Zero-Emission Bus Implementation Guidebook for California Transit Fleets

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April 2023

Report No. UC-ITS-2021-21
DOI: 10.7922/G2TD9VPM

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Acknowledgments

This study was made possible with funding received by the University of California Institute of Transportation Studies from the State of California through the Road Repair and Accountability Act of 2017 (Senate Bill 1). The authors would like to thank the State of California for its support of university-based research, and especially for the funding received for this project. The authors particularly thank Yachun Chow, Jing Guo, Shirin Barfjani, and Bo Yang for their support. The authors also thank the co-authors of the comprehensive review study from the National Renewable Energy Laboratory: Matthew Jeffers, Ken Kelly, Andre Fernandes Tomon Avelino, Caley Johnson, and Matthew Post. Finally, the authors thank the California Transit Association for their review of a draft version of this guidebook. The preparation of this guidebook would not have been possible without the support of the California Air Resources Board for the conduct of an underlying project titled “Comprehensive Review of California’s Innovative Clean Transit Regulation.”

Disclaimer

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Introduction

Transit bus operations in California are experiencing new challenges due to economic conditions and the ongoing global pandemic. A confluence of factors has created a focus on this critical public-needs serving industry, due to state and local efforts to reduce emissions of pollutants and climate-changing gases. Transit bus operations in California provide essential and additional useful services that offer critical mobility to needy populations (elderly and handicapped) as well as many other groups for whom transit buses provide the most economical, convenient, and low-emission options.

To address the role of transit bus operations in meeting California's aggressive greenhouse gas (GHG) and emissions, the California Air Resources Board (ARB) has implemented an ambitious Innovative Clean Transit (ICT) regulation that requires all public transit agencies to gradually transition to a 100 percent zero-emission bus (ZEB) fleet.[1] Beginning in 2029, 100% of new purchases by transit agencies must be ZEBs, with a goal for a full transition by 2040. Prior to that 25% of purchases of new buses must be ZEBs in 2023-2025 for large transit agencies, rising to 50% in 2026-2028. For smaller transit agencies, defined as those with less than 100 buses in annual maximum service, there is no requirement for 2023-2025 and the requirement for 2026-2028 is 25%, but the 100% ZEB purchase requirement starting in 2029 applies to all agencies.

The two technology options available for this are battery electric buses (BEBs) that recharge with electricity, and fuel cell electric buses (FCEBs) that refuel with compressed hydrogen gas. Adoption of these new types of buses by California transit fleets that traditionally have used diesel, diesel-hybrid, biofuels, compressed natural gas, and liquefied natural gas represents a marked departure from past practices. In addition to operational differences for the buses themselves related to their electric drivetrains and regenerative braking systems, BEBs require electrical charging systems and FCEBs require hydrogen refueling facilities. These systems can be complex and expensive to install and operate, presenting additional challenges to transit agencies in adopting these technologies. Figure 1 below shows examples of BEB and FCEB models by major bus manufacturers.

[1] See: https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit

Sources: Proterra and AC Transit

Figure 1: Battery Electric Bus by Proterra (left) and Battery and Fuel Cell Electric Buses by American Flyer (right)

California transit agencies number about 160 and range from very large ones with hundreds of buses (e.g., large agencies in major California cities such as Los Angeles and San Francisco) to small regional services. Large agencies typically have mostly full size (40 foot or larger) bus fleets while smaller agencies may offer a mix of small numbers of municipal buses coupled with regional paratransit type services.

Many transit agencies in the state are already deploying BEBs and FCEBs and have considerable experience to share with other agencies. However, there are extensive knowledge gaps and needs for additional information for many California transit agencies, especially with regard to the installation and operation of support charging and fueling infrastructure.

Source: Calstart

Figure 2: Transit Agencies with ZEB Implementation in California

ZEB Deployment and Performance Assessments, Supportive Policies, Market Offerings, and Fueling Solutions

Adoption of ZEBs by California transit agencies involves a complex array of assessments of the appropriate ZEB technologies and configurations that meet transit agency requirements, what refueling solutions are possible and most appropriate, and how supportive state policies may be applicable. Additional considerations include lessons learned from previous implementation experiences and their applicability to specific transit agency operations, geography, and climate. Included below is a brief review of key aspects of these considerations. Later sections of this guide include further details of key bus purchase and incentive programs, and workforce training programs and opportunities.

ZEB Real-World Performance Assessments

New bus models often go through extensive testing exercises at the Altoona test facility in Pennsylvania, operated by Pennsylvania State University for the Federal Transit Administration. The Altoona facility was initially established in 1989, and since 1997 has included the capabilities for testing and repairing vehicles that use gasoline, diesel fuel, compressed natural gas, liquefied natural gas, methanol/ethanol, propane, hydrogen, and battery-powered electricity. However, the true test of bus performance is in real-world service in a range of actual operation in different geography and climate zones, up to fully loaded with passengers, and with a variety of different drivers with various degrees of training and experience.

Several organizations have compiled real-world bus implementation and testing studies and related reports in recent years. These include:

Calstart latest 2023 assessment of ZEB implementation across the U.S.

https://calstart.org/zeroing-in-on-zebs-2023/

Center for Transportation and the Environment alternative fuel bus performance assessments

https://cte.tv/services-area/projects/

National Renewable Energy Laboratory fuel cell bus evaluations

https://www.nrel.gov/hydrogen/fuel-cell-bus-evaluation.html

Alameda-Contra Costa Transit District bus performance evaluation

ZEBTA%20v4_FNL_012423.pdf

These studies help to provide transit agencies with the latest information on how ZEBs are being adopted and integrated into transit fleets, and how they are performing in revenue service across a wide range of operational conditions and duty cycles.

Supportive Transit Bus Policies in California for ZEB Procurements

In order to encourage fleets to adopt low and zero-emission bus technologies, California has enacted several supportive policies. These include both current and pending policies that have been enacted through the passage or consideration of Assembly and Senate bills.

Assembly Bill (AB) 784 (Mullin, Chapter 684, Statutes of 2019) enacts a partial state sales and use tax exemption for the purchase of specified zero-emission technology transit buses by California transit agencies. The exemption does not apply to local sales and use taxes or transactions and use taxes.

The exemption currently applies through January 1, 2024. Subsequently, Assembly Bill (AB) 2622 was introduced by Assembly Member Mullin in February 2022 and is currently under consideration. If passed by the Legislature, it will extend the exemption for specified zero-emission technology transit buses from the state sales and use tax until January 1, 2026.

Senate Bill (SB) 350 (DeLeon, Chapter 547, Statues of 2015) comprises many grids and electrical utility related elements that benefit the deployment of medium- and heavy-duty infrastructure projects to support transportation electrification. SB1000 (Lara, Chapter 368, 2018)[2] further requires CPUC to explore more targeted rate-design strategies for commercial EV customers and fleets and to deploy charging stations where there is existing excess grid capacity.

SB 288 (Wiener, Scott, Chapter 200, 2020)[3] accelerates various transportation projects such as charging infrastructure for ZEBs and new rapid transit, bus, or light rail service, by temporarily exempting them from the California Environmental Quality Act (CEQA) until 2023. SB 922 was then introduced in February 2022 by Senator Wiener to amend Sections 21080.20 and 21080.25 of the Public Resources Code, relating to environmental quality. If passed, it will extend the CEQA exemption to January 1, 2030. [4]

Zero-Emission Bus Deployment Status

The deployment of ZEBs in California and around the U.S. has been increasing steadily in recent years. As of the end of 2021, there were a reported 3,533 ZEBs in the U.S. either in service or on order. Of these, 1,371 or about 40% were in California. BEBs comprised 1,244 of the California fleet and FCEBs numbered 127, but with a faster growth rate than BEBs from 2020 where the number of FCEBs nearly doubled from 2020 to 2021.[5]

Zero-Emission Bus Models and Key Specifications

There are six main manufacturers of BEBs for the U.S. market. These include BYD, Gillig, Greenpower, New Flyer, NovaBus, and Proterra. Table 1 below shows key specifications for the BEBs currently available in the U.S. market. Additional specifications are provided in Table A-1 in the appendix section.

[2] Pub. Util. Code Section §740.15

[3] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201920200SB288

[4] https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB922

[5] Zeroing in on ZEBs, 2021 edition, https://calstart.org/wp-content/uploads/2022/01/2021-ZIO-ZEB-Final-Report_1.3.21.pdf

Table 1: Battery-Electric Bus Models and Summary Specifications

Manufacturer	Model	Version	Length	Width	Height	Curb Weight	Battery Capacity	Range	Fuel Economy
BYD	Transit	30 ft	30.7 ft	95.7 in	132.3 in	22487 lbs	180 kWh	107 mi*	1.36 kWh/mi*
		35 ft	35.8 ft	101.5 in	134 in	28660 lbs	352 kWh		
		40 ft	40.2 ft	101.6 in	134 in	31750 lbs	324 kWh	129 mi*; Up to 1	1.988 kWh/mi*
		60 ft Articulated	60.7 ft	101.6 in	135 in	50706 lbs	578 kWh	220 mi*	3.02 kWh/mi*
	Double Decker	35 ft	35.8 ft	102 in	13.4 ft	36155 lbs	313 kWh	Up to 170 mi	
		45 ft	45 ft	102 in	13.4 ft	47000 lbs	446 kWh	Up to 230 mi	
	Motor Coach	23 ft	23.5 ft	81.1 in	108 in	13779 lbs	121 kWh	Up to 124 mi	
		35 ft	35.2 ft	101.6 in	11.6 ft	31967 lbs	313 kWh	Up to 200 mi	
		40 ft	40.5 ft	102 in	139.4 in	36376 lbs	352 kWh	Up to 200 mi	
		45 ft	45.8 ft	101.6 in	139.4 in	42990 lbs	446 kWh	Up to 230 mi	
New Flyer	Xcelsior CHARGE	35 ft	35 ft 5 in	102 in	11 ft 1 in [A]	28556 lbs	160, 213 kWh		
		40 ft	40 ft 9.5 in	102 in	11 ft 1 in [A]	32750 lbs	160 & 213 kWh, 267 & 320k	87 mi (Altoona a	1.84 kWh/mi*
		60 ft Articulated	60 ft 7.3 in	102 in	11 ft 1 in [A]	52070 lbs	Altoona done with 540kWh;	184 mi*	3.22 kWh/mi* for
Proterra	Catalyst / ZX5	35 ft DuoPower	443 in	102 in	128 in	26359 lbs	220 kWh (XR/ZX5)	95-125 mi	1.5-2.0 kWh/mi
						29658 lbs	440 kWh (E2/ZX5+)	172-240 mi	1.6-2.3 kWh/mi
		40 ft DuoPower	510 in	102 in	128 in	26649 lbs	220 kWh (XR/ZX5)	92-120 mi	1.6-2.1 kWh/mi
						29849 lbs	440 kWh (E2/ZX5+)	163-232 mi	1.7-2.4 kWh/mi
						33149 lbs	660 kWh (E2max/ZX5max)	221-329 mi	1.8-2.7 kWh/mi
NovaBus	LFSe		40 ft	8.5 ft	10.5 ft	30140 lbs	76 kWh (max rated)	28 mi*	1.76 kWh/mi*
	LFSe Plus		41 ft	8.5 ft	10.8 ft		Up to 594 kWh		
Greenpower	EV250		30 ft	8 ft 4 in	10 ft 8 in		210 kWh	>150 mi	
	EV350		40.7 ft	8.5 ft	10.7 ft	31320 lbs	320 kWh	>185 mi	
	EV550 Double Decker		45 ft	8.5 ft	13'6" to 14'4"		478 kWh	Up to 200 mi	
Gillig	Low Floor Electric	29 ft	30 ft 8.5 in	100 in	132 in	26510 lbs	90 kWh	42.5 mi*	2.27 kWh/mi*
*Altoona average									
[A] height over charging rails									

FCEBs are at an earlier point of commercialization than BEBs but are proving themselves to be capable of good performance in revenue service. These models are currently being produced by New Flyer, ENC, and Van Hool, with basic specifications shown in Table 2. Additional specifications for FCEBs are provided in Table A-2 in the appendix section.

Table 2: Fuel Cell-Electric Bus Models and Summary Specifications

Make and Model	Version	Length	Width	Height	Weight	Range	Fuel Economy	Hydrogen Storage
New Flyer Xcelsior Charge H2	40-foot	41' 2" [A]	102"	11' 1"	32250 lb (curb)	300/350 mi ? Mer	3.12 mi/lb	37.5 kg
	60-foot	60' [A]	102"	11' 1"	49900 lb (curb)	300/350 mi ? Mer	2.44 M/lb	60 kg
ENC AXESS-FC	35-foot low-floor	421.5" [A]	102"	NA	44300 lb (GVWR)			
	40-foot low-floor	484" [A]	102"	140"	44300 lb (GVWR)		3.14 M/lb	50kg
Van Hool	A330 Fuel Cell	13155 mm	2550 mm	3420 mm	39350 lb (GVWR)			40kg
[A] length over body								

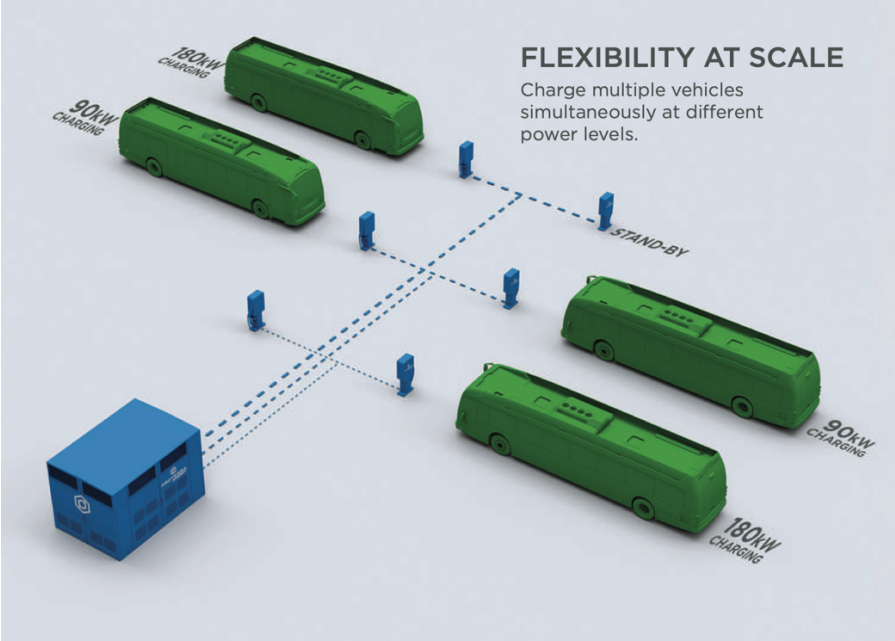
Battery Bus Charging Solutions

Battery bus charging solutions represent an important consideration and challenge for transit agencies. Transit bus yards are typically not equipped with sufficient grid infrastructure for large numbers of relative high power (50-250+ kW) chargers for BEBs. This likely requires working with the local utility to upgrade service and potentially install new transformers, as well as doing the requisite conduit and

other electrical work in the bus yard to install the chargers themselves. This can be disruptive to bus operations, as well as representing a significant capital cost challenge.

On the positive side, there are a suite of emerging solutions for BEB charging, including both traditional conductive as well as emerging inductive charging solutions. Conductive charging requires a physical connection between the charger and bus, using an established plug standard technology. Inductive charging can be done without a physical connection but does require a limited "air gap" of at most 5-8 inches between the inductive charging plate and the inductive charger interface on the bus.

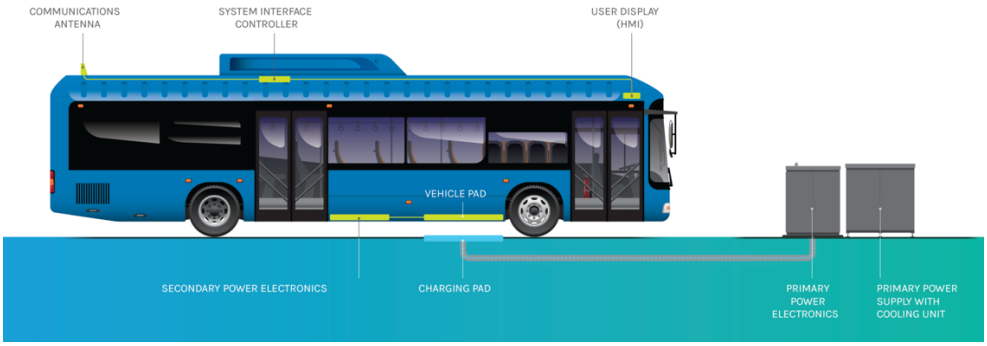
Examples of these technologies include solutions from Proterra for conductive charging solutions. As shown in Figure 3 below, Proterra's solution allows for multiple buses to be charged simultaneously from a central grid interface, and with potential for variable power levels per charge point. Other BEB charging solutions are offered by Siemens, ChargePoint, EVgo, and several others.



Source: Proterra

Figure 3: Example of Flexible Battery Electric Bus Conductive Charging Solution

Other inductive power solution charge providers for bus applications include those provided by Wave, with a general schematic shown in Figure 4 below. These charging solutions, currently in the 50-250kW range, could be provided at bus yards, obviating the need for physically connecting the buses to charge points, or perhaps more interestingly as in-route "range extender" charging solutions where buses pause during their routes. The latter idea brings up questions and issues of introducing chargers into the public rights of way, but some examples of implementation of this concept in California exist, including those by Antelope Valley Transit Authority.



Source: Wave

Figure 4: Example of In-Road Battery Electric Bus Inductive Charging Solution

BEB charging solution capital and installation costs vary widely based on transit agency needs, existing infrastructure, and site-specific installation costs. Transit agencies that are new to BEB implementation are encouraged to confer with sister agencies that may have similar/analogous charging solution installation situations. However, costs of electricity for charging are more predictable, but still subject to change over time particularly with utility "demand charge" policies that relate to peak power demands as well as the "volumetric" charges for the amount of electricity used. The California Air Resources Board has a "Battery-Electric Truck and Bus Charging Cost Calculator" that presents example charging costs, but we note that it has not been recently updated and the utility rates included may have changed somewhat in the past few years:

https://ww2.arb.ca.gov/resources/documents/battery-electric-truck-and-bus-charging-cost-calculator

Fuel Cell Bus Hydrogen Refueling Solutions

FCEBs share many similar characteristics with BEBs in terms of their electric motor-based propulsion systems but differ markedly in terms of the power system that provides electricity to the electric motor. FCEBs also incorporate an electrochemical battery in the power system, for regenerative braking and peak power assist, but are primarily powered by a proton-exchange membrane (PEM) fuel cell. The fuel cell system converts hydrogen gas from the fuel tank along with oxygen from the air to electrical power, producing only pure water as a tailpipe emission. This technology requires access to a hydrogen fueling station, either incorporated or adjacent to the transit agency bus yard, where buses are typically filled overnight or early in the morning each day for their daily duty cycle. Fill times can be on the order of 20 minutes per bus, with efforts to decrease that time, but much faster than BEB recharging.

Transit agencies that have adopted, currently operate, and who have developed hydrogen refueling solutions include Alameda-Contra Costa County Transit (AC Transit), Orange County Transit Authority, Stark Area Regional Transit Authority, and Sunline Transit Agency. AC Transit operates two fueling

stations, Emeryville and East Oakland, which receive deliveries of liquid hydrogen. Its Emeryville site produces hydrogen from solar power with onsite electrolyzers. During bus fueling, the facilities all-new cryogenic pumps dispense hydrogen at 350-bar (5,000 pounds per square inch) of pressure as well as providing light-duty FCV refueling at a higher-pressure level of 700-bar (10,000 pounds per square inch) along the adjacent street (Figure 5). A new dispensing system at AC Transit's Oakland station will be able to refuel up to 150 buses in a 12-hour refueling window, dramatically increasing the previous system's capacity.

Source: AC Transit

Figure 5: Fuel Cell Electric Bus Refueling with Gaseous Hydrogen

Best Training Practices for Operation and Maintenance

An important topic for ZEB implementation is the workforce development and human operations and resources needed to support the physical transition to new generations of bus technology. Transit agencies employ various strategies for achieving their training goals, working closely with bus OEMs, BEB charger manufacturers, hydrogen fuel providers, hydrogen station developers, and established training programs for operators, mechanics, and maintenance workers. Many transit agencies also work proactively with fire safety officials on first responder training. These training programs and transit agency experiences with training operations are briefly summarized in this section.

U.S. Federal and Non-Government National Training Programs

The FTA has established a Transit Workforce Center (TWC) that provides training support including through its International Transportation Learning Center, which was recently allocated $5 million in FY 2021 funding. The mission of the center is "to help transit agencies recruit, hire, train, and retain a diverse workforce needed now and in the future." The program provides technical assistance, human resources and training including outreach to under-represented communities, and innovative "frontline" workforce development projects. The workforce development grants through the TWC have previously been awarded to both urban and rural transit bus operators, typically on an 80% (federal) and 20% (match) basis. Further details of recent efforts can be found through the link below.

Program site: https://www.transit.dot.gov/research-innovation/workforce-development-initiative

Additionally, nationwide, there is an important program for training electricians to install EV charging infrastructure known as the Electric Vehicle Infrastructure Training Program (EVITP). This training program is offered at various locations such as industry training centers and community colleges. The EVITP program provides comprehensive training for the installation of EV supply equipment (EVSE) in North America. Along with a technical installation course, EVITP offers a larger overview of the EV industry. Modules include automaker experience with EV charging, types and characteristics of EV batteries, utility interconnect procedures, possible role of electricity storage in conjunction with EVSE, first responder training and fire hazards, as well as many other aspects in addition to the actual installation of various types and power levels of EVSE.

Program site: https://evitp.org/training/

Also, the U.S. Department of Energy has funded the Pacific Northwest National Laboratory (PNNL) to create a set of hydrogen fuel training materials known as H2Tools.[6] These include trainings around the

[6] https://h2tools.org

safe transport, storage, and use of hydrogen as a vehicle fuel. More specific trainings around hydrogen production systems (e.g., electrolyzers and methane/biogas reformers) would seem to be still under development. However, there are other large efforts related to the Hydrogen safety and best practices, including the Hydrogen Safety Council and the International Conference on Hydrogen Safety, organized biannually by the International Association for Hydrogen Safety.[7]

Statewide and Regional Programs

There is a new statewide program in California for operator and mechanics training for ZEB operations called the California Transit Training Consortium (CTTC). This is an expansion of a previous regional training program for Southern California that was known as the Southern California Regional Transit Training Consortium (SCRTTC). The CTTC course manual includes a wide range of training programs focusing on electrical systems, braking systems, engines, hybrid systems, HVAC systems, and system diagnostics. Both in-person and distance learning program options are available. Members of CTTC include transit agencies, government agencies, and community colleges. Further details on this program are available at: http://www.scrttc.com

Also, the Center for Transportation and the Environment leads an effort called the Zero Emission Bus Resource Alliance (ZEBRA). The consortium was developed to facilitate information exchanges, training programs, shared research, and public education. Over 40 transit agencies are currently members, where there are bi-monthly meetings for information exchanges as well as a membership portal with a collection of resources. Membership fees range from $1,000 to $5,000 per agency per year based on the size of the agency. Further details can be found at: http://zebragrp.org/zebra-mission/.

Industry Based Training Programs

In addition to these government and trade union sponsored programs, there also are significant industry-based training programs for transit bus operators and mechanics for new ZEB technologies. The following list describes additional training programs to support a transit ZEB workforce:

MCI Academy

New Flyer, a subsidiary of NFI Group Inc., has launched its Electrical Technician training program. The program provides employees with knowledge and skills to continue leading and supporting zero-emission adoption across North America.

MCI Academy website: https://www.mciacademy.com/

[7] https://hysafe.info/activities/ichs/

New Flyer Vehicle Innovation Center (VIC)

New Flyer also operates a more general training center called the Vehicle Innovation Center, emphasizing training for new workers on public transit buses and motor coaches.

VIC website: https://www.newflyer.com/company/vehicle-innovation-center/

New Flyer Anniston Workforce Development Program (AWDP)

This is one of several local programs developing under New Flyer's Community Benefits Framework (CBF), a national workforce development initiative announced by New Flyer and the Transportation Diversity Council in 2020.

The AWDP includes "the execution of a workforce development program, including training and development, skill gap assessments, wage and benefit commitments, fulfillment of diversity and hiring objectives, and pre-apprenticeship and apprenticeship programs."[8]

It also includes development of an innovative four-year Electrical Technician Apprenticeship Program which was launched in 2021.[9]

Proterra, Los Angeles County, Citrus College, and USM Local 675 – Electric Bus Manufacturing Technology Program

This manufacturing focused effort consists mainly of a 9-week workforce training program for advanced electric bus manufacturing.[10] It is a "unique partnership [that] launches new electric bus manufacturing training program and union contract."[11] The inaugural cohort of students completed the training program in January 2021.[12]

San Bernardino Valley College (SBVC), Heavy/Medium Duty Clean Vehicle Technology Certificate Program

"The curriculum prepares students for entry-level positions in Heavy-Duty Truck and electrical maintenance, field service, and networking, in the field of Hybrid/ Alternative fuel to include electrical power technology."[13]

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[8] https://www.newflyer.com/2020/09/a-new-workforce-development-initiative-for-the-new-mobility-era-new-flyer-of-america-launches-its-anniston-workforce-development-program-under-the-community-benefits-framework/

[9] https://www.newflyer.com/2021/10/nfi-launches-electrical-technician-training-program-in-continued-pursuit-of-enabling-the-new-mobility-era/

[10] https://www.proterra.com/press-release/workforce-training-program/

[11] https://www.masstransitmag.com/management/press-release/21157104/proterra-la-county-wdacs-proterra-united-steelworkers-local-675-community-groups-announce-electric-bus-manufacturing-and-workforce-partnerships

[12] https://vimeo.com/503316236

[13] https://catalog.valleycollege.edu/degree-certificate-program-index/hmdt/heavt-medium-duty-clean-vehicle-technology-certificate-achievement/#programrequirementstext

The “certificate program [is designed] to develop a local workforce of technicians that can provide the service and maintenance support needed long after the initial BEVs have hit the roads.”[14]

Sunline’s West Coast Center of Excellence in Zero-Emission Technology (CoEZET)

Sunline has a well-established workforce training center effort described as: "CoEZET is a workforce training program focused on maintaining and operating zero emission buses in public fleets. Public and private organizations, including transit agencies, colleges, private industry, and government agencies, are collaborating with SunLine to develop training and resources for zero emission bus maintenance including all kinds of alternative and emerging energy technologies."[15] CARB has instructed CALSTART to use HVIP outreach funding to support SunLine’s ZEB training center.

Alameda-Contra Costa County Transit

Finally, AC Transit has developed an extensive internal training curriculum for ZEBs. The transit district's unprecedented Zero Emission Transit Bus Technology Analysis (ZEBTA or the “5x5” Study) documented over 22,000 scheduled training hours, including more than 19 courses on ZEB technology, via an in-house learning management system.

Transit Bus Agency Training Plans and Experiences

The transit agencies interviewed have a wide range of plans and experiences around operator and mechanics training. The larger transit agencies tended to have established more extensive internal training programs while smaller agencies were more likely to rely on assistance from bus OEMs and charger manufacturers, and other established programs.

Bus operator training is often integrated with the initial bus purchase agreements. Transit agencies reported mixed experiences with training programs offered by OEMs, with some being relatively effective but others reporting some difficulties with unclear training manuals and difficulties in establishing their own internal mechanical and diagnostic programs.

Agencies also reported high variability in bus efficiency that is related to operators. Some reported that the efficiency of operators in driving the buses improved over time (converging closer to expectations), either as a function of training or experience, and largely related to the familiarity and proper use of ZEB braking systems. One agency reported that Proterra has a “train the trainer” program where the OEM's customer support staff first provide instruction to the lead trainers or designated operators at a transit agency, who then provide training to the rest of the individual operators. The focus is on

[14] https://www.lightsproject.com/executive-interview-electric-trucks-and-volvo-lights-are-bringing-new-job-opportunities/?elqTrackId=4d7f8c61ff10431a83bcf8c0f2727828&elq=74bdcb1dd1a3426598cd5a4ec11d08ac&elqaid=3478&elqat=1&elqCampaignId=2035

[15] https://www.sunline.org/alternative-fuels/west-coast-center-of-excellence-in-zero-emission-technology

acceleration and braking and how driving ZEBs is different than conventional buses in terms of achieving the highest fuel economy.

Operators of FCEBs are also trained on hydrogen safety issues, with some concerns about the flammability hazards of the fuel. They are trained to recognize and respond to warning signals and dashboard signs along with any other indications (e.g., unusual noises) of a potential problem and to react appropriately. These trainings are aided by support materials available through the U.S. DOE's Hydrogen Tools web portal and the California Fuel Cell Partnership resources website. [16] [17]

As for mechanics and service technician training, once trained, mechanics are reported to be generally able to deal with the basic electric bus mechanical issues, but high-voltage electrical system maintenance requires special training. One agency employs a two-phase plan for mechanics training. In Phase I, mechanics must complete 8 hours of training on proper use of electricity/volt meters and other basic electrical training. In Phase II, mechanics receive an additional 24 hours of technical training. The agency also requires completion of modules for mechanics on ZEB familiarization, high voltage system safety, charging infrastructure training, and arc flash electrical safety.

Another agency first requires 1 hour of basic safety training followed by a 5-week program for preventive maintenance. The program is conducted with pairs of mechanics, more and less experienced, so they can help train each other. The agency indicates that with proper training, many potential issues can be avoided and that upfront investments in operator and mechanic time and training are likely to more than pay off in the longer term.

Transit agencies have also indicated the importance of establishing training program plans at the time of bus purchase, including specific courses. One recommends having extensive multi-media training to record trainings for future use. Other suggestions including as many useful visual aids as possible, such as computer-aided design (CAD) drawings, posters, and mock-ups of key mechanical systems.

Another issue that arose along with problems of unclear safety and training manuals is the use of specialized diagnostic equipment needed for ZEBs. This is another area for needed training because these diagnostic systems (laptops and test stations) require specialized OEM software and operations that some agencies reported struggles with. In some cases, they would like to develop their own internal capabilities in this regard, to speed diagnostics and repairs and reduce downtime, but were unable to do so because of the specialized nature of these skills and systems. Thus, they are continuing to be reliant on the OEMs for these services, sometimes resulting in maintenance and service delays.

A few of the transit agencies also suggested the need to share best practices and other experiences among agencies, indicating that this has historically happened for previous new bus types and

[16] https://h2tools.org/
[17] https://cafcp.org/resources

emerging technologies. APTA's Zero Emission Fleet Committee[18] (open to all ZEB stakeholders) and the ZEBRA group[19] (open to transit agencies only) are two existing avenues for this type of valuable peer-to-peer information exchange. Some transit agencies feel that the state should more clearly define required safety training for mechanics and operators, and to make sure that the buses arrive with clear plans for immediate safety training to put safety first.

[18] APTA Zero Emission Fleet Committee, https://www.apta.com/member-resources/committees/clean-propulsion-support-technology/

[19] Zero Emission Bus Resource Alliance (ZEBRA), http://zebragrp.org/

Grant Program Resources for Transit Agencies

California and Federal agencies clearly recognize that transit agencies require grant and subsidy support especially for their initial adoption of

Advanced Vehicle Technology and Infrastructure Funding Finder Tool

First, as a useful step, the Advanced Vehicle Technology and Infrastructure Funding Finder Tool has been developed as a collaboration among various agencies, with the work led by CALSTART. It helps stakeholders to search and filter for medium- and heavy-duty alternative fuel vehicle and infrastructure programs in the state of California. The tool is a web-based resource for identifying these program funding opportunities:

HVIP Funding Finder Tool: https://fundingfindertool.org/?keyword=transit

This resource currently lists 41 incentive programs, with the ability to search and sort them in various ways. Figure 6 shows the homepage for the funding finder tool, as well as the primary search categories.

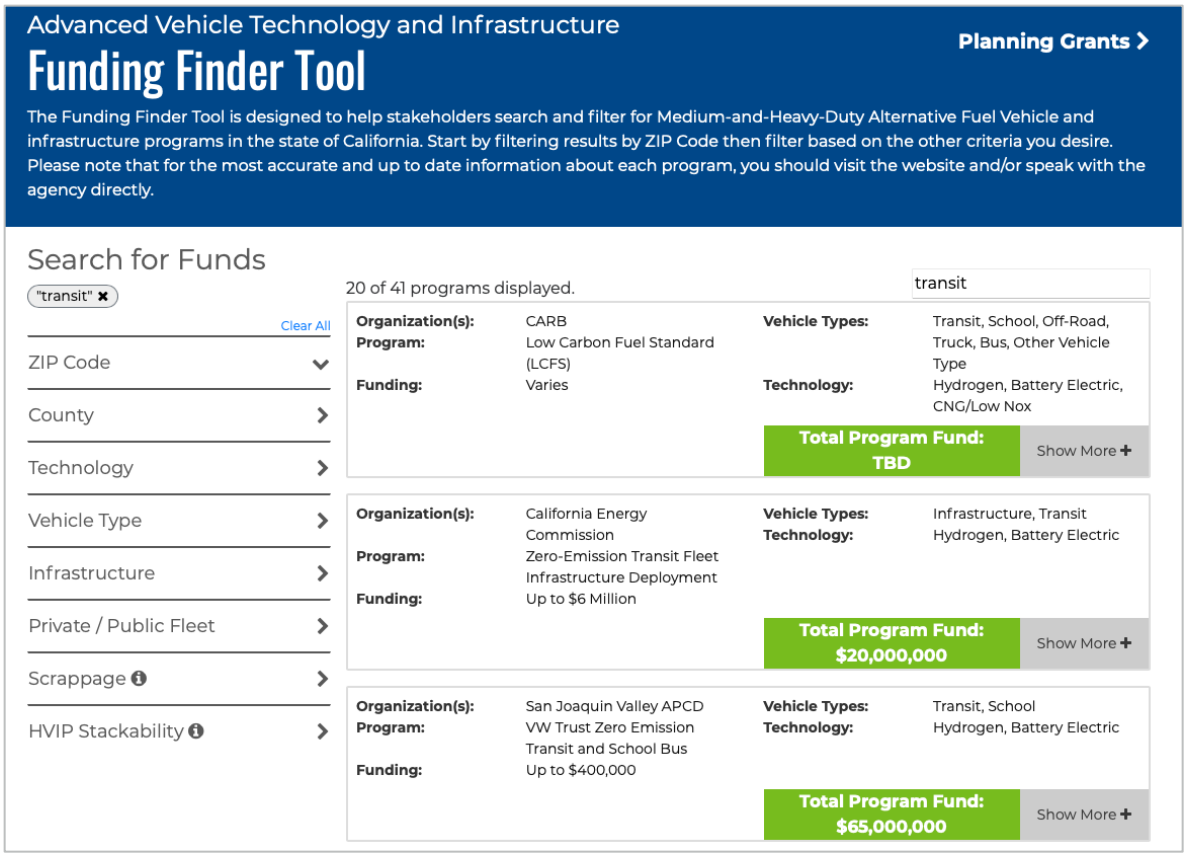


Figure 6: Advanced Vehicle Technology and Infrastructure Funding Finder Tool

The Funding Finder Tool can be used to find funding programs that are available in specific ZIP codes. Other criteria that can be applied to narrow the scope of the search include requirements for vehicle scrappage; "stackability" of, for example, HVIP grants with other programs; and other eligibility requirements.

United States Federal ZEB Incentive Programs

At the U.S. federal level, incentive programs for ZEBs are primarily available through the U.S. Department of Transportation (DOT), and specifically the Federal Transit Administration (FTA). Programs are also available through the U.S. Department of Energy (DOE), especially for infrastructure funding.

The Fixing America's Surface Transportation (FAST) Act of 2015 supported many transit funding programs from 2015-2020. The FAST Act provided over $300 billion for surface transportation including public bus transit support opportunities through various program areas including the Accelerating Innovative Mobility, Better Utilizing Investments to Leverage Development (BUILD), Transportation

Grants Program (formerly TIGER), Capital Investment Grants, and the Grants for Buses and Bus Facilities programs.

On November 15, 2021, a major transportation infrastructure support package (H.R. 3684) known as the Infrastructure Investment and Jobs Act was officially signed into law. The extensive legislation—over $1 trillion in total over 5 years—includes a historically high level of funding for public transit at up to $108 billion. Key provisions of the legislation that are relevant for public transit buses include Section 30018 "Grants for Buses and Bus Facilities," Section 11130 "Public Transportation," and Section 30008 "Bus Testing Facilities." [20]

The Section 30018 updates provisions of U.S. Code Title 49, Section 5339. This section provides for an overall increase in funding for Bus and Bus Facilities up to about $2.2 billion per year. Minimum funding for each state in formula funds increases from $1.75 million to $4 million per state, and from $0.5 million to $1 million per U.S. territory. The breakdown in authorized funding for formula, competitive, and the "Low or No Emission Vehicle (Low-No)" program (discussed further below) are shown in the following table.

Table 3: Funding Authorization for Grants for Buses and Bus Facilities in H.R. 3684

Fiscal Year	2022 (millions)	2023 (millions)	2024 (millions)	2025 (millions)	2026 (millions)
Formula Funds	$604	$617	$633	$646	$662
Competitive Grants	$376	$384	$394	$402	$412
Low-No Grants (competitive)	$1,122	$1,123	$1,125	$1,127	$1,128

Source: U.S. DOT FTA: "Bipartisan Infrastructure Law Fact Sheet: Grants for Buses and Bus Facilities"

The Section 11130, funding for Public Transportation, updates provisions of U.S. Code Title 23, Section 142. The language in the section includes that the "Secretary may approve payment for carrying out a capital project for the construction of a bus rapid transit corridor or dedicated bus lanes, including the construction or installation of: traffic signaling and prioritization systems, redesigned intersections that are necessary for the establishment of a bus rapid transit corridor, on-street stations, fare collection systems, information and wayfinding systems, and depots." Specific funding levels for this section are not identified in the enabling legislation.

Additionally, Section 3008 on Bus Testing Facilities includes an update to U.S. Code Title 49, Section 5318 with the language: "A facility operated and maintained under this section may use funds made available under this section for the acquisition of equipment and capital projects related to testing new bus models." Further details and funding levels are not specified in this section.

Finally, the Inflation Reduction Act of 2022 (H.R. 5376) includes various provisions related to support for clean fuel vehicle adoption. For transit bus agencies, the key provision is in Section 13403 titled

[20] https://www.transit.dot.gov/about/news/us-department-transportation-announces-key-priorities-funding-public-transportation

"Qualified Commercial Clean Vehicles." The law provides for a tax credit of up to 30% of the cost basis or $40,000 (whichever is less) per vehicle for qualified vehicles of over 14,000 pounds that are "not powered by a gasoline or diesel internal combustion engine." There is no mention of this tax credit being exclusive of or not "stackable" with Federal Low-No program funds.

U.S. Department of Transportation Programs

DOT has additional established grant programs specifically for transit agencies; again, these are largely administered by FTA. These include the Low or No Emission Vehicle (Low-No) program, which had its most recent solicitation close on April 12, 2021. Historical funding for the program has ranged from $55 million in FY 2016, increasing to around $84 million in FY 2018, and then to nearly $130 million in FY 2020. In April 2021, a total of $182 million in funding was announced for 49 projects. As shown in Table 3 and in Figure 7, authorized funding for this program has now increased dramatically for FY 2022-2026 at about $1.1 billion per year under the Infrastructure Investment and Jobs Act (H.R. 3684). This represents a major shift in program priorities toward funding the lowest emission bus technologies.

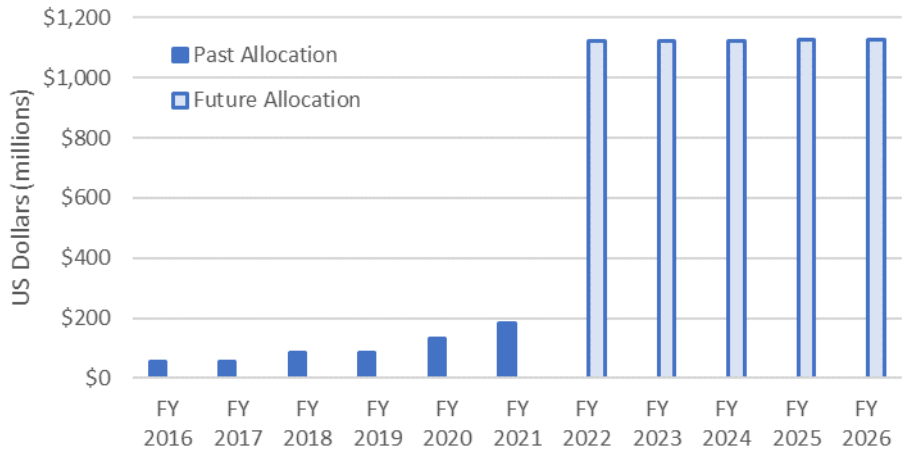


Figure 7: FTA Low-No program, Past and Future Funding Allocations

The Low-No program provides funding for purchase or lease of zero and low-emission transit buses along with supporting infrastructure. Eligible projects include (1) purchasing or leasing low or no-emission buses, (2) acquiring low or no-emission buses with a leased power source, (3) constructing or leasing support facilities and related equipment including intelligent technology and software, and (4) constructing, rehabilitating, or improving new public transportation facilities for low or no-emission buses.

Program website: https://www.transit.dot.gov/lowno

The Low-No program is competitively awarded, where funds can be spent in the award year and for 3 additional years. The recent 2021 awardees in California include the City of Anaheim, the City of Fresno, and the Golden Empire Transit Districts, each receiving approximately $2–$3 million. The City of Anaheim project is to support implementation of BEBs to replace diesel buses, and the Fresno and Golden Empire district awards are to support the implementation of FCEBs in Fresno and a hydrogen station in Bakersfield.

In addition, there is a recently renewed program at FTA called the Capital Investments Grant (CIG) program, that provides funds for light rail, transit bus, and streetcar capital projects. The renewal of the program and FY 2022 recommended awards were announced by DOT in May 2021, including awards to projects in 12 states. For FY 2022, 25 projects were selected for funding, totaling $2.473 billion in DOT funds. Most funding was for light rail and subway expansion projects, but seven bus rapid transit projects were also funded for a total of about $461 million.

Program website: https://www.transit.dot.gov/CIG

There is also a Low and No-Emission Component Assessment Program (LoNo-CAP) at DOT that funds institutions of higher education to work with component manufacturers and transit agencies to test new component technologies. Eligible activities under LoNo-CAP include testing and assessing voluntarily submitted LoNo components for transit buses, publishing the results of these LoNo component assessments, and preparing an annual report to Congress summarizing the assessment results. Although funding of $3 million per year was authorized in FY 2016, the last awards under LoNo-CAP were made in FY 2017 to Auburn University and The Ohio State University. With no recent awards, the future of this program remains unclear.

Program website: https://www.transit.dot.gov/research-innovation/lonocap

In a recent development, the Inflation Reduction Act (H.R. 5376) was signed into law on August 16, 2022. Among its many provisions related to addressing inflation and climate change, one provision for “Qualified Commercial Clean Vehicles” (Section 13403) provides for a new incentive of up to $40,000 for new commercial clean fuel vehicle purchases for vehicles over 14,000 pounds, and up to $7,500 for vehicles under 14,000 pounds. The value of the credit is the lesser of 15% of the total basis of the vehicle, or 30% for vehicles not powered by gasoline or diesel combustion engines (and with a battery capacity of 15 kilowatt hours or greater), or the incremental cost of the vehicle, with the overall cap levels of indicated above. Tax-exempt entities with no tax liability can receive the credit as a direct payment. The credit takes effect on January 1, 2023 and is available through December 31, 2032.

Further details: https://www.congress.gov/bill/117th-congress/house-bill/5376/text

California ZEB Incentive Programs

There are several State of California agency incentive programs that are available to transit agencies for potential procurements of ZEBs and associated infrastructure. These are primarily offered by CARB and CEC, and the California Department of Transportation (Caltrans) also offers the Transit and Intercity Rail Capital Program (TIRCP).

CARB HVIP Program

One of the most important incentive programs for California transit bus agencies is CARB's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). This long-standing program funded the first transit agency fuel cell bus at SunLine Transit in 2009 and has funded many other transit bus and other heavy-duty vehicle clean fuel and electrification programs. For example, 15 of the 33 FCEBs purchased in 2021 by Foothill Transit received HVIP vouchers to help reduce the capital costs of bus purchase.

The latest HVIP release for voucher applications occurred on October 28, 2021. Approximately $62 million in funds were available on a first-come, first-served basis and the program vouchers were immediately fully subscribed upon release. The previous funding opportunity period of the program for 2021 was released on June 8, 2021, with $84 million in support funding, and was also fully subscribed very quickly. These funds will support about 800 individual vehicle vouchers, including 172 ZEBs for transit agencies. HVIP voucher amounts vary from $20,000 to $240,000 per vehicle based on vehicle value.

Program website: https://californiahvip.org/purchasers/

New HVIP policies were approved by CARB on November 19, 2021. Significant changes to the program were made for FY 2022 including a $70 million carve-out for transit buses. Additional provisions now include an increase in voucher bonuses from 10% to 15% for vehicles domiciled in disadvantaged communities, for smaller fleets with 10 or fewer buses. The next open date for HVIP voucher applications is expected to be announced in Spring of 2022.[21]

California Energy Commission (CEC) Programs

The CEC awards grant funds especially for infrastructure projects to support clean-fuel heavy-duty vehicle deployments, complementing funds to help support procurements for the vehicles themselves that typically come from DOT, CARB, and local air districts. The CEC has awarded hundreds of millions of dollars in recent years for battery electric vehicle infrastructure and hydrogen fueling infrastructure in support of light-duty and heavier-duty vehicle applications of zero-emission vehicle deployments.

The CEC has recently released details of its multi-year funding plan for the Clean Transportation Program (CTP) for FY 2021 through FY 2023. The focus of the program is on zero-emission vehicles

[21] https://ww2.arb.ca.gov/our-work/programs/low-carbon-transportation-investments-and-air-quality-improvement-program/low-1

and infrastructure and includes a total of $95.2 million in FY 2021 and FY 2022, and $47.6 million in FY 2023. The program prioritizes reducing diesel emissions, including replacement of up to 1,000 transit buses. The CTP leverages an additional $747 million, $255 million, and $125 million in the next three fiscal years from the state General Fund.[22]

Activities that support transit bus deployments include the Medium and Heavy-Duty Zero-Emission Vehicles and Infrastructure program, funded at $30.1 million in FY 2021 in the CTP and $208 million from the General Fund, as well as the Transit activity funded at $28.5-$30 million per year for the General Fund. There are additional funds for Hydrogen Fueling Infrastructure at $20 million from the CTP and $27 million from the General Fund, as well as a Workforce Training and Development program at $5 million per year.

Program website: https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program

There also are CEC infrastructure blueprint grants, that range from $3-$6 million per year in total funding. These grants are targeted to "identify actions and milestones needed for implementation of medium- and heavy-duty (MD/HD) zero-emission vehicles (ZEVs) and the related electric charging and/or hydrogen refueling infrastructure." The last awards were made in early 2021, with 28 awards for a total of $5.6 million. A relatively small number of these awards were specifically for transit agency ZEB projects, with the majority targeted at truck/freight and school bus projects.

Program website: https://www.energy.ca.gov/solicitations/2020-07/gfo-20-601-blueprints-medium-and-heavy-duty-zero-emission-vehicle

California Department of Transportation (Caltrans) Programs

Additionally, Caltrans operates the Low Carbon Transit Operations Program (LCTOP). This program is one of several programs that are part of the Transit, Affordable Housing, and Sustainable Communities Program established by the California Legislature in 2014 by Senate Bill 862. The LCTOP is designed to reduce GHG emissions and improve mobility with a priority focus on disadvantaged communities. New or expanded bus or rail services, intermodal transit facilities, and other facility and operational support (such as reduced fare bus passes) are provided through the program.

LCTOP is funded by 5% of the annual proceeds of the California Greenhouse Gas Reduction Fund. A total of over $146 million was awarded in 2019-2020 to 166 programs across 12 Caltrans districts. Many of these were relatively small awards for operation support, but examples of the larger awards include $2.9 million to Orange County Transportation Authority to match other grant funds to purchase 10 BEBs and associated charging infrastructure; North County Transit District will receive about $2.2 million to purchase six BEBs and eight FCEBs; Omnitrans will receive $3.2 million to purchase five ZEBs, San Francisco MTA will receive $3.3 million to purchase three long-range BEBs; Santa Clara

[22] https://www.energy.ca.gov/publications/2021/2021-2023-investment-plan-update-clean-transportation-program

VTA will receive $2.4 million to support purchase of 15-20 BEBs; and San Diego MTS will receive $6 million to purchase 14 ZEBs in the future to replace aging CNG buses.

In the largest award, Los Angeles County MTA will receive $39 million for a major BEB charging facility, including new stationary and portable charging equipment. Because this is a formula program, it can be difficult for transit agencies to use these funds to build a hydrogen fueling station due to the allocation amounts, unless they can combine funds from multiple programs.

Program website: https://dot.ca.gov/programs/rail-and-mass-transportation/low-carbon-transit-operations-program-lctop

Caltrans also has a program called the Transit and Intercity Rail Capital Program (TIRCP), which is administered by California State Transportation Agency (CalSTA). This program was developed to "provide grants from the Greenhouse Gas Reduction Fund to fund transformative capital improvements that will modernize California's intercity, commuter, and urban rail systems, and bus and ferry transit systems, to significantly reduce emissions of greenhouse gases, vehicle miles traveled, and congestion."

TIRCP funds capital projects, including feeder buses to intercity rail services, as well as vanpool services that are eligible to report as public transit to the Federal Transit Administration. Also included are ferry and rail transit system projects. There have been three prior cycles of TIRCP funding, in which CalSTA, working with Caltrans, has awarded $5.3 billion in funding to 56 projects around the state. The 2018 funding cycle funded almost 300 ZEBs[23] and the 2020 funding cycle supported 37 ZEBs.[24]

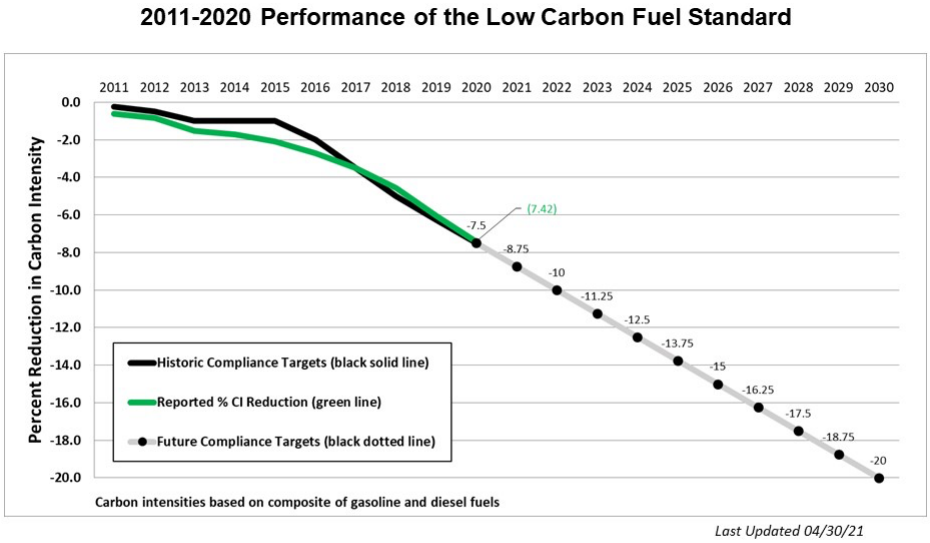
Program website: https://calsta.ca.gov/subject-areas/transit-intercity-rail-capital-prog

California State Support Incentive Programs

In addition to direct support for ZEBs and infrastructure from the incentive programs described above and below, California also has a Low Carbon Fuel Standard (LCFS) program that is a regulation for stimulating investments and implementation of low-carbon fuels for vehicles. This regulation provides strong support for implementation of clean fuels based on recent credit prices, providing a market-based policy designed to reduce the carbon intensity (CI) of transportation fuels in the state.

The California LCFS was first adopted in 2009 as a part of the state's overarching Global Warming Solutions Act (AB 32) with the goal of achieving a 10% reduction in CI from 2010 values by 2020. The LCFS was then amended several times, partly in response to litigation about treatment of fuels being imported from out of state. The last amendment in 2018 included additional methods of receiving credits and with a 20% CI reduction level from the 2010 baseline. This update also promoted further zero-emission vehicle adoption and carbon capture and sequestration techniques.

[23] https://calsta.ca.gov/-/media/calsta-media/documents/2018-tircp-award-list.pdf
[24] https://calsta.ca.gov/-/media/calsta-media/documents/2020-tircp-award-list.pdf



This figure shows the percent reduction in the carbon intensity (CI) of California's transportation fuel pool. The LCFS target is to achieve a 20% reduction by 2030 by setting a declining annual target, or compliance standard. The compliance standard was frozen at 1% reduction from 2013-2015 due to legal challenges, contributing to a build-up of banked credits as regulated parties bringing new alternative fuels to market continued to over-comply with the standard. The program will continue post 2030 at a to be determined stringency.

Figure 8: 2011-2020 performance of the Low Carbon Fuel Standard

Source: CARB, 2021, https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

LCFS credit prices were fairly constant from 2019-2021, trading in the band of about $180-$200 per credit through the first quarter of 2021. However, as shown in Figure 9, LCFS credit prices dropped in late 2021 and have been near or below $100 per credit since mid-summer 2022.

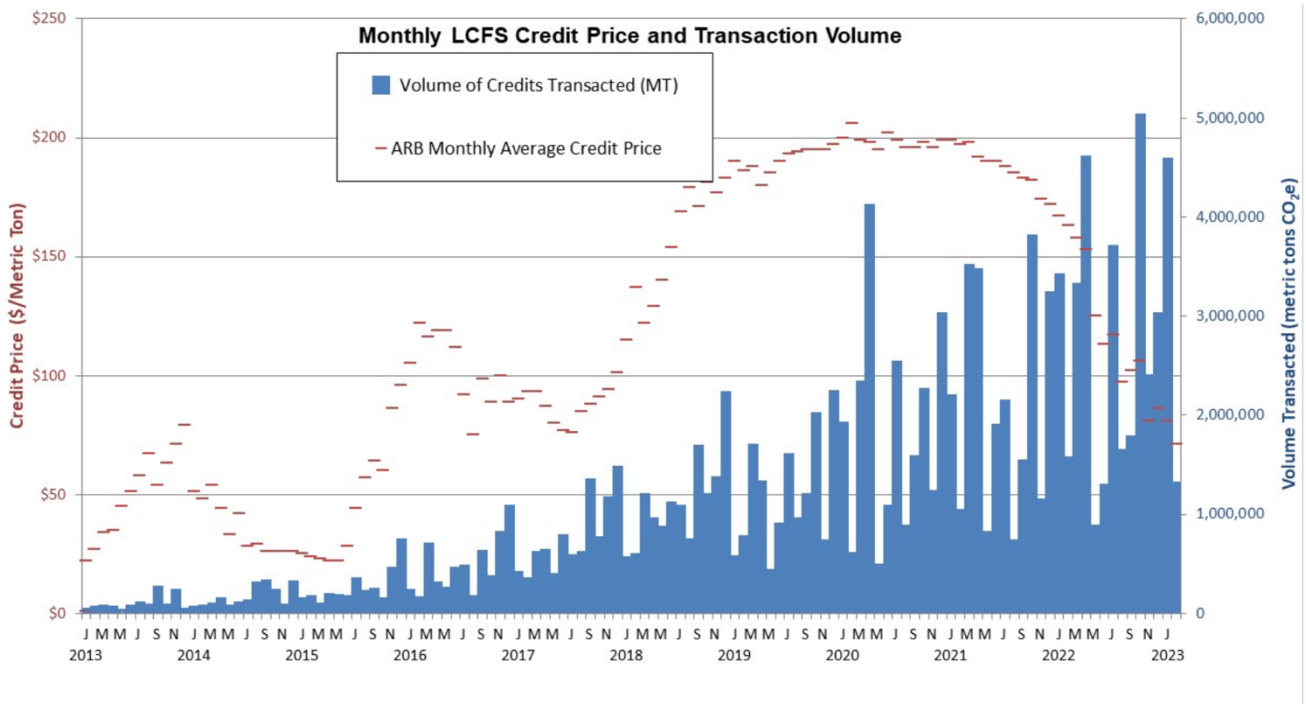


Figure 9: Monthly LCFS Credit Price and Transaction Volume

Source: CARB, 2023, https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

The impact on overall fuel prices can be significant when low CI fuels such as electricity and hydrogen are adopted by transit agencies, and with the historic credit prices. For example, at a credit price of $196 per credit and a replacement fuel with a CI score of 30 (versus about 90 for conventional alternatives), the credit value is estimated at $1.44 per gallon equivalent (CARB, 2021). This equates to about $0.26 per kWh based on a California grid mix for BEB charging, covering most or all of the total electricity cost, and about $1.44 per kilogram of hydrogen produced with an (example) fuel production pathway and CI score of 30.

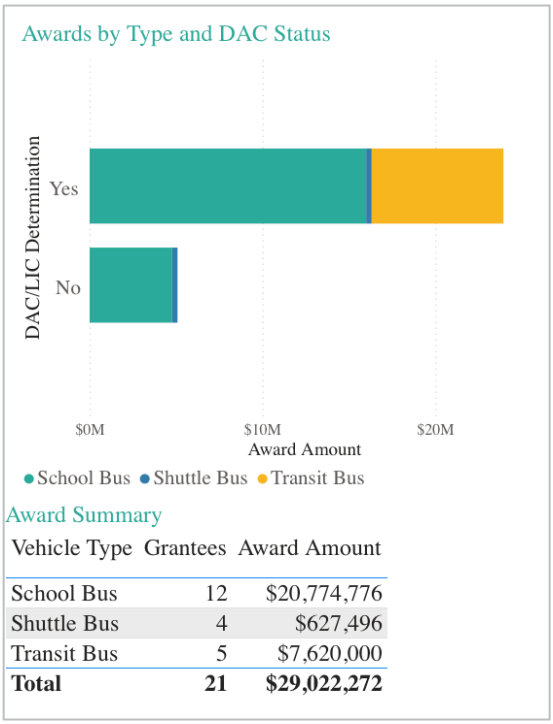
Volkswagen Mitigation Trust

The Volkswagen Mitigation Trust was established from a legal settlement in response to Volkswagen's use of illegal emissions testing defeat devices in certain Volkswagen diesel vehicles. A fund of $2.9 billion in total was established for the mitigation trust, of which $423 million was designated for California specifically.

The California mitigation trust program is divided into three program areas: (1) zero-emission transit, school, and shuttle buses; (2) zero-emission trucks and combustion freight and marine; and (3) zero-

emission freight, marine, and infrastructure. The zero-emission bus program has $130 million to help replace older buses with new battery or fuel cell buses.[25]

Awards through the mitigation trust have totaled about $29 million through mid-2021 as shown in Figure 10. Approximately three-fourths of the funds have gone to school bus programs thus far, with about one-quarter for transit buses ($7.6 million) and a small amount for shuttle buses. The transit bus awards have been directed at communities with disadvantaged or low-income community status, as shown in Figure 10.



Award Summary

Vehicle Type	Grantees	Award Amount
School Bus	12	$20,774,776
Shuttle Bus	4	$627,496
Transit Bus	5	$7,620,000
Total	**21**	**$29,022,272**

Figure 10: Volkswagen Mitigation Trust Expenditures by Type and DAC Status

Source: CARB, 2021, https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

A second installment of funding for the transit, school, and shuttle bus program opened on October 31, 2022. Funding is available on a first-come, first-served basis, with incentives of up to $400,000 per vehicle. A total of $130 million is available in this latest funding installment. The program is administered by the San Joaquin Valley Air Pollution Control District and funds are available for bus purchases across California.

Program information: https://ww2.arb.ca.gov/vwmitigationtrust

https://ww2.valleyair.org/grants/vw-mitigation-trust

[25] http://vwbusmoney.valleyair.org/

California Regional ZEB Incentive Programs

At the regional level, ZEB incentive programs are primarily provided at the AQMD level, although these programs are variable and typically focused more on light-duty vehicles and HDVs for trucks/ports than public transit agency buses. Also at a regional level, the major electric utilities in California are offering incentives for installing BEB charging infrastructure. These programs are listed below.

Air Quality Management District Programs

California includes 35 regional AQMD and APCD areas, including the South Coast (SCAQMD), Bay Area (BAAQMD), Sacramento, and San Joaquin Unified AQMDs. These AQMD programs typically focus on stationary sources of pollution such as oil refineries, large food processing centers, cement manufacturing and other industrial sources, with a particular focus on particulate matter (PM) emissions and precursors to ozone production such as nitrogen oxides (NOx) and volatile organic compounds (VOCs). They historically have provided some funds for vehicle retrofit technologies such as PM filters, especially for trucks, but also have been supportive of clean transit programs through various coordinated efforts with local transit agencies.

Links to the major air district programs addressing clean transportation and additional details are provided below:

Bay Area AQMD – MD and HD ZEV and Infrastructure Program

Details: http://www.baaqmd.gov/hdzev

“Up to $5 million is available for fiscal year ending (FYE) 2016.”

“The FYE 2016 cycle closed on June 22, 2016.”

The program allows subscription to receive information about future developments and solicitations.

Bay Area AQMD – Carl Moyer Program

Details: (https://www.baaqmd.gov/?sc_itemid=7A9A5ACC-1CD1-41E9-B429-7BFDAE17FEF3)

For 2022 application cycle, “more than $40 million is available for projects to upgrade or replace on-road vehicles, school buses, off-road and agricultural equipment, marine equipment, and locomotives.”

Funding provided first come first serve and can go towards vehicle replacement, engine replacement, power system conversion, or battery charging and hydrogen fueling infrastructure

Bay Area AQMD – Community Health Protection Grant Program

Details: https://www.baaqmd.gov/community-health/community-health-protection-program/grant-program

Sacramento Metropolitan AQMD

Details: http://www.airquality.org/Businesses/Incentive-Programs

Note: Provided up to $18M in most recent solicitation that closed in May 2021 for ZEBs and zero-emission trucks

San Joaquin Valley APCD – VW Trust Zero Emission Transit and School Bus

Details: http://vwbusmoney.valleyair.org/

Note: See VW mitigation fund above

South Coast AQMD – Clean Technology Programs

Details: http://www.aqmd.gov/home/programs

Vehicle and Engine Upgrades programs available:
http://www.aqmd.gov/home/programs/business/business-detail?title=vehicle-engine-upgrades

South Coast AQMD – Carl Moyer Program

Details: http://www.aqmd.gov/home/programs/business/business-detail?title=heavy-duty-engines&parent=vehicle-engine-upgrades

Vehicle and Engine Upgrade Programs (Carl Moyer, Clean School Buses, etc.):
http://www.aqmd.gov/home/programs/business/business-detail?title=vehicle-engine-upgrades

Electric Utility Programs

Programs sponsored by major electric utilities in California include “make ready” programs to develop electrical charging infrastructure, as well as vehicle rebate programs, charger installation rebate programs, and interim rate designs for electricity charging costs. Historically, the utility rate structures for medium and large commercial and industrial facilities have included “demand charges” that require payments for peak energy usage per month, as well as “energy charges” for actual kWh of electricity delivered. To help transit agencies adjust to increased use of electricity for bus charging, some utilities have eliminated demand charges on a temporary basis for these EV rate structures. However, there are plans to reintroduce these utility demand charges in the coming years and transit agencies should carefully review and understand these changes for financial planning purposes around fuel shifting from diesel and CNG to electricity and hydrogen.

The major California utility programs are provided by Southern California Edison (SCE), Pacific Gas and Electric Company (PG&E), San Diego Gas and Electric Company (SDG&E) and Sacramento Municipal Utility District (SMUD). These are summarized below.

SCE – Charge Ready Transport Program

Details: https://crt.sce.com/overview

"SCE's Charge Ready Transport (CRT) Program offers low- to no-cost electrical system upgrades to support the installation of electric vehicle (EV) charging equipment for qualifying vehicles"

SCE will help with planning and installation, as well as "install a separate meter dedicated to the EV charging infrastructure and waive customer demand charges through 2024 with our commercial EV rates"

In return, the customer must convert vehicles to electric, and keep chargers active for 10 years, as well as provide charging data for five years

PG&E – EV Fleet Program

Details: https://www.pge.com/en_US/large-business/solar-and-vehicles/clean-vehicles/ev-fleet-program/ev-fleet-program.page

Incentives for medium- and heavy-duty vehicle electrification

Provides incentives and rebates for vehicles and chargers

Also helps with planning, installation, and maintenance of relevant infrastructure

Requires 10-year commitment and sharing of data with PG&E

SDG&E – Power Your Drive for Fleets Program

Details: https://www.sdge.com/business/electric-vehicles/power-your-drive-for-fleets

Similar to other utility programs, assists with installation of electrification infrastructure

No costs to property owner for utility-owned infrastructure

Rebates are available for different tiers of chargers

Also can be combined with local and state programs to help with funding of electric vehicles: https://www.sdge.com/sites/default/files/documents/SDGE.PYDFF%20-%20Vehicle%20Funding%20Summary%20-%20Feb%202021.pdf

Sacramento Municipal Utility District (SMUD) – Commercial EV Fleet Program

Details: https://www.smud.org/en/Going-Green/Electric-Vehicles/Business

Program helps businesses with commercial vehicles including light-duty cars, trucks or semi-tractors and organizations (like school districts) with purchase of electric vehicles, with fixed rate incentives for different vehicle classes.

Transit Agency Experience and Use of Incentive Programs

Many transit agencies interviewed highlighted the critical importance of incentive programs to provide capital cost assistance for new buses and infrastructure as well as additional support programs. Some agencies indicated an interest and need in additional information about the full range of available funding programs, but others said they have enough information and are knowledgeable of the programs relevant for their agency. They stressed a desire for the funding to flow as effectively as possible and with the least amount of administrative difficulty.

Many of the agencies interviewed have taken advantage of the HVIP and Low-No programs and are planning to do so with their next procurements. Other programs were used to less extent among the agencies interviewed; those include the Carl Moyer program, the LCTOP, California Energy Commission projects supporting infrastructure, regional programs provided by South Coast AQMD and Bay Area AQMD, the Volkswagen Electrify America program, and utility “make ready” type programs such as those administered by Southern California Edison.

Despite recent announcements of increased funding levels for commercial electrification programs at the federal, state, and regional levels, transit agencies planning for ZEB transition still cite funding assistance as one of their most significant needs to comply with upcoming ICT ZEB purchase requirements. Additional funds are needed to purchase vehicles, to install charging/fueling infrastructure, as well as to train their workforce for operating and maintaining the ZEBs.

Conclusions

Transit bus agencies in California are facing unprecedented challenges related to revenue shortfalls and operations funding gaps, largely as a result of the global covid pandemic that started in early 2020. At the same time, they are being required to convert their fleets to zero-emission buses over the next twenty years, with no new purchases of combustion-engine buses after 2029. This conversion requires not only procurement of new-technology (battery and fuel cell) buses, but also the installation and operation of associated recharging/refueling infrastructure and training of drivers, mechanics, and maintenance workers.

The resources described in this document are intended to assist in this transition, along with new programs and resources that are likely to become available in upcoming years. These include additional California state, Federal, and regional/local bus purchase incentive and labor training programs, as well as efforts to share information and “lessons learned” among transit agencies to provide program efficiencies. While achieving the goals of the ICT program will be challenging, the operation of a new generation of transit buses in largely dense urban areas, including DAC areas, will provide important air quality and human health benefits as well as critical GHG reductions to meet California, U.S., and global climate change mitigation goals.

Table A-1: Specifications for Example Battery-Electric Bus Models

Manufacturer	BYD	New Flyer	Proterra	Nova Bus	Greenpower
Model	40' Transit	Xcelsior Charge XE40	Catalyst 40' E2 DuoPower	LFSe	EV350
Dimensions					
Length	40.2 ft	40 ft 9.5 in	510 in	40 ft	40.7 ft
Width	101.6 in	102 in	102 in	8.5 ft	8.5 ft
Height	134 in	11 ft 1 in [A]	128 in	10.5 ft	10.7 ft
Wheelbase	246.1 in	283.8 in	296 in	243.3 in	21.3 ft
Curb Weight	31750 lbs	32750 lbs	29849 lbs	30140 lbs	31320 lbs
Gross Weight	43431 lbs	44320 lbs	43650 lbs	41594 lbs	
Seats	37+1	Up to 40 [B]	40	Up to 41	40
Standees		Up to 42 [B]		Up to 35	
Wheelchair Positions	2 ADA compliant	2	2 ADA compliant		
Performance					
Top Speed	62.5 mph		65 mph		>60 mph
Max Gradeability	>= 17%		27.5% [C]		
Range	129 mi (Altoona avg)	87 mi (Altoona avg, 200 kWh)	163-232 mi		>185 mi
	Up to 156 miles	239 mi w/ optional 492 kWh capacity	Up to 329 mi w/ E2 max		
Fuel Economy	1.988 kWh/mi*	1.84 kWh/mi*	1.7-2.4 kWh/mi	1.76 kWh/mi*	
*Altoona Average		20.5 MPGe*	15.7-22.2 MPGe		
Turning Radius	44 ft	43.5 ft	503 in	40 ft 10 in	42 ft
Approach Angle	>=8.6 deg	9 deg	9.3 deg		
Departure Angle	>=8.6 deg	9 deg	9.3 deg		
Breakover Angle		9 deg	7.8 deg		
Powertrain					
Power	150 kW x 2 (max)	160 kW (rated)	338 hp (continuous)		300 kW (max)
Torque	550 Nm x 2 (max)	1033 lb-ft (rated)			1000 Nm (max)
Battery Type	Iron Phosphate	Lithium Ion-Nickel Manganese Cobalt		Volvo Li-Ion	LiFePO4
Battery Capacity	324 kWh	160 & 213 kWh, 267 & 320kWh	440 kWh	76 kWh (max rated)	320 kWh
		Long Range Options: 311, 388, 466 kWh	Also 220, 660 kWh options		
Charging Capacity	80 kW		132 kW Plug-In at 200A		
			330 kW Max overhead rate		

Footnotes

[A] height over charging rails

[B] based on 160kWh energy storage system configuration

[C] At seated load weight (SLW)

Table A-2: Specifications for Example Fuel Cell-Electric Bus Models

Manufacturer	New Flyer	ENC	Van Hool
Model	Xcelsior Charge H2 40'	AXESS 40' FC	A330 Fuel Cell
Dimensions			
Length	41' 2" [A]	484" [A]	13.20 m
Width	102"	102"	2.55 m
Roof Height	11' 1"	140"	3.42 m
Wheelbase	283.75"	275"	5.10 m
Front Overhang		97"	2.72 m
Rear Overhang		120"	3.64 m
Curb Weight	32,250 lbs	33,520 lbs	
GVWR		44,300 lbs	39,350 lbs
Seats	Up to 40	43	34
Standees	Up to 42		
Wheelchair Locations	2	2	
Performance			
Range			
Fuel Economy	3.12 mi/lb	3.14 M/lb	
Turning Radius	43.5'		
Approach/departure/breakover angles	9/9/9 deg	8.7/8.7/9 deg	
Propulsion			
Rated Power	160 kW		
Rated Torque	1033 lb-ft		
Energy Storage System			
Fuel Cell	Ballard Fcvelocity-HD85		Ballard
Hydrogen Storage	37.5 kg	50kg	40kg
Net Power	85 kW		

[A] length over body