice new steps that many would otherwise shy away from or avoid.

Similarly, augmented reality which incorporates mobile devices like smart phones, specialized glasses such as hololens or electronic tablets, introduces virtual objects or procedures into real world settings. Using special glasses, for example, would enable a mechanic looking at (or, "pointing to") the fuel cell's air compressor and see, on screen (or, in the lens) a series of instructions to complete an inspection or removal process. All safety steps, inspection procedures, and recommended tools to perform the tasks correctly and accurately would display by voice command ensuring that work is completed at the pace of the worker or as led by a trainer.

The ZEB Evolution

Putting it all together, what does it take to work on ZEBs? There are as many theories about this as there are training programs. As technologies emerge, so too do theories of requisite course criteria. At the highest level, though, the District's workforce development can best be shown in the table below. The hours are estimates, but the training time invested is indicative of the evolution of a mechanic's proficiency working on either FCEBs and/or BEBs.

The District believes that implementing the training programs address the safety, reliability and sustain- ability of zero emission buses to fully deploy this technology in public transit.

To date, AC Transit has provided mechanics with sixteen different zero emission training programs totaling over 20,558 hours. Equally significant, staff has trained all drivers at multiple operating divisions deploying BEBs and FCEBs.

FCEB-BEB Courseware	Hours
Orientation and PPE/High Voltage	8
Energy Storage System	40
Power Train Technology	40
Fuel Cell	30
5-Week Technical Training Program	200

AC Transit has spent the last twenty years learning-by-doing. This existential approach toward ZEB technology has yielded some of the best practices in the industry. Preparing mechanics will continue to evolve as experiences, training, and OEM partnerships burgeon.

SECTION H

Funding

Sufficient funding is critical in ensuring the District can successfully implement the Rollout Plan. Replacing nearly the entire District fleet of diesel, hybrid, and older FCEB buses with new zero emissions buses will have a significant cost impact over replacement with standard diesel buses. The new infrastructure required for fueling/charging and reconfiguration of existing facilities adds further to the cost.

Due to the uncertain nature of transit funding over a 19-year timeframe, the District will need to constantly monitor funding and financing opportunities. Through the Metropolitan Transportation Commission's existing Transit Capital Priorities (TCP) Program, the District is eligible to receive Federal Transit Administration (FTA) funds for 70-80% of the cost of a bus replacement, with the District responsible for the remaining 20-30% local matching funds. The table below identifies the most common funding source that District could possibly utilize to fund the Rollout Plan.

The District intends to pursue funding opportunities vigorously; however, given the 2020 Pandemic and uncertain future of transit financing and ridership, it is highly likely the implementation timeline, and fleet size will change. The District will keep the Board of Directors, Funding Partners, and Regulatory Agencies apprised of this evolving situation.

Figure 14: Existing Funding Sources

Agency Level	Program Name
Federal	FTA Formula funds (TCP)
	FTA Low and No Emissions Program
	FTA Bus & Bus Facilities Program
State	Cap & Trade - Low Carbon Transit Operations Program (Revenue)
	Cap & Trade - Affordable Housing & Sustainable Communities
	Cap & Trade - Transit & Intercity Rail Capital Program
	SB1 Local Partnership Program (Formula and Competitive)
	SB1 State of Good Repair
Regional	Bridge Toll Capital Funds (TCP)
	Regional Measure 3
	Carl Moyer Program (CARB, BAAQMD)
	Transportation for Clean Air (BAAQMD)

SECTION I

Start-up and Scale-up Challenges

Through more than 20-years of experience deploying ZEBs, AC Transit has learned there are still many unknowns and unexpected challenges to overcome:

- Deployment of ZEBs and infrastructure adds significant capital and operating costs
- Procurement of ZEBs now require careful timing to deliver ZEB infrastructure capital projects when ZEBs arrive on property
- Not all ZEBs are yet a one-for-one exchange of a diesel bus in terms of range and capability
- ZEB operation is vulnerable to utility company priorities and limited numbers of fuel suppliers
- ZEB technology is evolving at a rapid pace, which complicates O&M with compatibility of components and charging infrastructure.
- IT Infrastructure cost/challenges
- Funding challenges due to the uncertainty of funding availability such as the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP), and the complexities of funding matches by type and percentages.
- Unexpected short-term and long-term impacts due to an emergency such as the COVID-19 pandemic or a natural disaster.

Without a doubt, ZEBs are readily available; however, in order to successfully transition the fleet, AC Transit will need policy makers, industry OEMs and energy providers to help address the existing challenges and risks.

It is important to note, the District's ZEB Rollout Plan is a living document meant to guide the implementation of zero-emission bus fleets and help the District work through many of the potential challenges to explore solutions. The Plan provides estimated timelines based on best available information for bus purchases, infrastructure upgrades, workforce training, or any other timelines in the Plan. AC Transit may update the Plan as needed with the most current information and industry best practices.

1600 Franklin Street
Oakland, CA 94612

actransit.org

0162-22 051222

Leading the way to a **ZERO EMISSION FUTURE.**