SCAG

Innovative Clean Transit Regional Assessment

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Executive Summary

California's Innovative Clean Transit regulation requires all public transit agencies to transition to zero-emission by progressively increasing zero-emission bus (ZEB) purchases, with the goal of achieving a fully ZEB fleet by 2040. This study assesses how transit agencies in the Southern California Association Governments (SCAG) region are preparing for that transition. It reviews best practices, existing fleet and infrastructure conditions, regional readiness, key challenges and opportunities, and implementation actions to support practical ZEB deployment across Southern California.

The study was informed by document review, data analysis, case study research, targeted surveys, and interviews. Input was gathered from transit agencies, bus manufacturers, infrastructure providers, and utilities. As part of the stakeholder engagement process, the study team provided updates and held discussions with and solicited feedback from SCAG's Regional Transit Technical Advisory Committee, Transportation Committee, and Energy and Environment Committee.

Best Practices

ZEBs are moving from pilots to broader deployment, but implementation is still complex. Successful deployment depends on more than purchasing buses. Agencies also need strong planning, the right technology choices, reliable infrastructure, trained staff, and sustainable funding.

Regulation and Planning. ZEB deployment works best when regulations and planning documents reinforce each other. California's Innovative Clean Transit (ICT) regulation sets the transition requirement, but agency plans define how the transition will happen. ZEB rollout plans are more useful when they are connected to planning processes, such as short-range transit plans, capital improvement programs, climate action plans, and funding strategies. These planning documents help agencies align bus purchases and facility upgrades with budget cycles.

ZEB Technology. ZEB technology is ready for broader use, but it is not one-size-fits all. Battery-electric buses (BEBs) are generally a strong fit for shorter routes, predictable schedules, and operations with enough charging time. Fuel cell electric buses (FCEBs) may be better suited for longer blocks, higher-mileage service, or routes with limited charging windows. Best practice is to match technology to real operating data.

Infrastructure. Infrastructure is often the critical path for deployment. Charging and hydrogen fueling systems should be planned early and phased with vehicle procurement, so buses do not arrive before facilities are ready. Depot plug-in charging is the most common approach. Overhead and wireless charging may support specific route or site needs. Hydrogen stations can support longer range service, but they require more complex design. Cross-agency opportunities, such as shared charging or fueling hubs, public-private partnerships, and coordinated utility upgrades can help reduce costs and improve infrastructure use where service patterns and geography align. Permitting should also be addressed early, since local review and environmental approvals can delay projects if they are not coordinated from the start.

Operations, Maintenance, and Workforce. ZEBs change day-to-day operations. Agencies need to manage charging or fueling windows, ongoing electricity or hydrogen cost, battery health, and infrastructure availability. Maintenance also shifts from diesel engine work to high-voltage systems, battery diagnostics, fuel cell systems, and charging or fueling equipment. Workforce training should begin before vehicles and infrastructure arrive.

Cost and Funding. ZEB deployment costs include much more than vehicle purchases. Agencies must also plan for chargers or hydrogen stations and long-term energy costs. Best practice is to build a full lifecycle cost view and layer multiple funding sources. Federal grants, state incentives, utility programs, local funds, and public-private partnerships can all play a role. Phased deployment can help agencies align projects with funding cycles.

Existing Conditions of ZEB in the SCAG Region

The SCAG region has made significant progress toward ZEB transition, but deployment status varies across agencies.

Rollout Plans and Technology Pathways. According to the California Air Resources Board ICT reporting database, the region includes 78 transit agencies, including 10 large agencies and 68 small agencies. Currently, 49 of these agencies in the SCAG region have accessible ZEB rollout plans. Most agencies with identified pathways are planning for BEBs. Some are pursuing FCEBs or a mix of both technologies. Larger agencies are more likely to use mixed-technology strategies because they serve longer routes, operate multiple depots, and need more flexibility across service types.

ZEB Deployment Trends. As of 2024, approximately 566 ZEBs were operating in the SCAG region. This represents more than half of California's reported ZEB deployments. BEBs make up the majority of the regional ZEB fleet, while FCEBs are growing from a smaller base. Most deployed ZEBs are standard buses. Cutaways, over-the-road coaches, and double-decker buses remain limited.

Infrastructure. ZEB infrastructure is expanding across the region. Approximately 817 chargers are in operation or under development across 58 sites and 16 transit agencies. Depot plug-in charging is the most common approach and accounts for most chargers. Hydrogen infrastructure is more limited but growing. Stations are operating, or under development for agencies including Foothill Transit, SunLine, Omnitrans, Riverside Transit Agency, Pasadena Transit, and Victor Valley Transit Authority. A former hydrogen refueling station for Orange County Transportation Authority (OCTA) has been decommissioned, but the agency plans to bring it back online in the future. OCTA has also awarded a contract to Clean Energy for the construction of a second hydrogen fueling station at the Garden Grove Base.

Policy and Funding. ZEB deployment in the region is supported by federal, state, regional, local, and utility programs. Key funding sources include Federal Transit Administration Low-No and Bus and Bus Facilities grants, Clean Truck and Bus Voucher Incentive Project, Low Carbon Fuel Standards, EnergIIZE, Low Carbon Transit Operations Program, Transit and Intercity Rail Capital Program, air district programs, and utility make-ready programs. SCAG's Connect SoCal 2024 Regional Transportation Plan/Sustainable Communities Strategy also supports a full transition to ZEBs by 2040 and includes major investments in transit projects, operations, and maintenance. However, funding remains competitive and uncertain. Agencies must often stack multiple sources to make projects viable.

Workforce. The region has a growing ZEB workforce training ecosystem. Resources include national training programs, original equipment manufacturer (OEM) training, community college programs, and peer learning forums. These resources provide a strong foundation. However, agencies still need more consistent and role-specific training as ZEB deployment scales.

Regional Readiness, Challenges, and Opportunities

The SCAG region shows strong policy alignment and early deployment momentum. However, readiness varies widely. Larger agencies are advancing multi-depot programs and mixed-technology strategies. Smaller and municipal operators are often still in early planning or first deployment stages.

This study's targeted surveys and interviews confirmed these differences. The survey responses and stakeholder interviews conducted with transit agencies, infrastructure and utility providers, and bus OEMs showed that agencies are committed to the transition but need more support to move from planning to implementation.

Infrastructure readiness is the central factor shaping deployment timelines. Agencies most frequently identified utility coordination, grid capacity, as well as permitting and construction timelines as key risks. In many cases, vehicle deployment cannot move faster than supporting infrastructure. Utility and OEM input reinforced this point. Agencies also need to provide clear project information early so utilities can plan upgrades and avoid delays.

Cost and funding uncertainty remain major barriers. Agencies face high vehicle and infrastructure costs and funding programs that may not cover full project needs. Many agencies rely on stacked funding sources. These programs are often competitive and time sensitive.

Technology decisions are becoming more route specific. Agencies are not treating BEBs and FCEBs as interchangeable. Instead, they are matching technologies to operation needs, facility constraints, and infrastructure readiness. The market is still maturing, especially for cutaways.

Workforce readiness is another major need. Agencies identified maintenance technician training, safety and emergency response training, and operator and driver training as priority areas. As deployments scale, agencies will need practical training that prepares staff for daily ZEB operations, not just initial vehicle acceptance.

The study identifies several opportunities to accelerate implementation. These include linking ZEB plans to core planning documents, developing practical toolkits, supporting peer learning, improving funding intelligence, strengthening utility engagement, expanding workforce training, and promoting shared infrastructure where it is operationally practical.

Implementation Action Plan

The implementation action plan provides a roadmap to help agencies move from ZEB planning to delivery. It is organized around five goals that align with Connect SoCal priorities and respond to the key findings from the best practice review, existing conditions analysis, and stakeholder engagement.

Goal 1: Strengthen Regulatory Readiness and Technology Advancement. This goal focuses on accelerating ZEB deployment and helping agencies meet ICT requirements. Actions include supporting technology selection, sharing lessons learned from early adopters, improving peer exchange, and advancing joint procurement.

Goal 2: Improve Infrastructure Planning. This goal focuses on building reliable and resilient ZEB infrastructure. Actions include improving utility engagement, supporting permitting readiness, and identifying shared infrastructure opportunities where they are practical.

Goal 3: Create Sustainable Funding Pathways. This goal focuses on closing ZEB funding gaps. Actions include improving understanding of the funding landscape, helping agencies understand eligibility and stacking opportunities, and exploring alternative financial pathways.

Goal 4: Build Long-Term Staffing Capacity. This goal focuses on developing a skilled workforce. Actions include identifying priority training needs, expanding access to role specific training, and supporting partnerships with training providers.

Goal 5: Promote Integrated Planning. This goal focuses on identifying synergies with zero-emission truck planning where appropriate. Actions include exploring shared charging or hydrogen fueling opportunities while protecting transit service needs first.

Overall, the study shows that the SCAG region is moving from ZEB planning to implementation. The region has strong policy alignment, early deployment momentum, and a growing base of agency experience. The next phase will need to focus on practical delivery. This includes helping agencies move projects forward, address infrastructure and funding gaps, and prepare their teams for ZEB operations.

Report Organization

The report is organized to move from context to action. **Section 1** introduces the study purpose and regulatory background. **Section 2** reviews best practices for ZEB regulation and planning, technology, infrastructure, operations, workforce, and funding. **Section 3** summarizes existing conditions in the SCAG region, including rollout plans, deployment trends, infrastructure, policies, and workforce resources. **Section 4** assesses regional readiness based on research, surveys, and interviews. **Section 5** identifies key challenges and opportunities. Section 6 presents the implementation plan, including goals, actions, and supporting resources.

1 Introduction

Transportation accounts for approximately 37.7 percent of California's greenhouse gas (GHG) emissions, according to the California Air Resources Board (CARB). To address this, the state has adopted ambitious policies, such as the Innovative Clean Transit (ICT) regulation, which requires all transit agencies to transition to zero-emission buses (ZEBs), with the goal of achieving a 100 percent ZEB fleets by 2040, along with broader rules like the Advanced Clean Trucks (ACT) regulations. These measures support California's mid-term GHG reduction targets for 2030 and its long-term goal of achieving carbon neutrality by 2045.

The SCAG region features one of the largest and most complex transit networks in the state, spanning 33,485 miles of bus, express, and bus rapid transit routes. Transitioning the bus fleet in the region will play a critical role in achieving ICT compliance and meeting California's GHG reduction and carbon neutrality targets.

The ICT regulation was adopted in 2018 and became effective in 2019. It applies to all transit agencies that own, operate, or lease buses with a gross vehicle weight rating greater than 14,000 lbs., including standard buses, articulated buses, over-the-road buses, double-decker buses, and cutaway buses. All public transit agencies included in the ICT regulation are mandated to gradually transition to a 100 percent ZEB fleets. The regulation requires each transit agency to prepare a ZEB rollout plan and submit annual reports to CARB to track progress. Large agencies began ZEB purchase requirements in 2023, while small agencies began in 2026, with an increasing percentage of new bus purchases required to be zero-emission each year, as shown in Table 1. To ensure transit service is not adversely impacted, the ICT regulation includes flexible options such as bonus credits for early ZEB adoption, allowances for zero-emission mobility options, and the ability for agencies to form joint ZEB groups to meet compliance collectively. The regulation also includes provisions for a transit agency to request exemptions from ZEB purchase requirements.

Table 1. ZEB Purchase Schedule (ZEB Percentage of Total New Bus Purchases)

Year	Large Transit	Small Transit
2023	25%	-
2024	25%	-
2025	25%	-
2026	50%	25%
2027	50%	25%
2028	50%	25%
2029+	100%	100%

Source: ICT regulation, CARB

The intent of this study is to support the SCAG region's transition to ZEBs. It assesses transit operators' progress in developing and implementing ZEB rollout plans. It also evaluates regional readiness for zero-emission transit fleet deployment. The study reviews best practices, existing fleet and infrastructure conditions, rollout planning gaps, relevant policies and regulations, funding programs, and workforce training needs. It also identifies opportunities for stronger coordination across agencies to support practical implementation across Southern California.

2 Best Practices

ZEBs are moving from pilot projects to broader deployment, but implementation is still complex. Success depends on the right technology, reliable infrastructure, early utility coordination, available funding, and trained staff. This review looks at best practices and case studies from California and other regions. It identifies lessons that can help transit agencies plan and deploy ZEB fleets. It also highlights practical takeaways for the SCAG region as agencies move from rollout planning to implementation.

2.1 Regulation and Planning Integration

2.1.1 Regulations

Achieving a fully ZEB fleet requires a coordinated policy ecosystem (as shown in Figure 1) in which federal regulations, state mandates, and regional and local planning frameworks reinforce one another. At the federal level, the Clean Air Act and related U.S. Environmental Protection Agency (U.S. EPA) and U.S. Department of Transportation rules establish the foundational air quality and vehicle emission requirements that shape long-term transit investments. State policies translate national emission reduction objectives into enforceable mandates while offering incentive programs to accelerate market transformation. Regional and local agencies then implement these policies by integrating ZEB goals into land use plans, climate action strategies, utility coordination efforts, and funding partnerships.

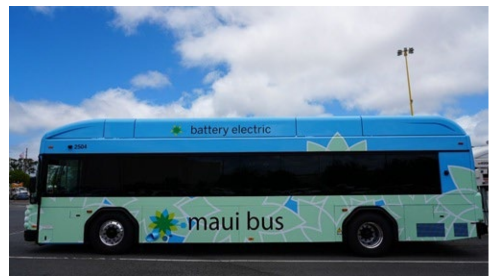
Figure 1. Alignment Across Federal, State, Regional, and Local Policies for a Successful ZEB Transition

At the federal level, the Clean Air Act established the core framework for federal air quality regulations by directing the U.S. EPA to set National Ambient Air Quality Standards for criteria pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, lead, ozone, and particulate matter. These pollutants were designated based on their documented impacts on public health and environmental quality. States must achieve and maintain these standards through emission reduction measures across transportation and other sectors.

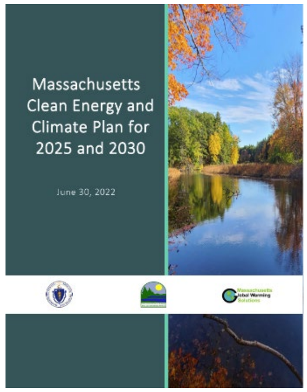
The transportation conformity process plays a critical role in linking infrastructure investments to air quality outcomes by ensuring that federally supported projects align with state air quality implementation plans and do not exacerbate pollution in nonattainment or maintenance areas. The U.S. EPA periodically updates emissions standards and technical guidance to drive continuous improvements in pollution emission reduction and public health. A full list of related federal-level regulations is documented in Appendix C.

At the state level, California was the first state in the nation to establish a comprehensive regulatory framework requiring all public transit buses to transition to zero-emission technology. The ICT regulation, adopted in 2018, remains the cornerstone policy for public transit electrification. Importantly, the ICT regulation sits within a broader suite of statewide clean transportation policies, such as ACT and Advanced Clean Fleets, which are intended to guide California's long-term shift toward zero-emission heavy-duty vehicles. California's policy framework was further strengthened by the 2025 Executive Order B-5-25, which reaffirms statewide carbon neutrality targets and directs state agencies to accelerate zero-emission vehicle (ZEV) deployment across all public fleets. To support implementation, California has also developed one of the nation's most extensive portfolios of ZEB incentives and funding programs, as summarized in the toolkit in Appendix I.

Beyond California, several other states have adopted strong ZEB targets and supporting incentive programs. These efforts typically include funding to reduce upfront vehicle and infrastructure costs, as well as pilot programs to evaluate the performance, reliability, and operational fit of battery-electric buses (BEBs) and fuel cell electric buses (FCEBs). Some examples are included below.



Hawaii requires all agencies purchasing light-, medium-, and heavy-duty vehicles to seek zero-emission and alternative fuel vehicles. Hawaii statute establishes vehicle purchasing priority for state agency vehicles, with ZEVs as the highest priority vehicle type. All counties in Hawaii have a goal of converting transit buses to 100 percent renewable fuels by 2035. Honolulu has already incorporated 17 ZEBs into its transit fleet and has secured funding to purchase up to 78 more ZEBs from 2025-28. **New York**'s Climate Leadership and Community Protection Act, adopted in 2019, requires statewide GHG reductions of 40 percent by 2030 and 85 percent by 2050 (from 1990 levels). The state's scoping plan establishes aggressive medium- and heavy-duty vehicle targets, including 40 percent ZEV sales by 2030 and 100 percent by 2050. To support these mandates, New York has launched multiple funding programs: the state committed over $100 million to the Zero-Emission Transit Transition Program, the New York State Energy Research and Development Authority provides ZEB purchase vouchers through the New York Truck Voucher Incentive Program, and Volkswagen settlement funds are used to replace aging diesel buses with battery-electric models. The Charge Ready NY initiative has also expanded to support transit charging infrastructure. These combined efforts have accelerated adoption; as of July 2024, New York operates 779 full-size ZEBs, second only to California.



Massachusetts' Clean Energy and Climate Plan for 2025 and 2030 establishes a transportation-sector sublimit requiring a 34 percent reduction in greenhouse gas emissions below 1990 levels. To help achieve this target, the state is prioritizing public transit as a low-carbon mobility option and investing in zero-emission technology. The Massachusetts Bay Transportation Authority has committed to a 100 percent ZEB fleet by 2040 and launched its Bus Modernization Program to electrify depots, upgrade facilities, and replace aging buses. The [state's climate plan] also emphasizes coordinated state and local funding and land acquisition support to enable the infrastructure needed for this transition.

Washington, along with California and New York, is a leader in ZEB deployment. The state supports transit electrification through programs such as Washington State Department of Transportation's Green Transportation Capital program, which funds bus electrification, facility upgrades, and charging infrastructure. Washington also makes ZEBs available on state procurement contracts and has redesigned its purchasing program to be fully Federal Transit Administration-compliant.

At regional and local levels, agencies implement ZEB commitments and requirements through climate plans, capital planning, and technical assistance. Metropolitan planning organizations (MPOs), air quality districts, and municipal governments act as regional hubs for data coordination, emissions modeling, community engagement, and grant administration, directly shaping the feasibility and pace of ZEB adoption. These agencies align transit fleet planning with climate objectives, land use strategies, and utility coordination, ensuring that zero-emission investments are fully integrated into broader regional mobility frameworks.

LOCAL BEST PRACTICES

Cape Cod Regional Transit Authority (CCRTA) in committed to a 2030 zero-emission goal as part of Massachusetts' Clean Energy and Climate Plan. CCRTA's 2023 ZEV Transition Best Practices Report translates the state mandates into a phased strategy, deploying hybrids immediately to cut diesel use while planning long-term adoption of BEBs and FCEBs.

Chicago Transit Authority (CTA) is electrifying its 1,900-bus fleet by 2040 in support of the City of Chicago's Climate Action Plan and regional air quality commitments. Backed by nearly $29 million in FTA funding, CTA is developing an overhead fast-charging system that enables efficient layover charging, supplemented by plug-in chargers for depot operations.

New York's Metropolitan Transportation Authority (MTA) is transitioning to a zero-emission fleet to meet state requirements under the CLCPA. MTA's 2025–2029 Capital Plan includes purchasing 500 ZEBs, prioritizing deployment in overburdened communities, and upgrading depots for grid-ready charging infrastructure.

Electric Ride 805, a coalition across Ventura, Santa Barbara, and San Luis Obispo counties, advances regional climate action goals by pooling EV resources, incentives, and outreach. The partnership supports local climate commitments by expanding zero-emission transit visibility and aligning agencies around shared funding and deployment strategies.

King County Metro is pursuing a fully electric fleet by 2035, aligned with Washington State's Clean Energy Transformation Act and Seattle's climate policies. Seattle City Light supports this commitment through its Transportation Electrification Strategic Investment Plan, providing engineering support for ZEB-ready bases, community engagement, and workforce development.

Beyond state and federal funding, local incentives and utility programs nationwide play a critical role in accelerating ZEB deployment. In the SCAG region, utilities such as Los Angeles Department of Water and Power (LADWP) and Southern California Edison provide make-ready upgrades, charger rebates, and on-site technical assistance. Regional agencies like the Los Angeles County Metropolitan Transportation Authority (LA Metro), Riverside County Transportation Commission , and San Bernardino County Transportation Authority complement these efforts through planning support and local match funding that help advance ZEB capital projects. Similar local frameworks exist across the country:

- Seattle City Light offers fleet electrification assessments and capital cost-sharing for the King County Metro Transit Department (King County Metro).
- New York Power Authority delivers turnkey design-build electrification support for transit agencies statewide.
- Austin Energy provides demand-charge mitigation and depot design assistance to CapMetro.

2.1.2 Planning

Transit agencies typically document their ZEB deployment strategies through several major categories of formal planning documents, including zero-emission fleet transition plans (ZEFTPs), short-range transit plans (SRTPs), capital improvement programs (CIPs), climate action plans, sustainability plans, and fleet electrification master plans. Although the specific titles vary by agency, these plans consistently define short- and long-term ZEB goals, outline transition pathways, and provide the institutional framework for implementing zero-emission technologies. The planning documents sequence fleet procurement with infrastructure readiness, align capital budgets with regulatory mandates, and embed electrification within broader climate, air quality, and land use objectives. They also formalize coordination with utilities, MPOs, original equipment manufacturers (OEMs), state agencies, and local governments to ensure ZEB deployment is feasible, financially supported, and compliant with federal programs and state policies. Stakeholders and partners associated with each plan type vary by purpose. A summary of key stakeholder roles is provided in Table 2. Additional details on each key planning document are summarized in Appendix D.

Table 2. Major Internal and External Stakeholders of ZEB Deployment Planning

Planning Type	Transit Internal Stakeholders	External Stakeholders / Partners
CARB’s ICT ZEB Rollout Plan	Planning; Fleet and operations	California Air Resources Board; Utilities; Local governments
ZEFTPs	Executive leadership; Planning; Facilities and engineering	Federal Transit Administration; Utilities; State transportation agencies
SRTPs	Planning; Operations; Finance	MPOs; State transportation departments; Local governments
CIPs	Finance and capital planning; Facilities and engineering; Executive leadership	Utilities; Local governments
Climate Action Plans/Sustainability Plans	Planning and sustainability staff; Executive leadership; Fleet and operations	Local governments; Local climate offices

Planning Type	Transit Internal Stakeholders	External Stakeholders / Partners
Fleet Electrification Master Plans	Planning; Facilities and engineering; Fleet and maintenance	Utilities; Technology vendors; Consultants and engineering partners

Source: ICF Research

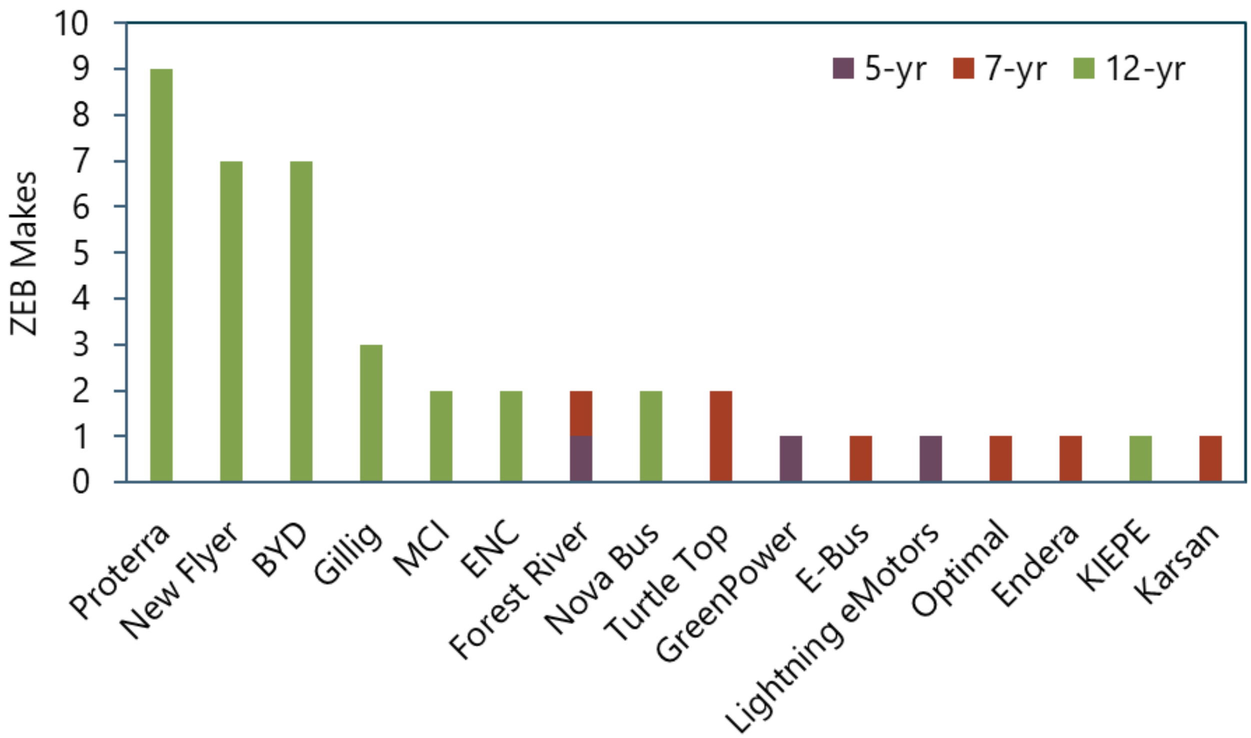
2.2 ZEB Technology

2.2.1 Technology Readiness, Testings, and Trials

Transit buses have led zero-emission technology adoption and are now among the most technologically ready platforms. The California Air Resources Board's (CARB) "beachhead" strategy centered on BEBs as the first-success application, proving core electric-drive components and architectures at scale. In CARB's context, "beachhead" refers to focusing early incentives, regulations, and infrastructure investments on one sector, typically where technology is most ready and public visibility is high, to create momentum and spillover benefits for related sectors. FCEBs build on the same powertrain backbone, drawing on the transit market's earlier hybrid experience. Per CARB's 2022 comprehensive review, ZEBs have progressed from pilot projects to early commercial deployment and are ready for market assessment. The review also documented continued growth in vehicle and infrastructure options while identifying remaining needs to improve bus reliability, range and cost.

Altoona testing is a mandatory federal evaluation process for transit vehicles purchased using FTA funds. Conducted at a specialized facility in Altoona, Pennsylvania, it verifies that new bus models are safe, durable, and reliable for mass public transportation. Altoona testing is a key indicator of ZEB market readiness because it provides independent testing of bus durability, safety, performance, and maintainability before broad deployment. Since 2012, ZEB Altoona testing has increased, with 16 manufacturers completing testing and 43 public reports available as of October 2025. Most Altoona reports are for BEBs, while only three are for FCEBs. Most tested models are 12-year heavy-duty standard or articulated buses, with fewer five-year and seven-year medium- and light-duty models tested since 2020, as shown in Figure 2.

Figure 2. Altoona Tested ZEBs by Minimum Service Life (43 in total)



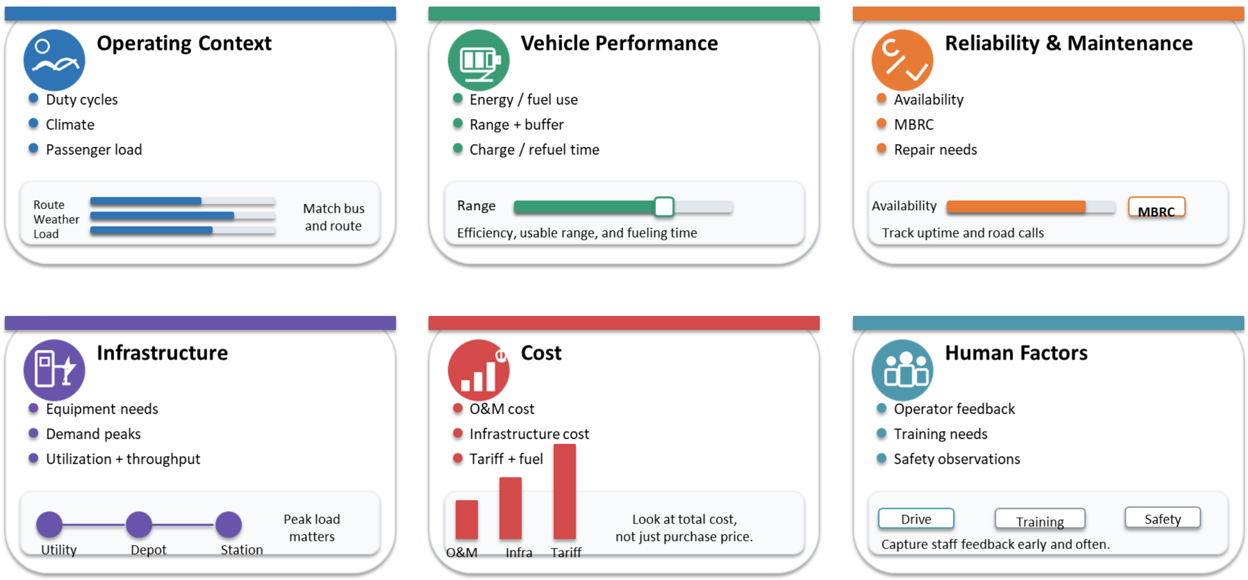
Source: Bus Research and Testing Center (BRTC)

A wide range of ZEBs are now commercially available. As of October 2025, 42 heavy- and medium-duty ZEB models are listed as eligible under California's Clean Truck and Bus Voucher Incentive Project (HVIP). Manufacturers with California-based production facilities include BYD Motors in Lancaster, Gillig in Livermore, and GreenPower Motor Company in Porterville, along with several others producing vehicles across the United States. Notably, there are significantly more BEB than FCEB models, reflecting both stronger early market demand for BEBs and the comparatively nascent stage of FCEB technology and infrastructure. In addition to OEMs building new ZEBs, companies such as Complete Coach Works (CCW) provide repowering and remanufacturing services that convert conventionally fueled transit buses to zero-emission powertrains. For example, TriMet in Oregon worked with CCW to convert a 60-foot articulated New Flyer bus to a BEB.

National Laboratory of the Rockies (NLR), formerly known as National Renewable Energy Laboratory, sponsored by the Federal Transit Administration (FTA), the U.S. Department of Energy, CARB, and other partners, uses a consistent evaluation method to compare BEBs and FCEBs against traditional benchmarks. It then extracts best practices, common pitfalls, and remaining technology barriers that agencies can directly apply to rollout planning, procurement, and facility upgrades. Since 2003, NLR has produced numerous ZEB evaluation and progress reports for at least 16 demonstration sites. Transit agencies, OEMs, and policymakers use these findings to reduce risks in procurement and prioritize research and funding. Because ZEB readiness depends heavily on specific local conditions, the multi-site portfolio reflects various routes, speeds, climates, and operating practices.

NLR structures each evaluation as an apples-to-apples, in-service comparison between ZEBs and conventional baseline (e.g., diesel/compressed natural gas (CNG)/hybrid) operating in the same duty cycle over 12 to 24 months, capturing seasonal effects. NLR's studies test parameters are summarized in Figure 3.

Figure 3. Parameters Captured in NLR ZEB Trials and Evaluations



Source: NLR ZEB Evaluations

A few examples of how transit agencies have conducted trials and evaluations have been summarized in Appendix E. Trial and evaluation analysis show that ZEBs can work in transit service, but performance depends on the operating conditions.

- BEBs are generally a good fit for shorter routes, predictable schedules, and operations with enough charging time.
- FCEBs may be better suited for longer routes, higher daily mileage, and services with limited time for charging.

The NLR evaluation results also show that infrastructure is just as important as bus technology. Reliable charging or fueling systems, staff training, and backup plans are all needed for successful deployment. Overall, ZEB technology is ready for broader use, but it is not a one-size-fits-all solution. Transit agencies will need to match the right technology to the right route and scale deployment in phases.

2.2.2 Technology Selection Criteria Framework

To develop a robust technology selection framework, the criteria should extend beyond vehicle specifications to include transit service characteristics, facility constraints, fleet management and technician capabilities, and data readiness. Agencies may evaluate these factors together through multiple deployment scenarios, such as BEB-only, FCEB-only, and mixed-fleet pathways, to determine which technology portfolio can reliably meet service needs over time. The California Statewide Transit Agency Deployment Toolkit laid out six stages for ZEB deployment, including agency alignment, education, transition planning, procurement and construction, service preparation, and performance optimization.

The summary below highlights how peer agencies have matched technologies to routes using real operating data and controlled costs.

Start with real operating data. Agencies start by mapping the service they run, such as block lengths, grades, layover windows, traffic choke points, and weather, and then stress test those blocks against expected energy use. For example, before going all electric, the Antelope Valley Transit Authority (AVTA) did this before going all electric: they overlaid hills and wind conditions on schedules, flagged blocks with short dwell, and timed a subset of trips to make sure that BEBs can reach chargers with adequate state-of-charge, avoiding overreliance on manufacturer-stated range and putting chargers where they delivered the most service per kilowatt-hour.

Match technology to duty cycle. The technologies cannot follow a "one-size-fits-all" approach. The Alameda-Contra Costa Transit District (AC Transit) assigns FCEBs to longer, hillier transbay and trunk routes because their longer range and quick refueling help maintain pull-out schedules, while BEBs cover shorter urban blocks with reliable layovers for top ups. That portfolio approach keeps performance predictable and minimizes schedule changes and adjustments. Both AC Transit and the Orange County Transportation Authority (OCTA) are intentionally deploying BEBs and FCEBs because it is too early to know which technology will dominate in 10-20 years. Building capability in both creates room to fully assess which option best meets operational range requirements while remaining financially efficient and sustainable. This strategy enables staff to evaluate, with real operational ZEB performance data and vehicle and infrastructure operation and maintenance costs, and adjust deployments accordingly. In addition to vehicle specifications, this assessment should also consider access to adequate fueling infrastructure as well as long-term hydrogen supply.

Choose proven, scalable platforms. ZEB deployment risks can be mitigated by testing multiple OEMs, standardizing specifications, and locking in parts and service support. For example, the Metropolitan Transportation Authority in New York ran a multi-depot BEB pilot with several manufacturers, compared maintenance tickets and telematics across depots, then issued common specifications for power interfaces, diagnostics, and spares.

Evaluate total cost of ownership. Transit agencies should use local utility tariffs and fuel prices, not national averages, when modeling total cost of ownership (TCO). FTA guidance highlights that demand management and managed charging can materially reduce electricity costs and should be built into charging plans and rate selection. For hydrogen, TCO depends on whether supply is delivered or produced on-site, required pre-cooling and fast-fill capability, and station throughput sized to daily pull-outs. The published evaluations show hydrogen cost per kilogram is highly volume sensitive. This means that the cost per kilogram of hydrogen changes significantly depending on how much hydrogen a station dispenses each day. In other words, the more volume that is moved, the lower the unit cost becomes, and the less that is moved, the higher the cost per kilogram.

Plan for performance monitoring and adjustment. The "California Statewide Transit Agency Deployment Toolkit" recommends defining the data and key performance indicators needed to validate planning assumptions after deployment. Long-term monitoring serves as an opportunity to identify performance concerns early on, including changes to fuel economy.

Using these best-practice insights, the ZEB selection criteria framework documented in Appendix I shows how transit agencies should move beyond vehicle specifications to align technology choice and specifies the data to collect for evidence-based decisions.

2.3 Infrastructure

2.3.1 Infrastructure Technology

2.3.1.1 Charging Technology

Currently, four primary types of chargers are used for BEBs. Their specifications are outlined in the following section and summarized in Table 3.

Table 3. Charging Specifications by Type

Parameters	Depot Plug-In	Depot Overhead	On-Route Overhead	On-Route Wireless
Power Range	50-350 kW (typical 150kW)	150-450 kW	300-600 kW (typical 450 kW)	150-300 kW
Charging Time	3-6 hrs for 300-450 kWh or 100-250 miles	1.5-3 hrs for 400-500 kWh or 150 to 300 miles	5-10 min per layover adds 20-40 mi range	5-10 min per layover adds 5-10 mi range
Infrastructure Footprint	Medium	Small	Small	Very small
	One pedestal per bus, parking stall access; ~25-35 ft cable length, pending on charger placement and design	Overhead gantries or cross-rails shared among multiple bus bays; minimal ground space	Compact fixed mast or shelter at terminals	Underground coil & flush pad
Charging Connector Standards	SAE J3068 CCS Combo 1/2	SAE J3105	SAE J3105	SAE J2954/2 TIR
Bus Compatibility & Requirements	All BEBs include at least one combine charging system (CCS)/J3068 charge port	Must be equipped with roof charging rails or bus mounted arm; factory installed interface	Must have roof rails or pantograph hardware; require thermal management and high-voltage pack rated for continuous >400 kW.	Must have underfloor receiver coil, wireless power controller, and EMI shielding; usually factory integrated, retrofit costly.
Key Characteristics	Standard across transit fleets; Manual plug-in connection; Lowest capital expenditure	Automated connection; Sequential charging for high throughput depots Medium CAPEX	Allows mid route charging; Smaller batteries, higher uptime; High CAPEX	Fully automated charging; Minimal maintenance and wear

Source: ICF Research

Another consideration for charging equipment is the battery architecture used on the vehicle. While battery capacity in kWh determines how much energy the bus can store, voltage architecture affects how quickly the energy can be replenished. Most large (35-foot or longer vehicles) incorporate 800V battery architecture which has several advantages: vehicles charge at nearly double the rate of the older 400V architecture (commonly found on passenger vehicles); vehicle wiring and connectors can be a smaller gauge, leading to vehicle and repair cost savings. However, 800V systems also have more expensive components (inverters, battery management systems), and also need higher kW charging connections to take advantage of their architecture.

Manufacturers are also beginning to roll out 1,000V battery architecture on some new buses, which will be able to charge even faster than 800V vehicles, making them viable for short opportunity charges on layover stops. Operators should consider these higher voltage systems for new deployments, as well as the necessary charging equipment to capture the full benefit of newer technology.

Depot Plug-In (conductive): Deport plug-in is the most common approach, i.e., using a manual cord and plug connection at the yard when buses are out of service. It is best suited for overnight or other long dwell periods. Most systems in operation today deliver roughly 60-200 kW, while modern direct current fast charger (DCFC) units can range up to 350 kW. Recharge times are typically measured in hours, depending on bus energy needs and charger power. Infrastructure footprint is modest, with pedestal or wall-mounted dispensers plus conduit, switchgear, and often a new or upsized transformer. Spacing must allow safe cable reach, Americans with Disabilities Act and egress clearances, and protection (bollards, wheel stops). As fleets scale, agencies often deploy charge management software to schedule charging, limit peak power, and prioritize vehicles.

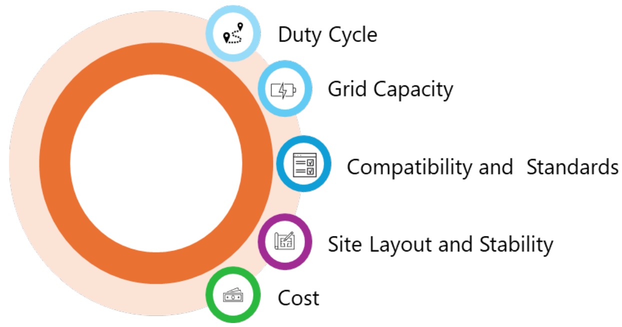
Depot Overhead (conductive): Automated pantographs compliant with SAE J3105 deliver high power DCFCs (typically 150-450 kW) within the depot. They eliminate manual plugging, enable tighter parking and quicker turnarounds, and can serve multiple lanes as “fast lanes.” Typical infrastructure includes overhead masts or gantries with defined clearance envelopes plus charging management integration to sequence buses and cap peak demand, while reducing connector wear through automated, interlocked connections. Agencies such as LA Metro (Division 9) and King County Metro use a hybrid yard design, by adding a limited number of high-power fast lanes while keeping most stalls on lower cost plug-ins to balance cost and operational flexibility.

On-Route Overhead (conductive): The same J3105 interfaces as depot overhead charging can be placed at layovers or transit centers to top off energy in minutes during scheduled breaks. Typical power is 300-600 kW or higher, allowing most sessions on suitable blocks to complete in under 15 minutes, extending range without adding buses. Deployments pair curbside charging equipment with nearby power cabinets and charging management rules keyed to dwell windows and demand limits, with attention to alignment markings, weather protection, clearances, and mixed-fleet interoperability. Foothill Transit’s Pomona deployment and LA Metro’s G Line are widely documented examples, with Minnesota’s Metro Transit’s C/D lines showing recent Upper Midwest practice.

On-Route Wireless (inductive): Buried pads transfer power to a receiver on the bus when it aligns over the pad, with typical systems delivering 150-300 kW. Charging efficiency is generally 80-90 percent when well aligned. It could be a few percentages lower than comparable conductive DCFC, while misalignment, greater air gaps, or extreme weather can further reduce efficiency and increase heat. The approach is fully automated and curb clean but requires bus side receivers, thermal management, precise alignment aids, and more complex subsurface civil work than above ground chargers. Deployments of wireless chargers include AVTA and Link Transit.

As illustrated in Figure 4, selecting the appropriate charging strategy should begin with a clear assessment of duty cycles. If most blocks can reliably recharge overnight, depot plug-in charging should serve as the foundation. For blocks that frequently end the day deeply discharged and have only 10-15 minutes of layover time window, supplementing with on-route charging can provide essential top offs between trips. The next step is to align the charging strategy with available grid capacity.

Figure 4. Charging Selection Criteria



Source: ICF Research

Where sufficient capacity exists at the depot, depot charging offers predictable costs; alternatively, if layover locations can accommodate high power cabinets, on-route charging becomes a viable solution.

Before finalizing the approach, confirm technology compatibility and standards. Fleets equipped with CCS and an Open Charge Point Protocol (OCPP) backend scale efficiently with depot plug-ins. Those supporting SAE J3105 can confidently integrate both depot and on-route overhead systems. Fleets capable of carrying certified wireless receivers might find on-route wireless charging a practical option. Site layout and future growth plans should inform the physical configuration: congested yards benefit from depot overhead to avoid cable drag and enable nose-to-tail parking, spacious yards are well-suited for plug-in systems, while predictable layovers with clean access favor on-route overhead and curbs that are visually sensitive or space-constrained may be best served by wireless solutions.

Finally, weigh lifetime costs against operational reliability. If minimizing capital expenditures and demand charges is the priority, depot plug-in charging is optimal. If scheduling certainty and rapid turnaround times justify higher unit costs, consider on-route systems.

Nevertheless, transit agencies are also increasingly adopting a suite of innovative technologies that enhance the performance, resilience, and cost-effectiveness of ZEB infrastructure, including advanced charging management systems, vehicle-to-grid integration, and solar-plus-battery energy storage solutions. Details on these innovative technologies and solutions can be found in Appendix G.

2.3.1.2 Hydrogen Technology

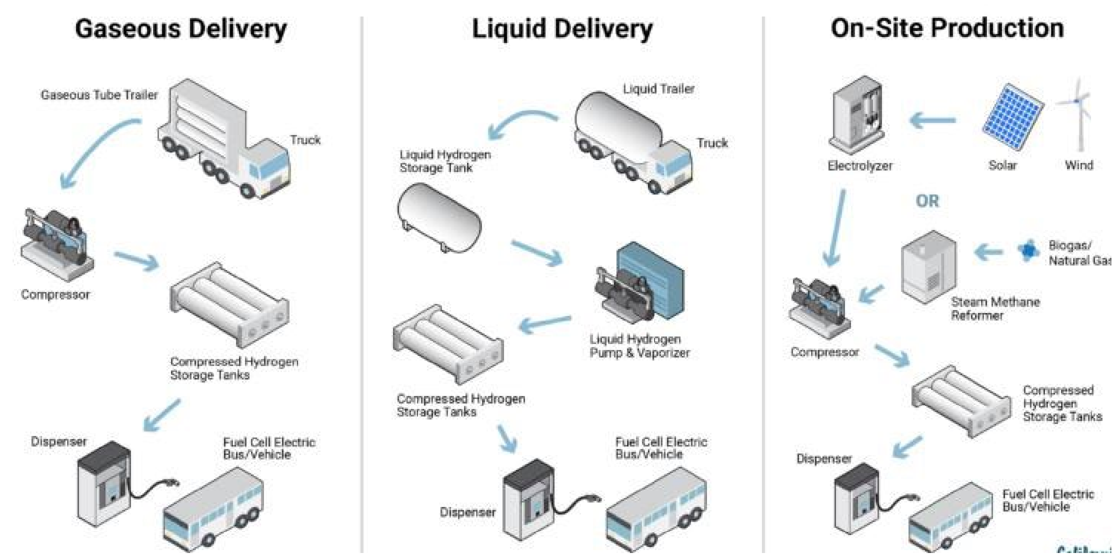
While hydrogen fueling stations share a common set of core components, their specific design varies based on how hydrogen is produced, delivered, stored, cooled, and dispensed. A typical transit scale FCEB fueling station includes the following key elements:

- **Hydrogen Storage Tanks**: High-pressure vessels used to safely store compressed hydrogen gas on-site prior to dispensing. Transit applications typically use gaseous storage at 350 bar (5,000 psi) for heavy-duty vehicles.
- **Hydrogen Compressor**: Compressors raise the pressure of hydrogen to the levels required for storage and fast fueling. For transit buses, compressors are usually sized to support 350 bar fast fill protocols, enabling efficient transfer of hydrogen to on-site storage and ultimately into the bus at the correct pressure.

- **Hydrogen Cooling Unit**: Hydrogen must be cooled during fast fueling to maintain temperatures within SAE J2601 fueling protocol limits. Stations serving heavy-duty fleets may use larger or more advanced cooling equipment, depending on storage configuration, fueling rate, and vehicle system requirements.
- **Hydrogen Fuel Dispenser**: Similar in function to a gasoline or diesel pump, the dispenser is the user interface for fueling FCEBs. Dispensers may be placed on a dedicated hydrogen fueling island or co-located with other fleet fuel infrastructure, depending on site design and safety requirements.

Hydrogen fueling stations can be categorized based on how hydrogen is supplied and how it is stored on-site, as shown in Figure 5. Supply chain type refers to where the hydrogen comes from and how it is delivered to the station. Storage type refers to the state of hydrogen on-site, either gaseous or liquid, before it is conditioned and dispensed to vehicles.

Figure 5. Hydrogen Station Types

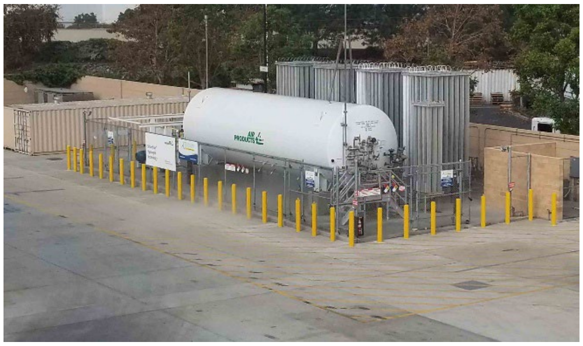


Source: California Fuell Cell Partnership

Common configurations for transit hydrogen stations include:

Gaseous delivery (tube trailers): Hydrogen is delivered by truck in high pressure gaseous tube trailers (typically 250-500 bar). Gaseous hydrogen is transferred under pressure to on-site storage, compressed to the required dispensing pressure, pre-cooled as needed, and then dispensed to vehicles.

- **Use case**: This configuration suits small to mid-sized fleets, early-phase pilots, and agencies seeking rapid deployment with lower capital costs and simpler permitting. It is often used when hydrogen demand is modest, and flexibility is needed during initial rollout.
- **Station scale:** The "California Statewide Transit Agency Deployment Toolkit" identifies simple gaseous systems as appropriate for one to five buses and more integrated skid-mounted gaseous systems as appropriate for up to 15 buses.
- **Industry practice**: Gaseous delivery is a common entry point for transit agencies due to its relatively low upfront cost and simple installation. It supports about 400-600 kg per day depending on equipment sizing and frequently serves as a bridge solution until fleet demand grows enough to justify liquid delivery or on-site production.
- **Transit agency examples**: Agencies such as Foothill Transit and SunLine Transit relied on gaseous delivery during their early FCEB demonstrations, and several smaller municipal operators continue to use this configuration for initial fleet pilots and lower volume fueling needs.



Liquid delivery (cryogenic): Liquid hydrogen is delivered by tanker and stored in a cryogenic, vacuum-insulated tank. A cryogenic pump and vaporizer convert the liquid hydrogen to gaseous hydrogen and pressurize it for dispensing. Because some hydrogen can boil off as the tank warms, station design and operations must account for potential losses.

- **Use case**: Liquid delivery is ideal for mid- to large-sized FCEB fleets requiring high fueling throughput and reliable daily operations. It is particularly beneficial for agencies aiming to minimize delivery frequency.
- **Station scale:** The "California Statewide Transit Agency Deployment Toolkit" recommends that agencies with 15 to 20 FCEBs begin evaluating liquid hydrogen. It also identifies large-scale liquid stations as a potential fit for approximately 50 to 150 buses and notes that these systems commonly include tanks of 15,000 gallons or more, and multiple dispensers.
- **Industry practice**: This approach is increasingly favored for large transit fleets because it offers higher volumetric density, reduced delivery logistics, and the ability to support 1000-2000 or more kg per day. As the market matures, many agencies transitioning beyond pilot scale adopt liquid hydrogen as their primary supply method.
- **Transit agency examples**: Stark Area Regional Transit Authority (SARTA) in Canton, Ohio, and CTtransit in Hartford, Connecticut, operate liquid supplied hydrogen stations to meet the daily fueling demands of their growing FCEB fleets.

On-site production (electrolyzer): Electrolyzers generate hydrogen from water using grid or renewable electricity, followed by purification, compression, storage, and dispensing.

PPP Key Considerations

- **Funding and policy support**: Grants, incentives, and clear policies help attract private investment.
- **Clear roles**: Define ownership, operations, maintenance, and accountability.
- **Flexible procurement**: Long-term PPP may need alternatives to low-bid contracting.
- **Revenue sharing**: Shared assets need clear cost and revenue terms.

- **Use case***:* On-site generation is well-suited for agencies prioritizing renewable or green hydrogen, greater fuel cost stability, or reduced reliance on external deliveries. It works for both small pilot fleets and larger operations depending on electrolyzer size and available electrical infrastructure. The "California Statewide Transit Agency Deployment Toolkit" notes that on-site electrolysis generally requires greater capital investment and substantial electricity demand compared with delivered hydrogen options, but it may offer lower emissions and improved fuel price stability when supplied with low carbon electricity.
- ***Industry practice****:* Electrolysis is increasingly incorporated into long term hydrogen strategies, often paired with delivered hydrogen for redundancy. Modern systems can support hundreds to thousands of kilograms per day and offer advantages under Low Carbon Fuel Standard (LCFS) programs.
- ***Transit agency examples***: SunLine Transit operates one of the largest on-site hydrogen production facilities in the country, producing hydrogen as a backup fuel supply for FCEB operations. AC Transit in the San Francisco Bay Area previously incorporated an on-site electrolyzer into its hydrogen supply as a backup to delivered liquid hydrogen, while other agencies, such as SARTA, are evaluating electrolysis as their fleets expand.

2.3.2 Cross-Agency Opportunities

Cross-agency collaboration, public-private partnerships, and facility sharing reduce costs, accelerate deployment, and improve infrastructure efficiency. Proactive utility engagement is equally critical to streamline permitting, interconnection, and capacity planning.

Public-private partnerships (PPP). PPP is a common strategy used by many developers to build charging infrastructure. This involves a partnership between a government entity and a private sector company. The government entity provides funding, land, and other resources, while the private partner is responsible for financing and operating the charging infrastructure. In the context of ZEB infrastructure, PPP models allow transit agencies to leverage private capital to accelerate deployment of charging and refueling facilities. Examples of PPP for ZEB infrastructure development in and outside of California are listed in the following graphic.

Fresno Area Express (FAX) is transitioning its fleet of 120 buses to ZEBs by 2040, with a mix of BEBs and FCEBs. As part of California's hydrogen hub initiative, FAX partnered with First Public Hydrogen (FPH2), a joint powers authority that connects hydrogen producers with public agencies.Through this partnership, FAX gained access to centralized procurement tools, technical expertise, and affordable fueling infrastructure. In addition, FPH2 facilitated the development of hydrogen fueling stations and helped Fresno secure a $24 million federal grant to purchase 22 FCEBs and associated infrastructure.

Montgomery County in Maryland partnered with AlphaStruxure, a joint venture of Carlyle and Schneider Electric, to develop the David F. Bone Equipment Maintenance and Transit Operations Center. Notably, this depot center is delivered through an Energy-as-a-Service model, including a 7.5-MW microgrid, solar arrays, battery storage, electric bus chargers, and a hydrogen electrolyzer. Eventually, this depot will support up to 200 ZEBs, primarily FCEBs, and operate in island mode during grid outages.

Inter-agency collaboration. Shared facilities can lower capital and operating costs, optimize limited urban space, and improve service reliability. Early coordination also strengthens joint applications for state and federal funding. The examples below illustrate how multi-agency partnerships are advancing zero-emission infrastructure development.

Inter-Agency Key Considerations

- Establish formal agreements, such as memoranda of understanding and joint-use agreements.
- Define roles, cost-sharing, access rights, and maintenance responsibilities.
- Set performance metrics to support accountability.

King County Metro is transitioning to a 100 percent zero-emissions fleet by 2035. A key part of this effort is its partnership with Sound Transit and Seattle City Light to co-develop charging infrastructure at shared facilities, including park-and-ride locations and the South Base Test Facility.

The new base will support 120 BEBs scheduled to begin service in 2026. Opportunity charging is jointly used by Metro and Sound Transit, while Seattle City Light provides carbon-neutral electricity and collaboration on grid upgrades.

The University of California, Los Angeles (UCLA) is developing a wireless inductive charging project that is intentionally designed to serve not only its own campus transit fleet but also multiple regional transit agencies operating in the Westwood area. Future phases of the program aim to create shared-use charging opportunities for as many as seven transit providers (AVTA, Big Blue Bus, Culver City Bus, the Los Angeles Department of Transportation, LA Metro, Long Beach Transit, and Santa Clarita Transit) that serve UCLA's campus and surrounding neighborhoods.

This approach positions UCLA's project as one of the first in the nation to explore multi-agency, shared wireless charging infrastructure, supporting broader regional electrification and improving operational flexibility for partner agencies.

Shared-use infrastructure. Charging and refueling infrastructure can serve multiple transportation sectors, including municipal fleets, commercial operators, and the public, rather than being limited to a single transit agency. Multi-fleet depots allow agencies and operators to access infrastructure without owning it. Several transit agencies have already extended their ZEB infrastructure for use by other fleets.

Shared Use Key Considerations

- Prioritize transit fleet charging and fueling needs.
- Allow external users only during off-peak or scheduled windows.
- Establish clear safety standards, signage, and site protocols for all users.
- Plan carefully to balance shared access with reliable transit operations.

SunLine Transit operates a liquid hydrogen fueling station in Thousand Palms that serves its fleet of 32 FCEBs. In 2024, SunLine partnered with Nikkiso Clean Energy to construct the station, which includes a third dual-hose dispenser for both public and commercial use, making it one of the first transit agencies in California to offer hydrogen fueling to external users. The station supports H35 and H70 fueling protocols. Its strategic location between Los Angeles and Phoenix makes it ideal for long-haul trucks and hydrogen-powered passenger vehicles traveling through the region, enhancing the regional hydrogen infrastructure and supporting broader adoption of fuel cell vehicles.

Thousand Oaks Transit shares its CNG fueling station with the city's municipal fleet. The station, maintained by the city's Municipal Service Center, supports over 228 vehicles and 500 pieces of equipment, one-third of which runs on alternative fuels. This arrangement reduces emissions from municipal operations and avoids the need for separate fueling infrastructure for transit and city departments. It also demonstrates how shared use can be implemented within local government operations to support clean fleet transitions.

Twin Transit
"GOING YOUR WAY"

Twin Transit's Mellen Street e-Transit Station includes DCFC for public use alongside inductive charging pads for its buses. The station was funded through a combination of state grants, including the Washington State Department of Transportation's Green Transportation Grant and the Volkswagen Clean Air Act Settlement. The site supports both transit and public electric vehicle (EV) charging, helping to build out a regional zero-emission corridor between Olympia and Kelso.

Coordination with utilities. As transit agencies electrify their fleets, depot electricity demand will rise sharply, often requiring significant grid upgrades, such as new transformers, or even substations. Agencies should engage their utility early to assess grid capacity, account for long lead times, and evaluate options like managed charging, solar, and battery storage. Experience from LA Metro, Foothill Transit, and Washington Metropolitan Area Transit Authority shows that early coordination enables strategic load management, supports microgrid integration, and reduces infrastructure bottlenecks. Utilities also offer substantial incentive programs to offset make-ready and equipment costs, such as SCE's Charge Ready Transport, San Diego Gas & Electric's Power Your Drive for Fleets, and LADWP's commercial EV charger rebates. Agencies should align grid upgrade planning with these programs and engage utility engineering teams early.

2.3.3 Permitting Streamline

The permitting process for deploying fueling and charging infrastructure often emerges as a significant barrier to expanding ZEBs. One of the primary challenges stems from the multifaceted nature of the approval process itself. Installing ZEB infrastructure typically requires navigating through several distinct permitting domains:

- **Zoning and land-use review** is usually the first step, confirming that the proposed station complies with local zoning codes and determining whether a conditional use permit is necessary. Agencies submit site plans detailing circulation patterns, parking layouts, and setback requirements for review by the local planning authority.
- **Environmental assessments** evaluate potential impacts including noise, traffic congestion, construction disturbance, and hazardous materials handling. In California, and many other states, this triggers local environmental review processes such as the California Environmental Quality Act (CEQA) and may require coordination with regional air quality districts when emissions, fuel handling, or construction impacts warrant additional scrutiny.
- **Building, electrical, mechanical, and structural permitting** requires agencies to submit detailed engineering plans to the local building department and the authority having jurisdiction (AHJ). For battery electric charging installations, this encompasses transformer upgrades, switchgear installation, conduit routing, and charger foundation specifications.
- **Fire and hazardous materials permitting** applies particularly to hydrogen fueling stations and involve comprehensive hydrogen storage and handling plans, ventilation system design, setback compliance, fire suppression infrastructure, and emergency response protocols. These requirements are typically governed by local fire marshals following National Fire Protection Association 2 standards. Some jurisdictions also require a Hazardous Materials Business Plan when hydrogen or other regulated materials will be stored on-site.

- **Utility interconnection** processes can become a critical bottleneck in infrastructure deployment timelines. For BEB charging, utilities must conduct load assessments, determine necessary transformer upgrades, and issue approvals for make-ready work and service connections. Hydrogen stations using electrolyzers or high demand compressors often require more complex interconnection studies. In many cases, utilities cannot reserve electrical capacity until the charging or fueling equipment and its power requirements have been specified. This can add uncertainty to the interconnection schedule until the project design is sufficiently advanced. Early and proactive coordination with utilities is essential given the extended lead times associated with major electrical infrastructure upgrades.

- **Encroachment or right-of-way permits** may be required from cities, counties, or state departments of transportation if station installations affect sidewalks, curbs, or state highway infrastructure.

- **Final inspection and commissioning** involve the AHJ inspecting all electrical and safety systems, utility energization of service, weights-and-measures certification for hydrogen dispensers where applicable, and issuance of final occupancy clearance.

Beyond the complexity of the process itself, another substantial challenge lies in the lack of coordination and consistency across local permitting requirements, which can vary dramatically between cities and counties. Many jurisdictions have limited institutional experience with high-capacity charging infrastructure or hydrogen fueling systems, leading to differing interpretations of electrical codes, safety requirements, and setback distances. This inconsistency translates into extended review periods, multiple rounds of plan revisions, and project schedules that become difficult to predict with confidence.

California has implemented one of the nation's most comprehensive permitting streamlining frameworks for electric vehicle charging stations and hydrogen infrastructure. A streamlining permitting checklist is documented in Appendix I.

2.4 Operation & Maintenance and Workforce Development

ZEB operations, maintenance, and workforce training differ substantially from internal combustion engine (ICE) buses. Operational planning must account for range, charging/fueling, and climate impacts. Maintenance shifts from engine work to battery health and hydrogen tank and fuel cell upkeep. This requires new tools, data analytics, and longer lead times for specialized parts. Operators need energy-efficient driving skills; technicians require high-voltage safety certification, lock-out/tag-out procedures, and hands-on battery and hydrogen training.

2.4.1 Considerations for Operation

Day-to-day operational practices ultimately determine whether ZEB fleets deliver reliable service. The following outlines core considerations, drawing on national best practices and FTA guidance.

Route suitability assessment is essential for effective deployment. Agencies must evaluate daily block mileage limits, available layover time for charging, extreme weather impacts on energy consumption, terrain characteristics, and average operating speeds when matching buses to routes. BEBs are particularly sensitive to heating, ventilation, and air conditioning (HVAC) load and ambient temperature, requiring many agencies to implement seasonal block assignment adjustments. Cold climate operations often necessitate modified route assignments or mid-day charging to maintain adequate state of charge margins. FCEBs offer more stable range through weather conditions, making them well suited for high mileage interlined or express routes that demand consistent performance year-round.

Operational procedures and workflow integration require substantial modifications from conventional diesel operations. Agencies must redesign pull out and pull in procedures, protect dedicated charging windows within schedules, and formalize yard workflows for initiating and verifying charger connections. On-route charging events must be incorporated directly into running times, while hydrogen operations require fueling bay sequencing and redundancy protocols to ensure availability during peak periods.

Real-time operational management increasingly relies on energy aware dispatching tools and telematics systems. Monitoring state of charge, energy consumption, charger availability, and ambient conditions enables dispatch teams to reassign blocks dynamically or initiate mid-day charging when circumstances require intervention. Predictive diagnostics and control center alerts help prevent energy-related roadcalls and maintain service reliability. Protecting layover windows has become critical, as even minor delays can compromise energy margins and jeopardize service completion.

Operator training and behavior significantly influence operational outcomes. Driving habits, including smooth acceleration, effective use of regenerative braking, and appropriate speed management directly affect BEB range and component longevity. Agencies benefit from working with manufacturers to define

BEST PRACTICE FOR OPERATIONS AND MAINTENANCE (O&M) READINESS

Align funding and infrastructure readiness with vehicle procurement. Transit agencies should time bus orders to match grant cycles and infrastructure completion, so vehicles arrive at fully prepared sites. This approach allows them to stage infrastructure work before vehicle arrivals.

Plan infrastructure to enable operational flexibility. Instrument and monitor from day one. Transit agencies should use telematics and charger (or dispenser) logs to track fleet performance from the start, then use those data to refine blocks, energy windows, and maintenance.

Coordinate operations and maintenance as a unified system. ZEB performance depends on the combined behavior of the vehicle and its supporting infrastructure.

Build resilience and contingency capacity. ZEB fleets depend heavily on energy availability and are therefore more vulnerable to utility outages, infrastructure failures, and energy supply constraints than conventional diesel fleets. Resilience planning should include redundant charging or fueling capacity, emergency operating blocks, and backup power to ensure uninterrupted service during grid disturbances or hydrogen supply disruptions.

Invest early in workforce development. Reliability often hinges on technician and operator skills. Agencies should establish structured training for high voltage systems, chargers, dispensers, and hydrogen safety from the outset.

efficient driving behaviors and establishing incentive programs that reinforce best practices among operators.

Long-term fleet management must account for battery degradation over the vehicle lifecycle. BEB usable capacity declines over time, potentially limiting a bus's ability to complete the same blocks late in its service life. Establishing baseline capacity measurements at delivery and conducting annual state of health assessments enables agencies to forecast midlife performance, plan battery replacement strategies, and reassign vehicles to appropriate blocks as capacity diminishes. While FCEBs experience less battery degradation due to shallower cycling patterns, periodic health assessments remain valuable for fleet management planning.

2.4.2 Maintenance Strategies

Early in ZEB deployment, agencies rely on extended OEM warranties while in-house capacity develops, providing a safety net as staff complete specialized ZEB training.

Bus Maintenance. Transit agencies maintain ZEBs through structured preventive maintenance programs. These programs typically follow OEM schedules, often every 5,000 to 10,000 miles or every 30 to 60 days. Maintenance covers high-voltage systems, software updates, cooling systems, power electronics, and other core components.

- **For BEBs**, key activities include tracking battery state of health, inspecting cooling loops, testing high-voltage insulation, and checking regenerative braking, HVAC systems, motors, and inverters.
- **For FCEBs**, maintenance also includes monitoring fuel cell stacks, hydrogen systems, compressors, sensors, and related safety equipment.

Agencies also use lockout/tagout procedures (i.e., formal safety protocols used to isolate buses, charging equipment, fueling systems, and maintenance equipment from hazardous energy sources before service or repair), continuity checks, and electrical insulation testing to reduce safety risks and prevent vehicle faults. Leading agencies are developing detailed maintenance protocols to improve reliability, extend equipment life, and reduce downtime.

Infrastructure Maintenance. Transit agencies recognize that maintaining charging infrastructure is as critical as keeping ZEBs in good condition. Agencies have developed systematic daily inspection routines covering all infrastructure components critical to reliable ZEB operations.

- **Charging system maintenance** varies by technology type. Plug-in chargers require inspection of connectors, cooling systems, communications interfaces, and OCPP functionality. Overhead pantograph systems need attention to alignment mechanisms, contact plate condition, and lubrication of moving components. Wireless inductive systems require checks of pad condition and alignment sensor calibration. Supporting electrical infrastructure maintenance includes inspecting depot circuit breakers, switchgear, and ventilation systems to prevent failures and manage heat buildup. Charge management software monitoring has become essential, with staff reviewing system logs, state of charge data, and load optimization to balance grid demand with vehicle energy needs.
- **Hydrogen fueling infrastructure** demands equally rigorous maintenance. Daily operations include pressure checks of storage tanks, leak detection protocols, and sensor calibration. Compressor maintenance focuses on monitoring oil levels, seal integrity, and vibration patterns to catch mechanical issues early. Dispenser systems require checking hoses for wear, replacing filters, and inspecting nozzle seals to prevent hydrogen leaks.

Safety systems receive continuous attention across both charging and hydrogen infrastructure, including testing alarms, verifying gas sensor accuracy, confirming emergency stop operation, and validating ventilation performance. Most agencies track infrastructure status through centralized telematics dashboards that provide real-time alerts when equipment performance degrades, enabling dispatch teams to adjust vehicle assignments proactively.

Spare Parts and Inventory. The relative newness of zero-emission technology and limited supplier networks can result in extended lead times for replacement components compared to conventional diesel buses. Agencies must strategically stock components across multiple categories to minimize downtime and maintain service reliability. Critical spares include:

- **For BEBs:** high-voltage connectors, contactors, DC-to-DC converters, cooling pumps, and inverters for electrical systems; thermal sensors, coolant components, and state of health testing equipment for battery systems; cables, dispensers, cooling modules, and communications modules for charging infrastructure.
- **For FCEBs:** balance of plant valves, filters, air compressors, and sensors for fuel cell operations; compressor seals, valve kits, programmable logic controller cards, and sensors for hydrogen fueling stations.

Spare parts management requires close coordination with OEMs to set inventory levels based on fleet size, reliability data, and lead times. Underestimating needs risks extended outages and diesel backup reliance. Leading agencies negotiate parts commitments during procurement, maintain safety stock for long-lead components, and join regional consortiums to share inventory costs.

WORKFORCE DEVELOPMENT BEST PRACTICES

Start Training Early. A leading practice among agencies nationwide is to begin workforce training well before ZEBs, chargers, or hydrogen systems arrive on site.

Create Role Specific Pathways. Agencies increasingly adopt role specific training pathways to ensure that operators, technicians, electricians, and dispatchers develop the exact competencies needed for ZEB operations.

Prioritize High-Voltage and Hydrogen Safety Certifications. High-voltage and hydrogen systems introduce safety considerations far beyond those of diesel or CNG buses, and national leaders treat safety training as a core requirement.

Multi-Modes Trainings. National experience demonstrates that ZEB training is most effective when theoretical learning is paired with extensive hands-on practice.

Leverage National Resources. Transit agencies benefit significantly from using national ZEB training standards and federally supported training centers.

2.4.3 Workforce Training Type and Resources

Agencies typically need to upskill personnel across all domains with training needs significantly broader than for diesel or CNG fleets.

Bus Operators. Operator training focuses on ZEB specific driving techniques, energy aware operations, and safe interaction with charging or fueling equipment. Operators need to learn how regenerative braking works, how to maximize energy recovery by anticipating stops, and how to manage energy consumption through smooth acceleration, reduced idling, and appropriate use of eco-modes.

Maintenance Technicians. Maintenance personnel face the most substantial transformation, requiring proficiency in high-voltage systems, electric drivetrains, battery management, and, for FCEBs, fuel cell stacks and balance-of-plant systems.

Facility Electricians and Charging/Fueling Technicians. Electrified depots require higher technical baselines. Electricians need to understand charger power electronics, networking, load management platforms, breaker coordination, and DCFC troubleshooting.

Dispatchers and Operations Control Center Staff. Dispatchers need to shift to energy-constrained fleet management, learn real-time SOC monitoring, charger dashboards, queuing logic, energy forecasting, and protocols for low-energy events and weather-related range reductions.

Emergency Response Personnel. Emergency response training needs to cover high-voltage hazards, battery thermal runaway, and hydrogen safety for both internal supervisors and external fire/hazmat partners. BEB incidents may require large-volume water cooling; hydrogen incidents involve invisible flames, rapid dispersion, and specific evacuation distances.

Transit agencies can rely on a structured ZEB training ecosystem that includes national training centers, OEM programs, standardized curricula, community colleges, and utility partners. Key training resources are documented in Appendix I.

2.5 Cost and Funding Strategies

2.5.1 Cost Analysis Framework

ZEB deployment costs are more than the cost of buying buses. Agencies also need to plan for program development, prepare permitting as well as staff training and long-term operations. Bus procurement and operation costs include both upfront capital costs and ongoing costs. Upfront costs may include buses, chargers, fueling equipment, and electrical upgrades. Ongoing costs may include electricity or hydrogen, maintenance, warranties, training, and replacement parts. Looking at the full cost picture helps agencies build realistic budgets, identify funding needs, and plan for long-term success.

Planning and Program Development: Before buses are procured or infrastructure is constructed, agencies usually invest in upfront planning and program development, steps which are sometimes underestimated but critical for long-term success. These soft costs typically begin with feasibility studies, a rollout plan, and detailed site readiness assessments. Such analyses help agencies understand route compatibility, charging or fueling strategies, and the most appropriate technology pathways.

Agencies also generally prepare for permitting and environmental review, which can add significant soft costs. CEQA and National Environmental Policy Act (compliance, zoning approvals, and Rule 21 interconnection (often 6-12 months) require specialist support and have historically delayed ZEB project. Finally, workforce readiness is equally essential. ZEB transitions require new skills from high-voltage safety to fuel-cell maintenance, which agencies like Calaveras Connect have built directly into their planning.

Bus Cost: ZEB costs include both capital and operations and maintenance (O&M). ZEBs cost more upfront than conventional buses but vary by vehicle type and technology. For example, the Public Transportation Vehicle Database 2023-25 shows that BEBs typically range from about $650,000 for cutaways to $1.35 million for articulated buses, compared with about $125,000 to $800,000 for comparable ICE buses. Standard FCEBs average about $1.52 million.

Fuel costs also vary. Because most conventional transit buses operating in the SCAG region use CNG rather than diesel, CNG is used as the primary ICE fuel comparison. CNG averages about $1.30/diesel gallon equivalent (DGE), BEB electricity averages about $0.13/kWh ($4.86/DGE), and hydrogen averages about $7.79/kg ($8.73/DGE), with reported values ranging from $5.27 to $10.10/kg (from $5.91/DGE to $11.32/DGE). However, these fuel costs should not be directly compared as a proxy for operating cost because BEBs and FCEBs are generally more energy efficient than ICE vehicles. A more meaningful comparison should instead be based on fuel cost per mile.

Maintenance costs are generally comparable across technologies, averaging about $0.85/mile for CNG buses and $0.43/mile for BEBs and FCEBs, though ZEBs require more specialized battery and hydrogen system support.

Infrastructure Cost: ZEB infrastructure has a major upfront cost and needs careful planning.

- **Charging infrastructure** includes charger hardware, installation, utility upgrades, software/network fees, maintenance, and facility updates for high-voltage work. Several studies in the past five years show that depot plug-in chargers can range from about $35,800 for a 50 kW charger to $150,000 for a 350 kW charger, with installation costs from about $28,100 to $61,600 per charger. Overhead chargers with higher power systems cost more: a 300 kW depot overhead charger can cost about $492,000 for hardware plus $328,000 for installation, while on-route charging can reach about $600,000 for equipment and $400,000 for installation.

  These estimates may not fully account for major civil construction or site-specific improvements. Costs can also vary significantly depending on charger placement and design, such as whether the project requires a raised charging island or an overhead gantry. Utility-side upgrades, including transformers and service connections, are often installed and funded by the utility through applicable utility programs.
- **Hydrogen stations** are also costly, typically ranging from about $4 million to $8 million depending on station capacity, storage type, production approach, and site needs. Examples include $4.7 million for OCTA (built in 2019), $6.6 million for Foothill Transit (built in 2022-23), and $9.1 million for SunLine's liquid hydrogen station. However, these are largely pre-pandemic costs and should be treated as historical benchmarks. More recent transit procurements in the past two years, such as OCTA's new Garden Grove station and Foothill Transit's new Arcadia station have reached or exceeded approximately $15 million when broader design, construction, and facility upgrades are included. Ongoing maintenance is typically included, about $800 per charger per year for plug-in chargers and roughly $11,800 to $15,500 per month for some hydrogen stations. Stations that produce hydrogen onsite using an electrolyzer, such as SunLine, could have maintenance costs as high as approximately $24,000 per month.

Details on ZEB and conventional transit bus cost, fuel and maintenance cost, charging infrastructure cost, and hydrogen station cost are documented in Appendix H.

FUNDING STRATEGY BEST PRACTICES

Foothill Transit has repeatedly combined FTA Low-No, FTA Bus and Bus Facilities, and CARB HVIP vouchers to purchase BEBs. The agency also secured state funding through CEC and TIRCP.

AVTA, the first agency in the U.S. to fully electrify its local fixed route fleet, relies heavily on LCFS credit revenue generated from its large depot charging operations.

LADOT's electrification of its Washington Bus Yard and other depots benefited from LADWP's Fleet Electrification Program, which funded or fully covered utility-side make-ready work.

SunLine Transit Agency has built one of the nation's most advanced hydrogen transit programs by using a structured public–private partnership model for it's fueling infrastructure. SunLine partners with leading hydrogen firms such as Linde, Hydrogenics (now Cummins), and Air Products.

LA Metro is implementing one of the nation's largest phased ZEB transitions, aligning deployment phases with major federal and state funding cycles. Metro was awarded with $320.6 million over four years via ZETCP established by SB125, in addition to a $77.5 million FTA award in 2024, to support deployment of 160 BEBs and chargers.

2.5.2 Funding Strategies

Transit agencies operate within a diverse and layered funding landscape. At the federal level, FTA's Low-No Program and Bus and Bus Facilities Program have been among the largest funding sources, consistently providing competitive capital for ZEB procurement, depot construction, and facility upgrades. Urbanized Area Formula Grants (Section 5307) provides more flexible formula funding that agencies may use for eligible bus and infrastructure investments. Surface Transportation Block Grants and the Congestion Mitigation and Air Quality Improvement Program can also support ZEB projects, particularly when they advance regional transportation priorities or demonstrate air quality benefits. However, available funding and award levels may vary from year to year based on federal appropriations, program priorities, and competition. At the state level, HVIP and LCFS are the most predictable and impactful programs for reducing vehicle and O&M costs. EnergIIZE, Low Carbon Transit Operations Program (LCTOP), and Transit and Intercity Rail Capital Program add recurring infrastructure and fleet funding that agencies often stack with federal grants.

Regional and local programs, including SCAG's planning initiatives such as the Connect SoCal Regional Transportation Plan/Sustainable Communities Strategy, South Coast Air Quality Management District Invest Clean Program and Carl Moyer Program, provide additional opportunities to support infrastructure needs, planning activities, and fleet expansion. Utility funding also plays a central role in reducing capital costs. Programs such as SCE's Charge Ready Transport and LADWP's fleet electrification incentives help offset make-ready and interconnection costs by covering electrical design, trenching, transformers, and rebates for charging equipment. A funding roadmap can be found in Appendix I.

It is not enough for transit agencies to be aware of available ZEB funding; they must also understand how to strategically combine, sequence, and leverage these programs to maximize their impact.

Funding Strategy I: Use Federal Funding as the Core While Layering State Incentives. Pairing federal grants, such as the FTA Low-No and Bus and Bus Facilities, with state incentives forms the foundation of a ZEB deployment program. Such layering can significantly reduce the local match requirement and lower the overall cost of early ZEB adoption.

Funding Strategy II: Generate Ongoing Revenue Through LCFS Credits. Participating in the CARB LCFS allows agencies to generate recurring revenue from the electricity or hydrogen used in ZEB operations. These LCFS credits provide a flexible funding source that can offset energy costs, support maintenance needs, or help finance future fleet expansion. As LCFS revenue is market-based non-competitive, it improves long-term financial stability for ZEB operations.

Funding Strategy III: Use Utility Programs to Reduce Make-Ready and Interconnection Costs. Utility make-ready programs are among the most valuable tools for reducing infrastructure costs, especially the high-cost elements of a ZEB project like utility-side electrical upgrades. Utility-side participation can save agencies substantial capital and accelerate infrastructure build-out.

Funding Strategy IV: Pursue PPPs for ZEB Infrastructure. PPPs can help agencies manage complex or capital-intensive ZEB infrastructure, including leasing or service-based hydrogen contracts, charging-as-a-service models in which third parties own and operate the chargers, and developer-built depots or microgrids. These partnerships reduce upfront capital exposure and shift portions of the technical and performance risks to private partners.

Funding Strategy V: Phase Deployment to Match Funding Cycles and Stack Multiple Sources to Maximize Outcome. A phased deployment approach allows agencies to align ZEB investments with funding cycles and to refine operations over time. This enables transit agencies to time federal and state grant applications across multiple years and distribute local match costs more evenly. Each phase relies on stacking multiple funding sources to reduce capital burden and ensure long-term financial viability.

3 Regional Existing Conditions

The existing conditions assessment provides a snapshot of where the SCAG region currently stands in the zero-emission bus (ZEB) transition. This section of the report reviews transit agencies' ZEB rollout plans, selected technology pathways, current ZEB deployment trends, charging and hydrogen fueling infrastructure, policy and funding support, and workforce resources.

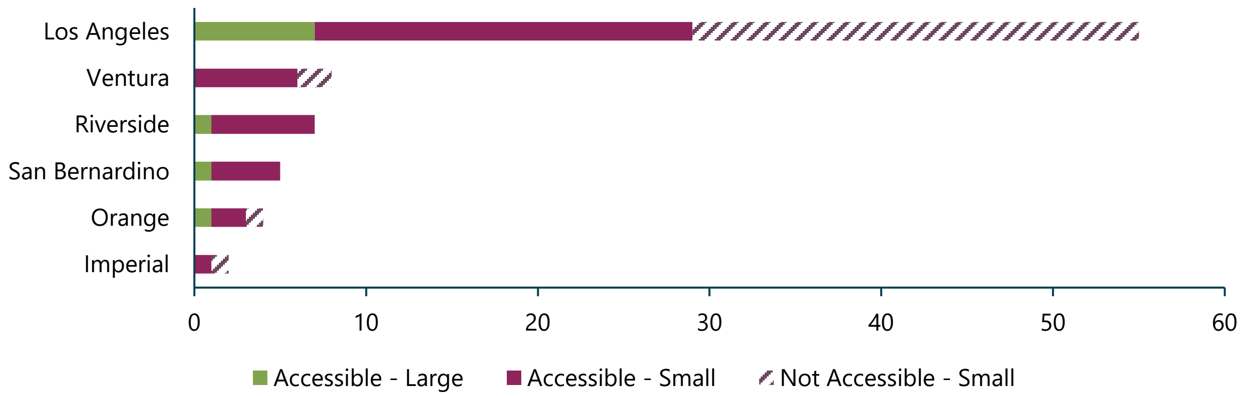
3.1 ZEB Rollout Plans and Technology Pathways

California's Innovative Clean Transit regulation requires all transit agencies in the state to submit a complete zero-emission bus rollout plan (rollout plan) to the California Air Resources Board (CARB) by 2020 for large transit agencies and 2023 for small transit agencies. Per the regulation, a large transit agency operates more than 65 buses in annual maximum service in either the South Coast Air Basin or the San Joaquin Valley Air Basin or operates in an urbanized area with a population of at least 200,000 and at least 100 buses in annual maximum service. All others are small transit agencies. These rollout plans must be approved by governing bodies and clearly outline the transit agency's selected ZEB technologies and synchronized plans for vehicle procurement and infrastructure build out.

According to the CARB ICT reporting database, of the 196 transit agencies in California reported in 2025, 81 are located in the SCAG region (across the six counties), including 10 large and 71 small agencies (Figure 6). The primary sources of rollout plans in this study include CARB's official website, direct email communications from CARB, and postings on individual transit agency websites. CARB maintains a public webpage with rollout plans, which was most recently updated in February 2026. CARB has also shared six rollout plans via email for smaller agencies that do not have their plans posted online at the time of this report.

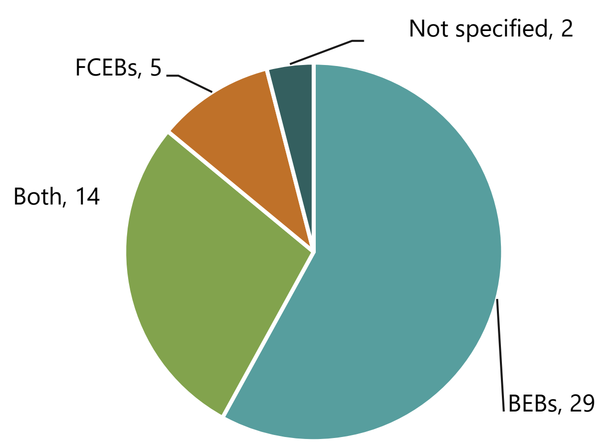
Currently, 49 transit agencies in the SCAG region have ZEB rollout plans accessible through CARB's webpage, email exchange, or agencies' own website. Although not a transit agency, the San Bernardino County Transportation Authority adopted its ZEB Rollout Master Plan in 2020, covering four transit agencies, namely Morongo Basin Transit Authority, Mountain Area Regional Transit Authority, the city of Needles, Victor Valley Transit Authority (VVTA), all of which later submitted their individual plans in 2023. The Antelope Valley Transit Authority (AVTA) did not have a rollout plan officially but achieved a 100 percent zero-emission bus fleet in March 2022. The city of Avalon also claimed a 100 percent electric fleet, including five GEM e6 shuttles and two Ford E- Transit vans.

Figure 6. Transit Agencies by County in the SCAG Region and Their Rollout Plans



Source: ICT Rollout Plan, CARB

Figure 7. ZEB Technology Pathways by Agency In SCAG



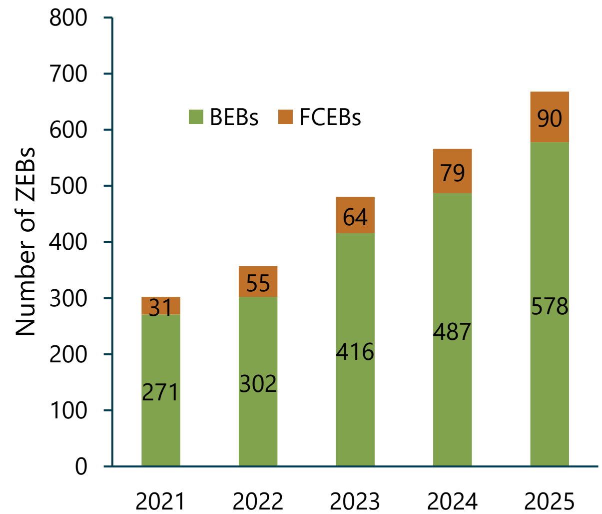
Source: ICT Rollout Plan, CARB

Rollout plans require each agency to identify a specific ZEB technology pathway, such as battery-electric buses (BEBs) or fuel cell electric buses (FCEBs), which directly guides the planning and development of supporting infrastructure. As depicted in Figure 7, more than half of the agencies chose to transition their entire fleet to BEBs in their rollout plans. Most of these were small agencies, and five agencies chose a full FCEB transition for their fleet. The other transit agencies did not specify the technology or decided to transition their fleet to a mix of BEBs and FCEBs due to technology readiness and considerations of operational resilience. For example, the Orange County Transportation Authority (OCTA) has planned to conduct pilot projects to test both FCEBs and BEBs before their final decision and long-term ZEB strategy. A full list of transit agencies in the SCAG region with accessible Rollout Plans and identified ZEB technology pathways is documented in Appendix A.

3.2 ZEB Deployment Trends and Fleet Characteristics

By 2025, California had deployed approximately 1,210 ZEBs statewide. Approximately 668 of the ZEBs, or more than half of them, operate in the SCAG region, with BEBs making up 86 percent of the deployments (Figure 8). The growing number of ZEBs in SCAG region reflects the increasing focus on transitioning to a low-carbon transit bus system, as well as public transit agencies' determination to achieve a full ZEB transition by 2040, under California's ICT regulation.

Figure 8. Number of ZEBs by Fuel Type in SCAG Region

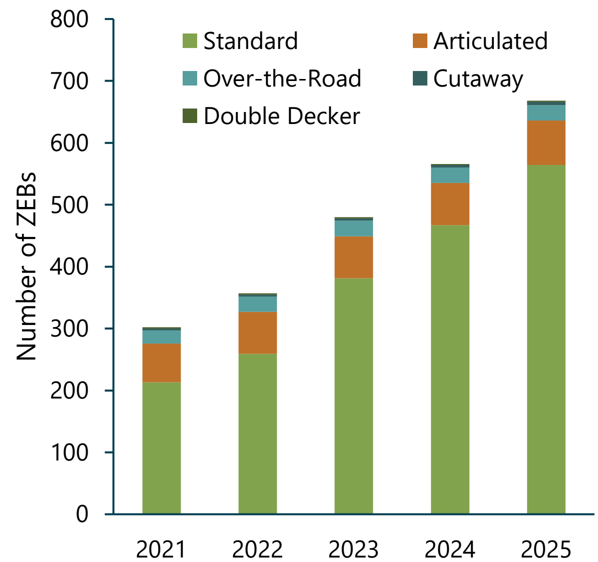


Source: ICT Reporting Tool & Data, CARB (2021-2025)

CARB reporting data as required by the ICT regulation (ICT reporting data), is the primary data source for this study. The reporting database is updated annually, with the most recent update completed in May 2026. This analysis uses ICT reporting data from 2021 through 2025. Retired vehicles were excluded when summarizing the total number of buses. The National Transit Database is also used for benchmarking.

Approximately 84 percent of the ZEBs in SCAG region are standard buses (typically 35 to 40 ft), commonly used for fixed routes (Figure 9). Around 11 percent are articulated buses, typically 60 ft long and made up of two sections connected by a flexible joint. The remaining 5 percent are over-the-road coaches, double-decker or cutaway, reflecting both the smaller number of these vehicle types in service compared with standard and articulated buses and the more limited availability of zero-emission options in these segments.

Figure 9. Number of ZEBs by Bus Type in SCAG Region



Source: ICT Reporting Tool & Data, CARB (2021-2025)

As shown in Table 4, two transit agencies, AVTA and the city of Artesia, had achieved 100 percent ZEB fleets by 2023. The cities of Glendora and South Pasadena also reached two thirds of ZEBs due to smaller fleet sizes. As of 2025, Los Angeles County Metropolitan Transportation Authority (LA Metro) and Los Angeles Department of Transportation (LADOT) have deployed 89 and 160 ZEBs, respectively. However, given their large fleet sizes (2,179 and 538, respectively), these numbers represent a smaller share of total ZEB adoption. Agencies listed in Appendix A but not shown in Table 4 likely have no reported ZEBs as of 2025, according to CARB's ICT reporting data.

Table 4. Number of ZEBs in SCAG Region by Transit Agency and Bus Type in 2025

Transit Agency	Number of ZEBs						Total Buses	% ZEB
	Articulated	Cutaway	Double Decker	Over-the-Road	Standard	Total ZEB		
Anaheim Transportation Network (ATN)*	10				36	**46**	**82**	**56%**
Antelope Valley Transit Authority	18			24	62	**104**	**104**	**100%**
City of Artesia					1	**1**	**1**	**100%**
City of Beaumont		2				**2**	**22**	**9%**
City of Culver City					4	**4**	**57**	**7%**
City of Gardena (GTrans)					18	**18**	**91**	**20%**
City of Glendale (Glendale Beeline)					5	**5**	**46**	**11%**
City of Glendora					2	**2**	**3**	**67%**
City of Norwalk					9	**9**	**44**	**20%**
City of Pasadena					1	**1**	**56**	**2%**
City of Santa Clarita		1				**1**	**111**	**1%**
City of Santa Monica					34	**34**	**193**	**18%**
City of South Pasadena		2				**2**	**3**	**67%**
Foothill Transit			2		50	**52**	**355**	**15%**
Long Beach Transit					29	**29**	**242**	**12%**
LA Metro	44				45	**89**	**2,179**	**4%**
LADOT				1	159	**160**	**538**	**30%**
Montebello Bus Lines					3	**3**	**68**	**4%**
Omnitrans					26	**26**	**245**	**11%**
Orange County Transportation Authority					21	**21**	**764**	**3%**
Sunline Transit Agency					36	**36**	**113**	**32%**
Victor Valley Transit Authority					23	**23**	**115**	**20%**
Total	**72**	**5**	**2**	**25**	**564**	**668**		
* ATN ended service on March 31, 2026. This table reflects ICT reporting in 2025, which included ATN in the analysis.								

Source: ICT Reporting Tool & Data, CARB (2025)

Table 5 summarizes ZEB deployment in SCAG region original equipment manufacturers (OEMs).

- **For BEBs**, adoption is led by BYD and New Flyer, which both have a strong U.S. presence and broad market penetration. BYD has shown strong growth, supported by its Lancaster plant and large Southern California fleet deployments. The Lancaster facility can produce up to 1,500 BEBs per year, making it the largest BEB manufacturing facility in North America. Gillig has steadily expanded its BEB offerings. Proterra's 2023 bankruptcy limited its future growth, although many legacy Proterra buses remain in service. Other OEMs, such as Alexander Dennis and GreenPower, play more specialized roles. Alexander Dennis focuses on the double-decker bus market, while GreenPower primarily serves school bus and cutaway applications.
- **For FCEBs**, New Flyer dominates the market, with steady year-over-year increases from 21 units in 2021 to 81 units by 2025. Eldorado National-California (ENC) represents the only other player in the region, with production recently resuming under new ownership but limited deployment to date.

Table 5. ZEBs by Technology and OEMs, 2021-2024

OEMs	2021	2022	2023	2024	2025
BEBs					
BYD	120	137	219	278	324
New Flyer	63	70	97	99	122
Proterra	56	43	43	43	43
Phoenix	1	1	2	2	2
GreenPower	2	2	4	4	4
Gillig	6	23	25	35	56
Motor Coach Industries (MCI)	21	24	24	24	24
Alexander Dennis	2	2	2	2	2
Ford	0	0	0	0	1
FCEBs					
ENC	10	10	10	9	9
New Flyer	21	45	54	70	81

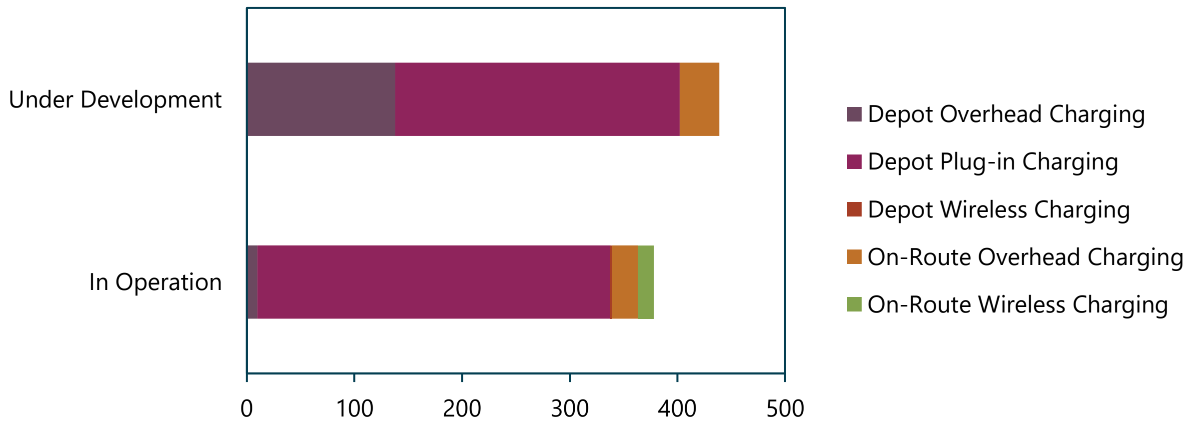
Source: ICT Reporting Tool & Data, CARB (2021-2025)

3.3 Charging and Hydrogen Refueling Infrastructure

To support ZEB deployment in the SCAG region, agencies are also advancing charging and hydrogen refueling infrastructure. BEB charging infrastructure includes depot (e.g., plug-in and overhead pantograph) and on-route (e.g., overhead and wireless) charging. Depot plug-in charging remains the most common approach and is well suited for overnight charging, while overhead and on-route systems can provide higher-power charging. Charging management software is also increasingly used to schedule charging and manage peak demand. Hydrogen refueling infrastructure for FCEBs varies by supply chain and storage configuration. Details of charging and hydrogen refueling station in the SCAG region are summarized in Appendix B and presented in Figure 11**.**

Figure 10 shows the distribution of charging infrastructure in the SCAG region by station status. Based on information confirmed by transit agencies in early 2026, approximately 817 chargers are either in operation or under development across 58 sites and 16 transit agencies. Depot plug-in chargers account for approximately 70 percent of the total. About 46 percent of all chargers are currently in operation, while the remaining chargers are under construction or in the planning stage.

Figure 10. Charging Station by Charging Type in SCAG Region



Source: Transit agency provided data and ICF research

The SCAG region also has three hydrogen refueling stations currently supporting FCEB operations for Foothill Transit, SunLine Transit Agency, and Omnitrans.

- **Foothill Transit (Pomona Depot):** Liquid hydrogen station in operation; fuels 33 FCEBs today and is expected to support 52 FCEBs by the first quarter of 2026. Capacity is approximately 1,800–2,000 kg per day and can expand with additional tanks and dispensers.
- **SunLine Transit Agency (Headquarters):** Hydrogen station in operation since 2000; uses delivered liquid hydrogen and on-site electrolyzer production. Capacity is approximately 900 kg per day from electrolyzer plus 1,800 kg per day from liquid hydrogen station.
- **Omnitrans:** operates a small-scale compressed gas pilot station with 350-bar dispensing and 500-kg trailer storage. The agency is also advancing a proposed liquid hydrogen station with 350/700-bar dual-hose dispensing.

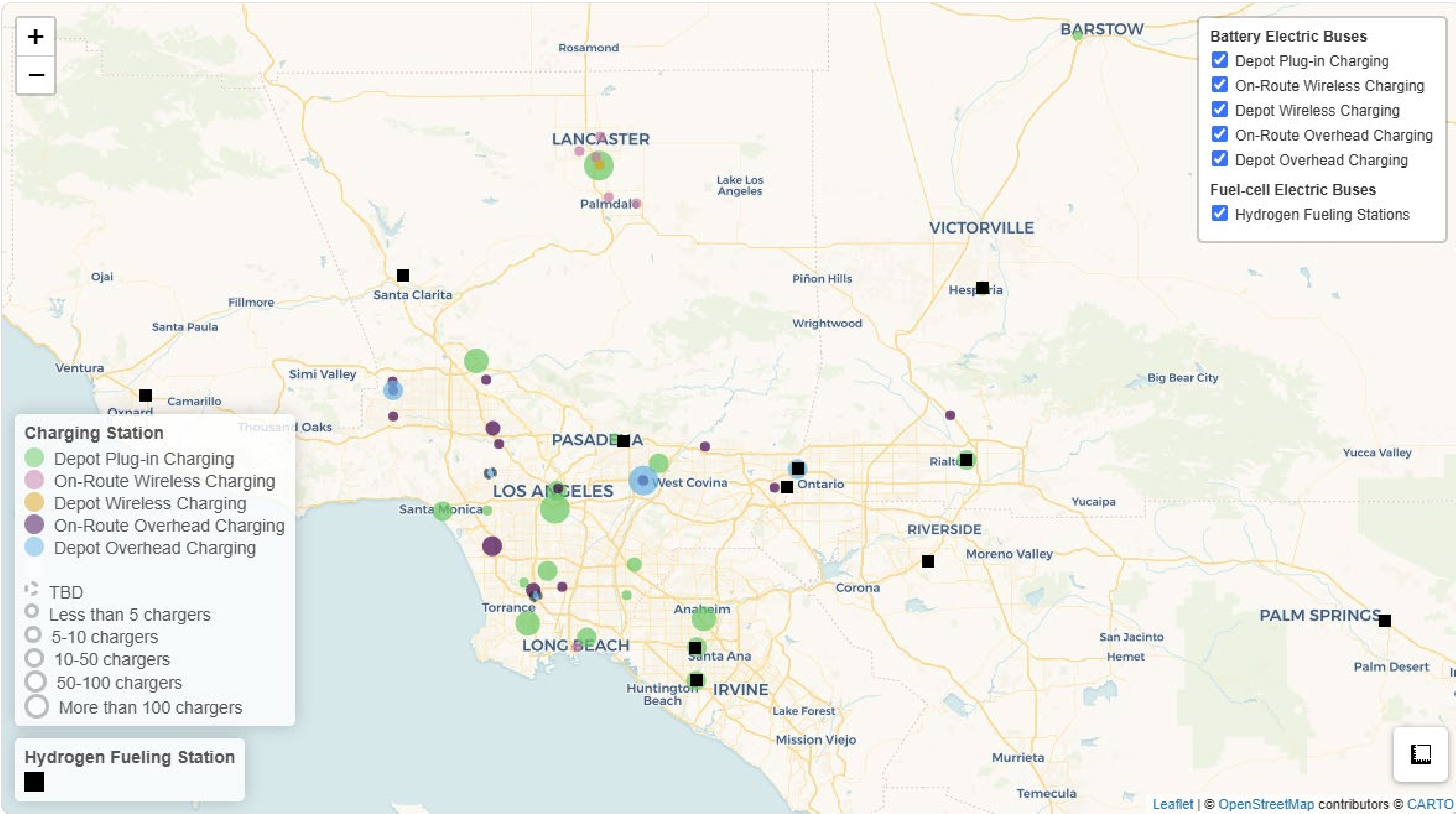
OCTA's liquid hydrogen station at the Santa Ana Bus Base was decommissioned in 2026 after Air Products removed its leased equipment following their inability to reach an agreement on continued operation. The station was formerly one of the largest transit hydrogen fueling stations in the United States and was designed to fuel about 50 buses per day with modular expansion capability. OCTA plans to rebuild the station and has also awarded a contract to Clean Energy for the construction of a second hydrogen fueling station at the Garden Grove Base. In the meantime, the agency's existing FCEB fleet is refueling at alternative locations during this transition.

Several additional hydrogen stations are planned or under development, as shown below. However, other hydrogen projects, such as the proposed Gold Coast Transit District station and Foothill Transit (Arcadia depot), have been placed on hold or reevaluated following the cancellation of federal funding for the ARCHES hydrogen hub.

- **OCTA**: Second liquid hydrogen station planned at the Garden Grove Bus Base; designed for up to 3,000 kg per day through two fueling lanes and capacity to support up to 100 FCEBs.
- **Riverside Transit Agency:** Liquid hydrogen station under construction; designed for up to ~3,300 kg per day peak fueling and initial support for five FCEBs, with plans to grow to 100+ buses. Expandable with additional dispensers.

- **Pasadena Transit:** Liquid hydrogen station under construction at 159 S. Kinneloa Avenue; expected to be operational by fall 2027 and support up to 45 FCEBs. Expandable with additional storage tanks and dispensers.
- **VVTA:** Liquid hydrogen station under construction with dual-pressure 350/700 bar dispensing. Planned for both public and fleet fueling, with co-located DC fast charging.
- **Santa Clarita Transit:** Liquid hydrogen station under construction with the ability to produce up to 400kg per day. Planned for transit use only.

Figure 11. Operational and Under Development Charging and Hydrogen Refueling infrastructure for ZEBs in the SCAG region



Source: Transit agency provided data and ICF research

3.4 Policy and Funding

ZEB transition in the SCAG region is supported by a broad mix of federal, state, regional, and local policies. Key policies and funding programs at federal, state, as well as regional and local levels are summarized below.

3.4.1 Federal

Federal policies, programs, and funding mechanisms are helping shape the transition to ZEBs across the United States. Through tax credits, grants, and infrastructure investments, these initiatives provide both regulatory and financial support for transit agencies. Federal funding programs are especially important because they help offset the high upfront costs of ZEB vehicles and related infrastructure. These efforts include but are not limited to:

- **The Inflation Reduction Act,** which provides major near-term incentives for ZEBs and related infrastructure, with specific provisions that allow tax-exempt transit agencies to benefit through direct pay (elective payment) mechanisms.
- **The Federal Transit Administration (FTA) programs**, such as Low-No and Buses and Bus Facilities grants, provide direct funding for bus purchases and supporting facilities. In fiscal year 2024, more than $226 million was awarded to 15 projects across California, including four in the SCAG region.
- **The 2024 National Zero-Emission Freight Corridor Strategy** identifies priority corridors for high-capacity charging and hydrogen fueling infrastructure, helping guide ZEB fueling hub siting and integration with broader freight and transportation networks.

3.4.2 State

California has established a comprehensive policy framework to accelerate the transition to zero-emission vehicles (ZEVs), with public transit fleets as a key focus area. This framework combines regulatory mandates, executive orders, and financial incentives that provide clear direction and support for agencies to plan and implement fleet electrification.

- **Executive Orders**: A major early milestone came with Executive Order N-79-20 (September 2020), which set the statewide goal of 100 percent zero-emission passenger vehicle sales by 2035 and directed state agencies to develop strategies for transitioning all medium- and heavy-duty vehicles (including transit buses) to ZEVs by 2045. Building on that executive order, Governor Newsom signed Executive Order N-27-25 (June 2025), directing agencies to advance Advanced Clean Cars III, update state purchasing In response, CARB issued its August 2025 report to the governor, which provides a statewide action plan for accelerating ZEV adoption.
- **Regulations**: The ICT regulation is at the heart of California's transit policy, supplemented by other policies that have shaped the ZEB transition in California, including Advanced Clean Fleets and Advanced Clean Trucks. The ICT regulation remains one of the most influential zero-emission policies in the United States, providing a clear and enforceable mandate.
- **Funding Programs:** Key programs include CARB's Clean Truck and Bus Voucher Incentive Project for upfront vehicle purchase incentives, Low Carbon Fuel Standard credits to offset operating costs, California Energy Commission's EnergIIZE program for charging and hydrogen infrastructure, Caltrans' Low Carbon Transit Operations Program for ZEB vehicles and related infrastructure, and California State Transportation Agency's Transit and Intercity Rail Capital Program for major transit modernization and zero-emission capital projects. Together, these

programs provide critical financial support for ZEB procurement, fueling and charging infrastructure, and long-term implementation.

3.4.3 Regional and Local

Regional policies further support ZEB deployment. SCAG's long-range plan, the Connect SoCal 2024, Regional Transportation Plan/Sustainable Communities Strategy, reflects a target for all transit agencies to fully transition to ZEBs by 2040, supported by more than $300 billion toward transit projects and operations, including $248.7 billion specifically for transit operations and maintenance. SCAG has also assisted local governments with electric vehicle-ready planning and adopted the Clean Transportation Technology Policy Resolution No.23-654-6 in April 2023, as well as the "Clean Technology Compendium," which identifies transit fleets as a priority for zero-emission deployment to guide zero-emission transition. Utilities like Southern California Edison remain supportive of transit agencies electrifying through the Charge Ready Transport program.

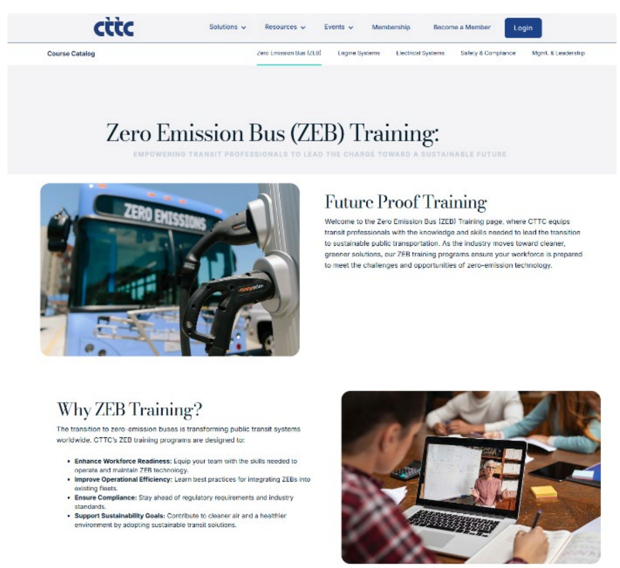
In 2023, SCAG completed work with 18 cities to expand EV charging through policy guidance, site analyses, and infrastructure planning. While designed for passenger EVs, these initiatives build the same planning, siting, and utility coordination capacity that transit agencies need for ZEB charging.

SCAG clean cities COALITION

3.5 Workforce Landscape

Workforce development is an essential enabler for scaling ZEB operations across the SCAG region. Nationally, the FTA-funded Transit Workforce Center provides technical assistance and training resources to help agencies recruit, train, and retain staff for ZEB operations and maintenance. The Electric Vehicle Infrastructure Training Program certifies licensed electricians to install and maintain charging infrastructure.

California also hosts several regionally focused ZEB training resources, such as the California Transit Training Consortium, and the Zero Emission Bus Resource Alliance, which many Southern California transit agencies are already participating in. Other convenings, such as the Southern California Zero Emission Transit Forum, and the ZEV Equity Task Force, provide additional collaboration platforms. While the Transit Transformation Task Force has concluded, its findings and recommendations continue to provde important context for workforce related priorities and help inform the development of the action plan presented in Section 6 of this study.



Local institutions play a growing role in ZEB workforce development. Community colleges such as San Bernardino Valley College and Santa Ana College offer programs preparing technicians for electric and alternative-fuel heavy-duty vehicles, supported in part by IDEAL ZEV Workforce Pilot Projects. Manufacturers like New Flyer and MCI provide hands-on training in ZEB maintenance, electrical systems, and safety as well as seen in New Flyer's Vehicle Innovation Center and MCI Academy. Agencies like SunLine Transit integrate workforce development into their broader ZEB transition strategies, leveraging their Workforce Training Center.

4 Regional Readiness

4.1 Survey and Interview

Targeted outreach was conducted with transit agencies, bus manufacturers, charging infrastructure providers, and utilities to reflect regional deployment needs, barriers, and opportunities.

Targeted surveys were distributed to gather focused input from key stakeholder groups. Each survey included five to six questions. The targeted outreach survey received responses primarily from transit agencies, including large, medium, and small operators across the SCAG region. Outreach also included bus original equipment manufacturers (OEMs), infrastructure providers, and utilities; however, the survey findings are primarily driven by transit agency responses, with one response received from an infrastructure provider.

Interviews provided a deeper understanding of how the SCAG region is moving from zero-emission bus (ZEB) planning to implementation. While the survey results highlighted common priorities, the interviews added important context on why these issues matter, how they vary by agency size and service model, and where regional support could be most useful. In summary the interviews were conducted with transit agencies, infrastructure and utility providers, and bus OEMs through one-on-one virtual meetings, and the remaining inputs were gathered through email exchanges.

The targeted outreach confirmed that transit agencies in the SCAG region are committed to ZEB transition, but implementation readiness varies widely across the region.

- **Infrastructure readiness emerged as the most important factor shaping ZEB deployment.** Agencies most frequently identified utility coordination, grid capacity, as well as permitting and construction timelines as key risks. In many cases, vehicle deployment cannot move faster than supporting infrastructure. Inputs from the OEMs reinforced this finding. They note that utility upgrades and charging infrastructure installation often require longer lead times than bus production and can become the critical path for deployment. Gillig reported a typical BEB delivery lead time of approximately 15-18 months from contract execution, while emphasizing the importance of early transformer and switchgear planning, and charging vendor selection.
- **Utility input further confirmed that ZEB infrastructure deployment depends on early, detailed, and consistent coordination between agencies and utilities**. Riverside Public Utilities noted that transit projects typically begin with a request for new electric service, followed by documentation review, and electric service design. This process highlights the importance of initiating utility coordination early enough to align project design and construction timelines. They also indicate that a strong partnership is required. Agencies need to provide timely and accurate project information so utilities can have clear visibility into future load growth and they can effectively plan infrastructure investments.
- **Cost and funding uncertainty remain major barriers.** Agencies cited high vehicle and infrastructure costs and rising prices, uncertainty around future incentives, and funding that does not always cover full project needs. OEM input similarly pointed to funding uncertainty as a factor that can delay order placement and, in some cases, lead to cancellations. Utility input also showed that infrastructure costs can increase when service capacity is not available nearby or when additional line extensions are required.

- **Technology decisions are becoming more route specific.** Agencies are not treating BEBs and fuel cell electric buses (FCEBs) as interchangeable. BEBs are generally being considered where range, charging windows, and depot capacity are workable. FCEBs are being considered for longer blocks, higher mileage service, or locations where charging constraints remain difficult.
- **The ZEB market is still maturing.** Agencies and interviewees cited limited OEM options and cutaway vehicles and real-world performance issues. OEMs noted that agencies can reduce risk by engaging manufacturers early and using pilot bus builds for larger procurements.
- **Workforce readiness is a major support need.** Agencies identified maintenance technician training, safety and emergency response training, and operator/driver training as priority needs. Interview responses also showed that agencies benefit when ZEBs are used consistently in daily service, allowing the team to build familiarity with the technology and operating procedures.
- **Regional coordination would be valuable, but it needs to be practical and implementation focused.** Agencies expressed strong interest in best practice sharing and peer coordination. They also find that centralized funding information, joint procurement opportunities, and shared training could be helpful. In addition, agencies, particularly small ones with limited resources, are looking for utility engagement support and clear implementation guidance.

4.2 Summary of Research and Engagement

The SCAG region shows strong policy alignment with Innovative Clean Transit (ICT) regulation requirements and early deployment momentum, but transit agency readiness varies across key dimensions. This section summarizes regional readiness based on the existing conditions assessment presented in Sections 2 and 3, as well as stakeholder engagement findings from the surveys and interviews discussed in Section 4.1.

Regulatory and Planning Readiness

As mentioned in Section 3, California's ICT regulation requires submission of a ZEB rollout plan. While transit agencies have submitted rollout plans, the level of operational details vary, reflecting available capacity and resources. Supported by greater in-house technical expertise, larger agencies provide detailed ZEB implementation roadmap, including route/block energy modeling, infrastructure schedules, utility coordination timelines, and workforce development strategies. Smaller agencies focus primarily on meeting ICT regulation compliance and face more uncertainty in technology selection due to the evolving ZEB market and infrastructure.

Technology pathway varies by transit agency because of uncertainties of ZEB market and infrastructure availability. Some agencies outline a mixed-technology strategy with clear decision triggers. Others keep options open while they evaluate technologies through pilot projects.

Bus Deployment and Infrastructure Readiness

As mentioned in Section 3, multiple chargers and hydrogen stations have been deployed to support ZEBs in the SCAG region. However, ZEB deployment progress is uneven. Large agencies are scaling multi-depot plans and standardizing approaches, while many small agencies are still in early planning stages. They are discussed below by three groups:

Tier 1 - Operational Leaders and Advanced Scalers

These agencies are already operating substantial ZEB service (or fully transitioned) with established infrastructure, so readiness is driven less by whether ZEBs work and more by scaling efficiently and reliably. Examples include AVTA, LA Metro, OCTA, Foothill and SunLine.

Next steps for this tier typically focus on system optimization and replication: enhancing site resilience with solar/BESS where feasible, tightening O&M and parts strategies, standardizing charger/fueling configurations, and documenting playbooks that can be transferred to other agencies.

Tier 2 – Bus and Infrastructure Delivery in Progress

These agencies have clear ZEB pathways and near-term fleet activity, but the schedule to full transition is governed by infrastructure and or bus delivery. Examples include Omnitrans, Santa Clarita Transit, RTA, and VVTA.

Next steps for this tier are execution heavy: work on permitting and interconnection, finalize operating strategies (e.g., temporary/mobile fueling or mobile charging), lock construction phasing that preserves operations, and plan for commissioning and training.

Tier 3 – Early-stage or Foundational Readiness

These agencies are at pre-deployment or planning only stages, where readiness is primarily limited by planning maturity, staffing capacity, and early utility engagement, rather than bus availability alone. Examples include Simi Valley, PVVTA and Beach Cities Transit.

Next steps for this tier are about building an executable first project: establishing a realistic ZEB roadmap and fleet phasing through the development of the ZEB rollout plans, completing site and load studies, beginning structured utility coordination, and packaging funding application for "Phase 1" infrastructure to move from concept to design and procurement.

Mixed-technology pathways are common and often require trial-and-test. As mentioned in Section 2.2 and Section 3.1, agencies, particularly the large ones, are frequently pursuing a mix of BEBs and FCEBs to match route blocks, facility constraints, and operational flexibility. This technology selection process is an "adaptive" strategy rather than a single best-fit solution.

Facilities and infrastructure are often the critical paths. As summarized in Section 3.3 and reflected in surveys and interviews findings in Section 4.1, infrastructure maturity is uneven and frequently drives the schedule for full fleet transition. Common roadblocks include utility upgrades and interconnection timelines, limited depot space, construction sequencing, and permitting.

Funding Readiness

The Senate Bill (SB) 125 "Transit Transformation Task Force Final Report" emphasizes that funding programs are central to this transition. The scale of required investment is substantial, especially as agencies move toward full fleet conversion. Early pilot project success helps to derisk implementation, but it does not materially reduce long-term capital and operating funding needs. This dynamic is echoed by transit agencies, which have highlighted that one-time or short-term funding awards are not sufficient to support a systemwide ZEB transition because ZEB transition costs are significantly higher than conventional fleets. Transit agencies also reinforce that sustained, multi-year funding is essential to maintain rollout momentum.

At the same time, the current funding landscape is insufficient and uncertain. Multiple transit agencies described heavy reliance on a patchwork of federal/state/local sources (e.g., Clean Truck and Bus Voucher Incentive Project, SB 125, Low/No, Bus & Bus Facilities, Congestion Mitigation and Air Quality Improvement Program, Transit and Intercity Rail Capital Program) but noted that several of the most important programs are highly competitive, require repeated application effort with uncertain outcomes, or face budget and policy volatility. For example, some agencies reported unsuccessful attempts at major federal grant programs and escalating vehicle costs that may force reductions in planned purchases. There are also concerns that state budget uncertainty could disrupt key transit operations. Smaller agencies often have limited in-house grant writing and technical capacity, and they are in great need for targeted external support to access funding.

Institutional and Workforce Readiness

While most agencies recognize the need to build internal capacity, the institutional and workforce readiness varies significantly by agency size and resources.

- **Institutional capacity differs by agency size.** Larger operators generally have dedicated internal staff for planning, procurement, grants, and project delivery, while smaller agencies often operate with lean teams that must cover multiple functions, making it harder to move quickly from concept to implementation.
- **There is growing recognition that ZEB transition requires new skill sets and roles**. Regionally, agencies increasingly acknowledge the need for specialized capabilities spanning utility coordination and interconnection management, and ZEB and infrastructure operations. Existing workforce development programs and OEM training are available, but transit agencies indicate that training and role development, particularly for maintenance and safety, remain ongoing needs.
- **Regional collaboration can partially offset staffing constraints and accelerate readiness**. Interviews with transit agencies highlight practical mechanisms, e.g., joint procurements and shared training, that can help agencies with lean teams access expertise, reduce duplicative effort, and shorten learning curves as technologies and standards evolve.

Overall, research and transit agency interviews suggest that regional readiness for a full ZEB transition is constrained mainly by implementation factors. The most common constraints include sustained capital and long-term operations and maintenance funding, vehicle availability and reliability, and utility service upgrades and interconnection timelines. Workforce development programs and OEM training opportunities are available, but smaller agencies often lack the staffing and in-house technical capacity to move efficiently without targeted technical assistance and program support.

5 Key Challenges and Opportunities

Based on the best practices summarized in Section 2, the regional existing conditions presented in Section 3, and the survey and interview findings discussed in Section 4, key challenges and opportunities for zero-emission bus (ZEB) deployment are summarized in this section of the report.

Challenges to ZEB Deployment

- **ZEB Rollout Planning, Scheduling and Analytical Gaps**: ZEB rollout plans are an important starting point, but the level of detail varies across agencies. Many plans still need stronger route analysis, charging and fueling strategies, cost analysis, risk planning, and clearer steps for workforce, equity, and resilience. They also need realistic implementation schedules that account for procurement, permitting, utility coordination, and workforce readiness.
- **Technological and Operational Barriers**: ZEB technologies are advancing, but real-world performance still depends on route length, terrain, climate, duty cycle, and vehicle type. Agencies continue to face challenges with range, reliability, scheduling flexibility, vehicle availability, spare needs, and limited options for cutaways and other specialized vehicles.
- **Policy, Permitting, and Institutional Challenges**: ZEB deployment requires agencies to manage policy uncertainty, local permitting, utility coordination, and long infrastructure timelines. These challenges can be especially difficult for small and rural agencies with limited staff capacity.
- **Cost and Funding Gaps**: High upfront costs and uncertain operating costs remain major barriers to scaling ZEB deployment. Competitive funding programs, changing incentive rules, and the need to combine multiple funding sources make project timing and readiness especially important.

Opportunities to Accelerate ZEB Deployment

- **Regulatory and Planning**: Transit agencies can strengthen ZEB implementation by aligning rollout plans with other planning efforts, such as short-range transit plans and capital improvement programs. There are also opportunities to coordinate transit and truck infrastructure planning.
- **Technology**: A regional ZEB coordination structure can help agencies share lessons learned, align on best practices, and reduce duplicated effort. Practical toolkits, standard templates, and joint procurement approaches can also help agencies lower soft costs and move more efficiently from planning to implementation.
- **Infrastructure**: A regional utility engagement framework can help agencies coordinate earlier with utilities. Shared charging or fueling models may also work in targeted locations where multiple operators already converge or where shared access can improve resilience.
- **Funding**: Transit agencies would benefit from a centralized funding tracker to monitor program timelines, eligibility, match requirements, and application opportunities. Coordinated funding advocacy can also help elevate shared regional needs and support future program design.
- **Workforce**: A shared workforce strategy can help agencies build the skills needed to operate and maintain ZEB fleets, especially for smaller agencies with limited training capacity.

6 Implementation Action Plan

This Implementation Action Plan provides a roadmap to help transit agencies in the SCAG region transition to zero-emission buses (ZEBs). The action plan organizes near-, mid-, and long-term actions around five goals, identifies opportunities for SCAG to support, and highlights helpful pathways to support implementation. This implementation plan is grounded in the regional priorities established in the Connect SoCal Regional Transportation Plan/Sustainable Communities Strategy and is also designed to align with and support the state's zero-emission deployment priorities outlined in the "Transit Transformation Task Force (TTTF) Final Report." Together, these frameworks reinforce the importance of advancing ZEBs in a way that supports mobility, communities, environment, economic prosperity, while also addressing related needs in funding, workforce, asset management, and capital planning.

6.1 Goals and Objectives

The implementation goals were developed to align the regional goals outlined in Connect SoCal 2024:

- **Mobility:** Build and maintain an integrated multimodal transportation network.
- **Communities:** Develop, connect and sustain livable and thriving communities.
- **Environment:** Create a healthy region for the people of today and tomorrow.
- **Economy:** Support a sustainable, efficient, and productive regional economic environment that provides opportunities for all people in the region.

In alignment with the Connect SoCal goals, this implementation plan establishes the following goals:

- **Goal 1: Strengthen Regulatory Readiness and Technology Advancement with the Objective of Accelerating ZEB Deployment.** This goal aims to help transit agencies meet Innovative Clean Transit (ICT) regulation purchase requirements and to accelerate ZEB deployment. It supports the Connect SoCal Environment goal by reducing greenhouse gas emissions and improving air quality. It also supports the Mobility goal by integrating ZEB actions into core planning and investment programs.
- **Goal 2: Improve Infrastructure Planning with the Objective of Building Reliable, Resilient ZEB Infrastructure.** This goal aims to build reliable and resilient ZEB infrastructure. It supports the Mobility goal by improving system reliability and continuity of service. It also supports the Environment goal by strengthening climate resilience through better infrastructure readiness and reduced interconnection risk.
- **Goal 3: Create Sustainable Funding Pathways with the Objective of Closing ZEB Funding Gaps.** This goal aims to enhance funding accessibility and to close ZEB funding gaps. It supports the Communities and Mobility goals by improving equitable and timely delivery of projects. It helps agencies compete for and stack funding so investment may reach communities with the greatest need.
- **Goal 4: Build Long-Term Staffing Capacity with the Objective of Developing a Skilled Workforce.** This goal aims to develop skilled workforce. It supports the Economy goal by expanding inclusive training pathways and job opportunities. It also supports the Mobility goal by strengthening the operational and maintenance capacity needed to run ZEB fleets, including capacity for small and resource limited agencies.
- **Goal 5: Promote Integrated Planning with the Objective of Leveraging Synergies with Zero-Emission Trucks.** This goal aims to leverage planning synergies with zero-emission trucks (ZETs).

It supports the Economy and Environment goals by connecting transit electrification with goods movement and municipal fleet decarbonization. It identifies corridor scale and municipal level opportunities where shared planning or infrastructure may reduce cost and accelerate progress while protecting transit operational requirements.

Table 6 summarizes how the implementation plan's goals align with the goals of Connect SoCal, and Table 7 details which entities could be involved with implementation of the actions, including lead agencies or entities, and respective responsibilities. It also outlines relevant stakeholders and partners to support the implementation of the goal.

Table 6. How ZEB Implementation Goals Align with Connect SoCal Goals

ZEB Implementation Goals	Connect SoCal Goals			
	Mobility	Communities	Environment	Economy
Goal 1: Strengthen Regulatory Readiness and Technology Advancement **Objective:** Accelerate ZEB deployment	◊		♦	
Goal 2: Improve Infrastructure Planning **Objective:** Build Reliable, Resilient ZEB Infrastructure.	♦		◊	
Goal 3: Create Sustainable Funding Pathways **Objective:** Close ZEB Funding Gaps	♦	♦	◊	◊
Goal 4: Build Long-Term Staffing Capacity **Objective:** Develop a Skilled Workforce.	◊			♦
Goal 5: Promote Integrated Planning **Objective:** Leverage Synergies with ZETs			♦	♦
Legend: ♦ primary alignment; ◊ secondary alignment				

The implementation plan was organized into short-, mid-, and long-term actions.

- **In the short term (0-2 years)**, the focus is on building a strong foundation by helping transit agencies clarify technology pathways, learn from early adopters, and make use of practical tools and guidance.
- **In the mid term (3-5 years)**, the emphasis shifts toward stronger coordination and greater scale, including regular peer exchange, more standardized procurement approaches, and repeatable support resources that help smaller agencies move from planning to deployment.
- **In the long term (5+ years)**, the focus is on institutionalizing the regional transition through common metrics, a regionwide readiness dashboard, and data-driven coordination that may identify where delays are systemic and where targeted action may help unlock progress across the region.

Table 7. Summary of Roles and Responsible Parties by Goal/Objectives

Goal/Objective	Leading Agency/Entity	Responsibilities	Stakeholders and Partners
Goal 1: Strengthen Regulatory Readiness and Technology Advancement **Objective:** Accelerate ZEB Implementation	California Air Resources Board (CARB)	Administer ICT regulation requirements and provide regulatory oversight and guidance; also provide funding support	SCAG, California Energy Commission (CEC), State and Local Agencies, Bus OEMs and Industry Partners
	Transit agencies	Implement ZEB Rollout Plans, purchase ZEBs, and integrate fleet and infrastructure needs into budgets and capital plans.	
Goal 2: Improve Infrastructure Planning **Objective:** Build Reliable, Resilient ZEB Infrastructure.	Transit agencies	Install infrastructure to support ZEB deployment	SCAG, Utilities, California Public Utilities Commission (CPUC), Infrastructure Vendor
Goal 3: Create Sustainable Funding Pathways **Objective:** Close ZEB Funding Gaps	State agencies	Establish, align, and administer funding programs for ZEBs and supporting infrastructure	SCAG, Transit agencies, OEMs, Utilities, Private Partners
Goal 4: Build Long-Term Staffing Capacity **Objective:** Develop a Skilled Workforce.	State agencies	Lead ZEB workforce planning, training coordination, and barrier reduction	SCAG, Transit agencies, Training Providers
Goal 5: Promote Integrated Planning **Objective:** Leverage Synergies with ZETs	Transit agencies, Municipal, and Freight & Port Fleet Owners	Identify operationally feasible shared sites	SCAG

6.2 Action Plans

6.2.1 Goal 1: Strengthen Regulatory Readiness and Technology Advancement

This goal is to help transit agencies meet ICT regulation ZEB purchase requirements and accelerate ZEB deployment. Under the ICT regulation, beginning in 2029, 100 percent of new purchases by transit agencies must be ZEBs, with a goal for full transition by 2040. This goal also encourages embedding ZEB rollout plans into broader agency planning such as short-range transit plans (SRTPs) and capital improvement programs (CIPs) so fleet and infrastructure needs are reflected in capital programming and budgeting cycles, which strengthens implementation.

This goal will help transit agencies comply with ICT regulation requirements and accelerate ZEB deployment through coordinated planning, strong regional collaboration, and practical implementation support. This includes integrating ZEB needs into agency capital and budget planning; improving coordination among transit agencies, CARB, SCAG, funding partners, original equipment manufacturers (OEMs), and procurement entities; and reducing barriers through shared tools, standardized approaches, peer learning, and technical assistance.

This goal aligns with Strategy 11 of the TTTF, which encourages review and discussion of ICT regulation requirements and solutions. The strategy also recommends establishing a dedicated task force to develop recommendations for the Newsom administration and legislature.

The key stakeholders for Goal 1 and their roles are summarized in Table 8 .

Table 8. Goal 1 Stakeholder Roles and Responsibilities

Goal/Objective	Agency/Entity	Responsibilities
Goal 1: Strengthen Regulatory Readiness and Technology Advancement **Objective:** Accelerate ZEB deployment	CARB (Lead)	Administer ICT requirements and provide regulatory oversight and guidance; also provide funding support.
	Transit agencies (Lead)	Implement ZEB Rollout Plans, purchase ZEBs, and integrate fleet and infrastructure needs into budgets and capital plans.
	SCAG	Convene partners, coordinate regional support, and connect agencies; also use established committees as forums to share lessons learned.
	CEC, California Department of Transportation (Caltrans), California State Transportation Agency (CalSTA), and South Coast Air Quality Management District (South Coast AQMD)	Provide funding support and implementation assistance.
	Bus OEMs and Industry Partners	Supply buses, equipment, and technical support.
	Department of General Services (DGS)	Support joint procurement by leveraging cooperative contracts, aggregate demand, and streamlined bus and equipment purchasing.
	State Legislature	Consider funding, policy, and statutory actions needed to support compliance.

Role of CARB (Lead)

CARB is the lead agency responsible for implementing and enforcing the ICT regulation, but its role extends well beyond compliance oversight. CARB works closely with transit agencies throughout implementation to help identify agency specific challenges and clarify regulatory requirements, often through direct, one-on-one technical assistance. CARB also plays an important support role in helping agencies understand and pursue available regulatory flexibilities and exemptions. CARB's exemption templates are a good example of this hands-on approach, as they are intended to simplify the application process and help agencies document circumstances such as vehicle unavailability or financial hardship in a more consistent and efficient way.

CARB has been conducting a comprehensive review to evaluate ZEB adoption and readiness for each stage of ICT implementation and is currently completing Phase II. As deployment advances, CARB should continue this evaluation by tracking vehicle performance, infrastructure uptime, costs, and other key metrics to assess progress toward ICT milestones.

Beyond regulation, CARB also supports transit agencies by administering and coordinating incentive funding that may help advance fleet transition, such as the Clean Truck and Bus Voucher Incentive Project. These funding programs may help reduce the cost of ZEB deployment and related investments.

Role of Transit Agencies (Lead)

Transit agencies are at the center of ICT implementation and ZEB deployment. They may meet ICT requirements by implementing their board approved ZEB rollout plan. In addition, they may strengthen ZEB delivery by integrating phased fleet and infrastructure needs into their core planning, such as SRTP and CIPs, and asset management programs. As the primary project leads, they manage the end-to-end ZEB delivery cycle, from securing federal and state funding to coordinating with utilities, OEMs, and infrastructure providers so that vehicle, infrastructure, and facility upgrades are aligned with operational needs.

Transit agencies also play an important role in making the ZEB delivery more efficient. In alignment with the TTTF's recommendations (Strategy 12 and Strategy 13), transit agencies may collaborate on standardized bus and paratransit specifications to help manufacturers scale production. By limiting unnecessary customization and aligning common purchasing approaches, transit agencies may leverage joint procurement. This shift not only reduces costs through volume but also secures stronger contract terms to mitigate late deliveries and performance risks.

Beyond execution, transit agencies serve as vital knowledge partners for each other, validating regional tools through pilot testing and sharing real-world lessons on procurement, deployment and maintenance.

Role of SCAG

SCAG supports transit agencies in meeting ICT requirements by leveraging its core strengths: regional planning and coordination. Rather than engaging in direct implementation, SCAG facilitates compliance by aligning ZEB transition into Connect SoCal and regional funding programs. SCAG conducts essential regional analysis to identify regional barriers and gaps, while simultaneously serves as a regulatory bridge and elevates regional needs to the state agencies.

Additionally, SCAG leverages its convening power through established forums like the Regional Transit Technical Advisory Committee (RTTAC), the Energy and Environment Committee, and the Transportation Committee to break down silos between transit agencies, utilities, and manufacturers. These platforms foster information sharing and allow agencies and local jurisdictions to discuss common challenges, strengthening regional coordination without infringing on local operational responsibilities. To further support this effort, SCAG has developed targeted toolkits under this study, such as factsheets, that translate complex data, technologies, processes, or policies into accessible information.

Role of CEC, Caltrans, CalSTA, and South Coast AQMD

The CEC manages critical infrastructure funding, such as the EnergIIZE Transit Set-Aside, specifically designed to synchronize equipment incentives with utility upgrade timelines. Caltrans and CalSTA administer vital capital and operating grant programs, such as the Low Carbon Transit Operations Program, the Transit and Intercity Rail Capital Program, and Zero-Emission Transit Capital Program, which provide the large-scale funding necessary for vehicle procurement and facility master planning.

Caltrans also provides technical assistance and practical implementation resources. For example, Caltrans partnered with the Center for Transportation and the Environment to develop the "2026 California Statewide Transit Agency Deployment Toolkit." The toolkit provides step-by-step guidance, readiness checklists, funding information, and technical resources.

At the local level, regional air quality management districts bridge the financial gap by offering streamlined grants and simplified application processes, reducing the administrative burden for agencies and speeding up the procurement of zero-emission technology.

Role of Bus OEMs and Industry Partners

Bus OEMs accelerate ICT regulation implementation by evolving into strategic partners who provide transparent, real-world performance data and manage supply chain risks through proactive delivery forecasting. Beyond hardware, they bridge the planning gap by translating complex vehicle duty cycles into charging requirements and offering smart energy management solutions.

Consistent with TTTF Strategy 12 and Strategy 13, and the American Public Transportation Association's (APTA) Bus Manufacturing Task Force recommendations, OEMs play a vital role in industry stabilization by promoting standardized vehicle specifications. By offering standardized baseline configurations, OEMs may minimize unnecessary customization that often leads to engineering delays and increased costs. This action enables joint procurement and bulk purchase discounts. Furthermore, industry partners support operational readiness through comprehensive commissioning, troubleshooting, and hands-on technical training for the existing maintenance workforce.

Role of DGS

DGS streamlines the ZEB transition and ICT regulation compliance by providing pre-negotiated, cooperative procurement contracts that aggregate regional demand. These established purchasing tools allow transit agencies, particularly smaller operators facing the 2026 purchase mandate, to bypass the high soft costs of individual requests for proposals and access standardized ZEB and infrastructure models.

Role of State Legislature

The California State Legislature serves as the primary engine for the statutory and financial frameworks necessary for ICT regulation compliance. By enacting key legislation, such as SB 125, the legislature provides the multi-year funding certainty required for large-scale ZEB procurement and infrastructure. Beyond funding, the legislature evaluates and implements policy shifts to address systemic barriers.

Goal 1 Action Plans

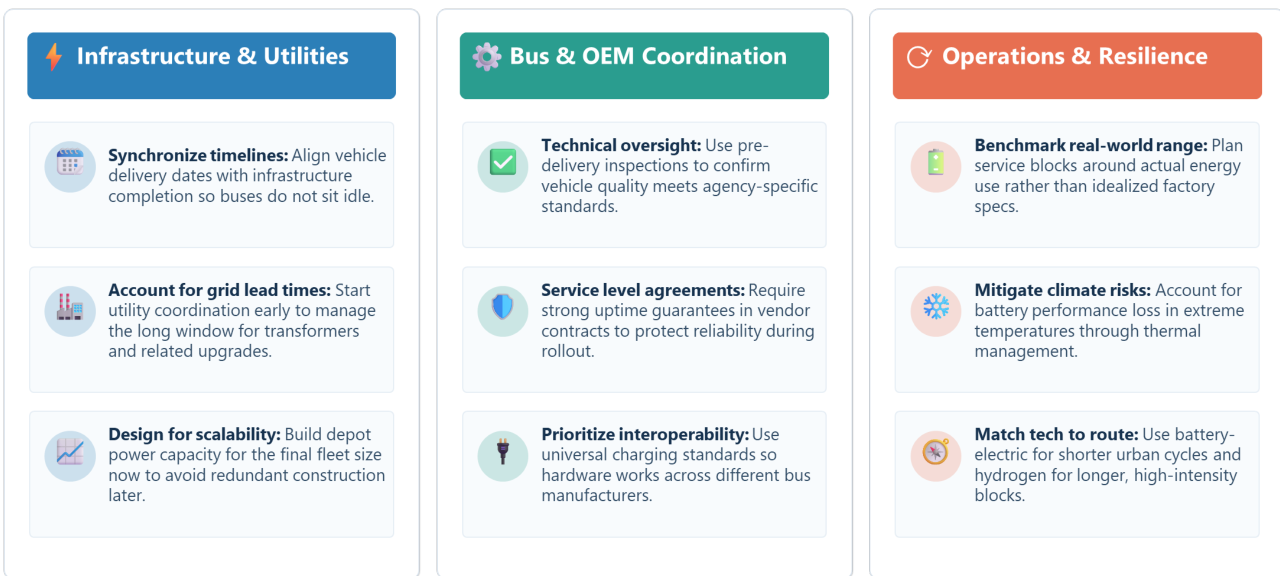
Near-Term

ZEB Technology Selection Framework: The toolkit developed as part of this study includes a ZEB technology selection framework with a standardized framework to help agencies choose between BEBs and FCEBs. It includes a decision matrix based on topography, route length, and depot electrical capacity. The toolkit also establishes foundational guidance for technology selection, which may be supported by transit agencies and OEMs to provide ongoing refinement.

It is also important to emphasize early stakeholder engagement. Agency leadership and governing boards should be involved before major technology decisions are finalized. Staff should clearly communicate the tradeoffs and operational impacts so that technically sound recommendations also receive policy level support.

Peer Lessons Learned Exchange: This exchange could be a centralized sharing of lessons learned from early adopters such as Antelope Valley Transit Authority (the first 100 percent electric fleet) and Foothill Transit (a pioneer in FCEB and on-route charging). It could focus on high-impact constraints, as demonstrated in Figure 12. SCAG could facilitate peer exchanges through communication channels, such as the RTTAC, while transit agencies could provide the essential technical leadership by sharing their experiences and lessons learned.

Figure 12. Topic Examples of Peer Lessons Learned Library



Mid-Term

ZEB Implementation Forum: Unlike the near-term peer lesson exchange, which would focus exclusively on transit agencies, this forum aims to engage with a broader set of stakeholders, including transit agencies, OEMs, utilities, and private vendors. It could be conducted quarterly or at another agreed cadence and structured as a series of high-intensity troubleshooting sessions rather than standard presentations. The goal is to resolve immediate deployment bottlenecks through multi-faceted information exchange. For example, a clinic could facilitate a dialogue on how agencies may align standardized vehicle specifications to help OEMs streamline production and reduce lead times. By convening the entities responsible for both the bus and the infrastructure, these sessions would transform isolated challenges into coordinated solutions.

For this effort, SCAG may take the lead to facilitate the forum using its convening power and secure support from transit agencies, utilities, OEMs, and other private vendors.

Joint Procurement Guide: In alignment with TTTF Strategy 13, which advocates for the stabilization of the ZEB manufacturing industry, this action focuses on aggregating demand to reduce unit costs and move toward standardized vehicle and infrastructure specifications. California's DGS may take the lead role in this effort by developing and administering the statewide cooperative contracts and joint procurement vehicles. SCAG could explore partnership with DGS by conducting regional analysis and pursuing funding for further study on this topic. Collaboratively, SCAG and DGS could identify common service profiles and technical requirements across Southern California transit agencies, such as battery capacity, charging plug types, and warranty terms. Transit agencies and OEMs could also provide support to streamline the process.

ZEB Asset Management & Technical Assistance: To address the complexities of project delivery and long-term asset maintenance, state agencies have already been taken action and provided an opt-in technical assistance program for transit agencies. For example, CARB provides free, one-on-one technical assistance through Cal Fleet Advisor, which is administered by CALSTART on behalf of CARB. This action aims to build specialized capacities to assist with lifecycle management and the strategic prioritization of routes for fleet transitions. This action would include offering expert guidance on whether specific routes are most suitable for BEB or FCEB technology, as recommended by TTTF Strategy 15. In this context, SCAG's role is to serve as a regional facilitator and liaison, helping connect transit agencies with state-led resources and coordinating with the State so that support is directed to agencies with the most immediate needs.

Long-Term

Regionwide Readiness Dashboard: A centralized publicly accessible dashboard may be helpful to visualize the zero-emission transition across all transit agencies in the region or statewide. This tool would serve as a strategic roadmap, moving beyond simple number of ZEBs deployed to track the granular health of the transition, including fleet electrification milestones, infrastructure installation and construction progress, and utility interconnection stages.

State agencies, such as CARB and CalSTA, are best positioned to lead this effort, as they already collect and maintain mandatory compliance data through ICT reporting and SB 125 accountability programs. State agencies may analyze the regional data. They also utilize the dashboard's regional data to identify where delays are systemic and where targeted intervention is required to unlock progress. SCAG may support this process through convening, communications, or analysis.

6.2.2 Goal 2: Improve Infrastructure Planning

This goal focuses on building a reliable and resilient infrastructure network that keeps pace with the region's ZEB transition. The infrastructure includes not only charging and refueling stations but also the utility side electrical upgrades—such as transformers and transmission and distribution—required to support them. A central objective is ensuring that infrastructure delivery aligns with bus procurement schedules by clarifying lead times and coordinating early with utilities and infrastructure vendors. This goal also emphasizes designing for scalability and resilience from the outset, including installing electrical backbones that support future expansion and incorporating on-site storage and back-up power, where feasible.

The strategy for this goal is to strengthen early coordination, improve utility and permitting readiness, and plan for long-term reliability. This requires aligning transit agencies, utilities, SCAG, CPUC, and infrastructure vendors around shared timelines, consistent planning assumptions, and scalable facility design so that charging and fueling systems are ready when buses arrive and remain dependable to support service during disruptions or extreme events. Table 9 summarizes key stakeholders and their roles for Goal 2.

Table 9. Goal 2 Stakeholder Roles and Responsibilities

<table>
<tr><th>Goal/Objective</th><th>Agency/Entity</th><th>Responsibilities</th></tr>
<tr><td rowspan="5">Goal 2: Improve Infrastructure Planning
Objective: Build Reliable, Resilient ZEB Infrastructure.</td><td>Transit agencies (Lead)</td><td>Install infrastructure to support ZEB deployment.</td></tr>
<tr><td>SCAG</td><td>Use convening power to align regional utility planning and advocate for streamlined local permitting.</td></tr>
<tr><td>Utilities</td><td>Execute grid upgrades in alignment with agency timelines.</td></tr>
<tr><td>CPUC</td><td>Establish accountability mechanisms and standardized timelines for utilities to support transit.</td></tr>
<tr><td>Infrastructure Vendor</td><td>Provide hardware and charge management software.</td></tr>
</table>

Role of Transit Agencies

Transit agencies are the front line and should play lead roles to deliver reliable and resilient infrastructure. Key responsibilities include:

- **Rigorous load and site assessments:** Transit agencies quantify power and fueling needs for both near-term deployment and future expansion. This includes evaluating peak and extreme condition demand so infrastructure designs may support reliable service.
- **Designing for resiliency and extreme events:** Transit agencies can improve the resilience of their facilities against wildfires, seismic risks, and grid outages. They should integrate onsite energy assets, such as battery storage or backup power solutions, to support limited operations during outages and reduce service disruption.
- **Strategic cross-agency collaboration:** Transit agencies should explore shared charging or fueling hubs where feasible and coordinate procurement for common equipment to reduce costs. They can also develop mutual aid approaches that allow emergency access to charging, fueling, or spare capacity during emergencies. This aligns with TTTF Strategy 14, which encourages shared facilities and co-location of charging and fueling.

Role of SCAG

SCAG can support ongoing regional transit–utility working groups to help maintain alignment on deployment timelines. SCAG can encourage communication and data sharing between transit agencies and utilities, so that utilities may develop high-level load outlooks and identify priority sites and corridors that require urgent discussion and grid readiness. To streamline the process, SCAG can assist state agencies to support basic planning tools. Furthermore, SCAG can coordinate and identify opportunities for shared infrastructure by mapping overlap points where multiple operators converge.

Role of Utilities

Utility providers play a central supporting role in building reliable, resilient ZEB infrastructure by providing interconnection and service upgrades. Utility providers should define expected timelines for studies, permitting, and grid upgrades, and then manage projects to those schedules. Utility providers can also streamline early coordination by using a standard customer submittal package from transit agencies at the time of application, such as a site plan, load schedule, single-line diagram, and fleet plan. A dedicated account manager who serves as the primary point of contact throughout the project lifecycle can further improve coordination, reduce handoffs, and help keep design, construction, and energization on track.

Role of CPUC

As a regulatory agency, the CPUC ensures that the electrical grid meets the high-power demands of ZEBs. CPUC's primary responsibility is to create accountability for investor-owned utilities (IOUs) to prevent infrastructure delays from becoming a bottleneck for bus deployments. Suggested actions include enforcing standardized energization timelines, such as the 125-business-day average target for charging stations, and streamlining electric vehicle (EV) infrastructure rules.

Role of Infrastructure Vendors

Infrastructure vendors provide the critical hardware and management systems needed to bridge the gap between energy supply and fleet operations. For electric fleets, this includes dispensers and charge management software to optimize power draw and avoid utility spikes. For hydrogen fleets, vendors provide high-capacity storage, compressors, and dispensing systems, often bundled with fueling management software to track pressure, purity, and inventory.

Goal 2 Action Plans

Near-Term

Actions focus on eliminating administrative delays and ensuring that agencies and utilities speak the same technical language.

Smart Charging Factsheet: The toolkit, developed as part of this study (Appendix I), explains what smart charging is, why it matters, and how it helps improve reliability, operational readiness, and cost control for electric bus charging. It also outlines how smart charging works in practice, summarizes common charging strategies. It gives examples of transit agency deployments and example vendors used in transit smart charging systems.

Utility Engagement Starter Kit. Developed in this Study (Appendix I), the toolkit includes a framework that helps transit agencies identify the right utility points of contact. Transit agencies may want to clarify with their respective utility provider if a dedicated transportation electrification or fleet team is defined, so coordination stays consistent as fleet phasing, upgrade schedules, and funding timelines evolve. The framework also includes a high-level concept package that agencies can share up front to start productive conversations and reduce back-and-forth. It provides a generic utility data request checklist to support an initial assessment.

Permitting and Approval Checklist. This checklist included in the study toolkit (Appendix I), aims to reduce rework and schedule uncertainty. It navigates local permitting for both EV charging and hydrogen fueling by highlighting California streamlining laws and centralizing where to find specific requirements for each jurisdiction. The guide outlines common application essentials, including project narratives, site layouts, equipment specifications, and detailed electrical or station plans, to ensure submittals are complete on the first try. This effort aligns with TTTF Strategy 9, which focuses on shortening capital project delivery timelines by streamlining environmental review, permitting, and decision-making.

Mid-Term

Actions of this stage move beyond basic power connections to focus on long-term reliability and resilience to strengthen the regional network.

Resiliency Guidance for Depots: Transit agencies may lead this effort to ensure future proofing facilities against grid outages and extreme weather. This action echoes SCAG's Regional Resilience Toolkit, which emphasizes integrating resilience into transportation and infrastructure planning.

- **Managed Charging Readiness:** Transit agencies should explore software and hardware that may throttle power during peak heatwaves, protecting the grid while ensuring bus power meets needs for services.
- **Backup Power and Facility Resilience:** Transit agencies should evaluate battery storage, microgrids, and other energy resilience measures to maintain depot operations and charging capability during outages.
- **Contingency Planning:** Transit agencies should establish backup protocols for service continuity during wildfires, seismic events, or extended blackouts to ensure the region stays mobile during emergencies.

Regional Collaboration: While SCAG should encourage agencies to work together, reducing the burden of standalone projects, large transit agencies **can** take the lead role to implement regional collaboration, examples include:

- **Shared Utility Upgrades:** Transit agencies can coordinate with utilities and offer multi-agency agreements where two or more operators share a high-capacity circuit or substation, splitting the cost and accelerating the utility construction timeline.
- **Joint Infrastructure Delivery:** TTTF Strategy 14 recommends shared use charging or fueling hubs, allowing agencies to offer mutual aid or emergency backup power to one another across jurisdictional lines. Transit agencies should lead this effort, supported by SCAG to assist planning and state agencies to prioritize funding.

Long-Term

Corridor Co-Location Mapping Tool: Development of a GIS-based mapping tool would synchronize regional transit infrastructure demand with available grid and fueling capacity. This tool would serve as the regional master plan for infrastructure deployment by:

- **Identifying Phased Grid Upgrades:** The tool may include GIS map layers of transit depot, hubs, and routes with utility substation data (e.g., integration capacity analysis maps from IOUs) to flag where the grid is strongest and where it is most constrained. Transit agencies can use this data to coordinate with utilities on a phased schedule of bulk upgrades, ensuring high-power circuits are ready before multiple agencies in the same corridor hit peak demand.
- **Pinpointing Shared-Use Opportunities:** By mapping points where different operators converge, such as common transit hubs or adjacent service boundaries, transit agencies can identify prime locations for shared-use charging or hydrogen fueling stations.
- **Optimizing Regional Redundancy:** The mapping tool may identify geographic gaps in fueling and power. This would enable a regional strategy for placing backup infrastructure in locations that serve as emergency islands for multiple agencies during regional disasters or grid failures, ensuring the system remains resilient at scale.

This effort may be co-led by SCAG (assuming funding permits) and utilities, with inputs and strong support from transit agencies, particularly about data sharing.

6.2.3 Goal 3: Create Sustainable Funding Pathways

Goal 3 focuses on securing the financial resources needed to sustain the ZEB transition by closing the gap between today's budgets and future requirements. The scale of required investment is substantial, especially as agencies move toward full fleet conversion. One-time or short-term awards are not enough to support a systemwide transition because ZEB costs remain higher than conventional fleets. To respond, the region needs a clearer understanding of lifecycle costs and specific funding gaps, with long-term maintenance and energy costs prioritized alongside bus purchases.

State agencies establish, align, and administer funding programs for ZEBs and supporting infrastructure. They are also responsible for improving funding flexibility and predictability and streamlining grant processes, as recommended by TTTF Strategy 4, Strategy 7, Strategy 8, and Strategy 26. SCAG can play an advocacy role by supporting broadened available funding opportunities, enhancing regional project competitiveness through alignment with state and federal priorities, and promoting collaborative approaches including multi-agency grant applications.

The strategy for this goal is to build a stable and coordinated funding framework that can support the full cost of the ZEB transition over time, not just early pilot projects. State agencies can lead by aligning and administering funding programs for vehicles and infrastructure, while SCAG can support regional coordination, project prioritization, and funding strategy development. Transit agencies should define needs, develop fundable projects, and secure and manage awards with support from OEMs, utilities, and private partners to reduce costs, improve project readiness, and expand financing options for vehicles and supporting infrastructure. The key stakeholders and their roles for this goal are summarized in Table 10.

Table 10. Goal 3 Stakeholders Roles and Responsibilities

Goal/Objective	Agency/Entity	Responsibilities
Goal 3: Create Sustainable Funding Pathways **Objective:** Close ZEB Funding Gaps	State agencies (Lead)	Establish, align, and administer funding programs for ZEBs and supporting infrastructure.
	SCAG	Support regional coordination, project prioritization, and funding strategy development.
	Transit agencies	Define needs, develop projects, secure and manage funding.
	OEMs	Align production, pricing, and sourcing with grant requirements, while providing compliant options and identifying cost-saving opportunities.
	Utilities	Reduce upfront infrastructure costs, provide technical support.
	Private Partners	Offer financing models.

Role of State Agencies

State agencies, such as CalSTA, Caltrans, CARB, and CEC, can lead funding for ZEBs and supporting infrastructure by aligning grant programs, procurement tools, and technical assistanceand coordinating funding timelines, utility support, and project delivery requirements.. These agencies should seek to provide the foundational and high-impact funding architecture. In addition, local agencies, such as the South Coast Air Quality Management District, should offer specialized local grants to accelerate infrastructure deployment in the region's most pollution-burdened corridors. The state legislature can support this work through appropriations and statutory changes.

Role of SCAG

SCAG is uniquely positioned to serve as a regional anchor and funding advocate. By centralizing data and coordinating a unified regional voice, SCAG may support in the following areas:

- **Strategic Legislative and Policy Advocacy:** SCAG can elevate shared regional needs in state and federal budget conversations. By engaging with the state legislature and federal partners, SCAG can advocate for flexible, long-term funding streams that cover vehicle purchases and essential charging and refueling infrastructure, as well as soft costs if possible.
- **Technical Assistance and Grant Ready Resources:** SCAG can provide additional support to help smaller transit agencies navigate complex federal requirements. Additional support could include offering workshops and regional data to strengthen local applications, as well as direct assistance with reviewing and offering feedback on grant narratives.
- **Prioritize ZEB Projects in Regional Funding Programs:** SCAG can work to prioritize ZEB vehicles and supporting infrastructure through its calls for projects and other regional funding processes, helping direct available funds toward high-priority transit fleet and infrastructure needs while reinforcing regional readiness and implementation goals.

Role of Transit Agencies

Individual agencies should define priority projects, develop scopes and cost estimates, and prepare application materials. Agencies can also coordinate with peer agencies to share upcoming needs, cost estimates, and planned submissions so SCAG can support coordination, strengthen positioning, and reduce avoidable competition. Meanwhile, transit agencies can identify opportunities for joint procurement, simplified customization, and other cost-saving strategies that maximize how far available funding goes in getting ZEBs on the road.

Role of OEMs

OEMs can support funding for ZEBs and related infrastructure by aligning vehicle production, pricing, and technical specifications with grant requirements and agency procurement timelines. They can also help reduce costs by offering more standardized vehicle configurations, providing reliable cost and delivery information, and identifying sourcing and manufacturing approaches that improve affordability where funding rules allow.

Role of Utility Providers

To achieve Goal 3, utility providers may support and serve as strategic co-investors by providing the technical infrastructure to bypass massive upfront capital hurdles. Investor-owned utilities may enhance funding access through make-ready programs, such as Southern California Edison’s Charge Ready Transport, which cover the costly electrical upgrades from the grid to the meter, effectively absorbing millions in site preparation expenses.

Role of Private Partners

Private partners offer public-private partnership (PPP) models, such as infrastructure-as-a-service, where private entities design, build, and maintain charging or fueling hubs in exchange for predictable service fees. These collaborations strive to convert high-risk capital outlays into manageable operating expenses while leveraging private-sector expertise to ensure long-term system reliability and resilience.

Goal 3 Action Plans

Near-Term

Actions focus on establishing basic funding clarity and making sure all agencies are aware of immediate funding opportunities.

Regional ZEB Funding Roadmap: The toolkit (Appendix I) developed with this study provides a funding roadmap that summarizes funding streams available for ZEB deployment. This summary categorizes funds for vehicles and infrastructure and clarifies funding eligibility and stackable opportunities.

Mid-Term

As agencies prepare larger deployments, a grant application accelerator can reduce the administrative burden of complex federal applications.

Grant Application Accelerator: A regional accelerator program could be launched to provide a suite of grant-related resources. SCAG could lead this effort through the RTTAC by sharing best practices on standardized project narratives and templates, permit processes to deploy ZEBs, and cost-benefit analysis. SCAG can also continue to provide support letters to partners and transit agencies for grant applications.

Strategic Legislative and Policy Advocacy: State agencies can lead efforts to secure and align flexible, long-term funding for ZEB vehicles, charging and refueling infrastructure, and related implementation costs. SCAG may play an important supporting role by elevating shared regional needs in state and federal budget discussions and advocating for funding structures that better reflect transit agencies' real deployment challenges.

Long-Term

Shared Infrastructure Financing: Transit agencies may explore joint-use financing models where multiple agencies share the cost of a single high-capacity charging or hydrogen fueling hub, leveraging economies of scale to lower the per-bus cost of the transition.

PPPs for Scalable Delivery: Transit agencies can take the lead role to explore PPP delivery models, including Infrastructure-as-a-Service or Charge-as-a-Service.

6.2.4 Goal 4: Build Long-Term Staffing Capacity

Goal 4 focuses on building the skilled workforce needed to sustain the ZEB transition. Workforce capacity is an obstacle as agencies scale from pilots to full fleet conversion. Training needs across maintenance, operations, safety, and facility roles are growing fast. Smaller and capacity-limited agencies particularly face bigger barriers because they have fewer staff and limited access to structured training. To respond, the region needs clearer and more consistent workforce pathways, with shared core competencies and common certifications. This goal aligns with TTTF Strategy 17 and Strategy 18, which emphasize workforce recruitment, retention, and development.

The strategy for Goal 4 is to create a more consistent and accessible workforce development system that equips transit agencies with the staff and skills needed to support long-term ZEB operations. This includes defining shared training needs across agencies, improving coordination among state agencies, SCAG, transit operators, and training providers, expanding practical and role-based training opportunities, and building repeatable pathways that make it easier for agencies of all sizes to recruit, train, and retain qualified personnel.

Table 11 outlines the key stakeholders and roles for Goal 4.

Table 11. Goal 4 Stakeholder Roles and Responsibilities

Goal/Objective	Agency/Entity	Responsibilities
Goal 4: Build Long-Term Staffing Capacity **Objective:** Develop a Skilled Workforce.	State agencies (Lead)	Lead ZEB workforce planning, training coordination, and barrier reduction.
	SCAG	Coordinate regional partners and identify shared training needs through RTTAC.
	Transit agencies	Define workforce needs and participate in training.
	Training providers	Deliver training program.

Role of State Agencies

State agencies can lead workforce development by setting statewide training priorities for ZEB maintenance, charging and fueling infrastructure, and related safety skills. CalSTA and Caltrans may lead coordination and workforce planning by advancing shared training programs (such as those listed in Section 3.5) and standardized credentials. Transit agencies, colleges, and labor partners are important partners, but state agencies can lead and scale the overall effort.

Role of SCAG

SCAG can play a coordinating role by using RTTAC to bring together transit agencies, community colleges, labor partners, and training providers around shared workforce needs for the ZEB transition. While RTTAC can help identify common workforce gaps by role, SCAG may facilitate the exchange of practical resources such as job role definitions, core competencies, and training approaches. SCAG could also use RTTAC to strengthen coordination across existing programs so agencies are better connected to available training resources and may pursue more aligned regional solutions.

Role of Transit Agencies

Transit agencies can define the specific skills and certifications they need, based on their fleet mix, facilities, and maintenance practices. They can provide input on curriculum content, share lessons learned from early deployments, and offer hands-on learning opportunities such as site visits, guest instructors, or apprenticeship placements. Agencies can also commit staff time for cohorts when feasible and coordinate with training providers to ensure graduates are prepared for day-to-day ZEB maintenance and safety requirements.

Role of Training Providers

Training providers, including community colleges, labor training centers, and OEMs, can translate regional needs into practical training. By designing curricula aligned with the region’s core competency framework, these entities provide essential hands-on instruction using modern buses, charging infrastructure, fueling equipment, and high-voltage safety tools. To ensure technical relevance, OEMs support role specific training through train-the-trainer programs and the sharing of proprietary service bulletins and diagnostic protocols. Simultaneously, community colleges and regional partners mitigate access barriers by offering flexible scheduling, cohort-based delivery models, and comprehensive wraparound services.

Goal 4 Action Plans

Near-Term

Actions may focus on defining what skills the region needs first and make training options easy to find and use.

Workforce Development Toolkit: The toolkit developed as part of this study (Appendix I), provides a roadmap and starting point to help transit agencies identify ZEB workforce needs, target role specific training, and prepare staff for safe and effective zero-emission fleet deployment.

Priority Roles and Gap Identification: Transit agencies define priority job roles such as bus operators, maintenance technicians, facilities staff, and safety leads. SCAG can support transit agencies to document required skills for each role and identify gaps by agency size and technology pathway by sharing best practices through the RTTAC. This effort may be led by transit agencies and supported by ongoing work by the CARB through the reporting toolkit and associated database.

Regional Training Catalog and Minimum Competencies: This effort would develop a regional catalog of existing training programs and entry requirements. This could also include a minimum competency checklist, so training providers and agencies align baseline expectations. CARB already conducts several trainings through CALSTART and could lead this effort by providing a list of trainings and schedules to SCAG to be shared with the RTTAC and other transit stakeholders. Transit agencies may also coordinate additional trainings and competency efforts in partnership with APTA, California Transit Association, and California Transit Training Consortium (CTTC).

Mid-Term

As deployments scale, actions can be shifted from planning to delivery by launching hands-on partnerships that create more training seats and reduce burden on small agencies.

Local Training Partnerships and Hands-On Modules: Local partnerships can be formed among community colleges, OEMs, labor partners, and transit agencies. These partnerships may deliver hands-on modules using real equipment and real depot conditions.

Train-the-Trainer and Shared Instruction Capacity: Train-the-trainer options are encouraged for transit agencies to build internal champions. Transit agencies can coordinate to pool instructors and equipment across agencies, so smaller agencies can participate without building their own programs from scratch. This may be facilitated through existing groups like SunLine Transit's West Coast Center of Excellence in Zero-Emission Technology, CTTC, and Southern California Zero Emission Transit Forum.

Long-Term

Over the long-term, state agencies can lead the development of a sustained training pipeline that repeats every year and grows with the market. SCAG can support this work by coordinating regionally and helping connect agencies to shared training resources. Transit agencies may participate by identifying workforce needs and enrolling staff.

Repeatable Regional Cohorts: Recurring cohorts may be established for each key role, with consistent schedules and clear prerequisites. This may create a predictable pipeline for hiring and upskilling across the region.

Shared Training Capacity and Facilities: Shared access to training sites, labs, and mobile training units may increase training throughput and reduce duplication of equipment purchases.

Workforce Funding: State agencies can lead workforce funding by developing and aligning funding programs that support ZEB training. They can also coordinate funding opportunities across agencies to sustain workforce development over time, rather than relying on one-time efforts.

6.2.5 Goal 5: Promote Integrated Planning

Goal 5 focuses on leveraging synergies with ZETs, including municipal fleet vehicles, to accelerate the ZEB transition. This goal is supported by TTTF Strategy 14, which encourages shared maintenance and infrastructure support. Transit and freight are moving through similar market constraints. They face similar charging and hydrogen refuel infrastructure installation, utility upgrade timelines, interconnection queues, and construction and permitting bottlenecks. They also rely on overlapping workforce skills in high-voltage safety, diagnostics, and facility operations.

To respond, the region should prioritize shared solutions that reduce cost and schedule risk for transit first, while using freight scale to improve investment efficiency where it aligns. Coordination and corridor planning are essential so transit depots and truck hubs align with grid readiness needs and utility upgrade plans. Identification of joint-use opportunities for charging or hydrogen hubs where operators converge can lower costs and improve reliability. Finally, the region should develop shared workforce and safety training programs where competencies overlap.

The strategy for this goal is to encourage early and coordinated planning among transit agencies, municipal and freight and port fleet owners, and SCAG to identify and advance shared opportunities that support both ZEB and ZET deployment while protecting transit service needs first. Planning is especially important because transit and freight depend on similar infrastructure, utility upgrades, workforce skills, and corridor conditions. Early coordination helps reduce costs, avoid schedule conflicts, and improve long-term system reliability.

Stakeholder roles and responsibilities for this goal are summarized in Table 12.

Table 12. Goal 5 Stakeholder Roles and Responsibilities

Goal/Objective	Agency/Entity	Responsibilities
Goal 5: Promote Integrated Planning **Objective:** Leverage Synergies with ZETs	Transit agencies (Lead)	Identify operationally feasible shared sites, set transit-priority rules
	Municipal, and Freight & Port Fleet Owners (Lead)	Can also identify possible shared sites, bring demand for shared-use projects, help define site operating rules, coordinate integrated utility upgrade planning
	SCAG	Convene partners, help identify promising corridors and candidate sites through future research

***Role of Transit Agencies*:** Transit agencies should validate which public sites are operationally feasible based on routes, dwell time, and facility constraints. They can set and enforce transit-priority operating rules and site procedures. Transit agencies also lead site-specific design and operations decisions and address logistics such as payment, circulation, liability, security, and uptime expectations. Shared-use policies or business rules should be established to ensure that truck fleets are treated as equal partners in the operating plan.

Role of Municipal, and Freight & Port Fleet Owners*:* When charging or hydrogen infrastructure is shared at designated depots, municipal and private truck fleet owners can strengthen shared charging or hydrogen projects by bringing clear demand that help improve utilization near ports and freight corridors. Collaboration can begin with site selection and planning, conducted by both the transit agencies and municipal and private truck fleet owners, recognizing that each party will have different capacity and infrastructure needs. Truck fleet owners could commit to utilization targets or service agreements and help define operating rules so the shared site is financeable and reliable. When truck fleet owners host the site, they can provide land and manage daily operations with truck uptime as the priority. Communications should be initiated during the early planning stages with transit agencies. Transit access should be clearly pre-defined for emergency conditions and when space capacity is available.

***Role of SCAG*:** SCAG may use the Connect SoCal process and "Southern California Zero-Emission Truck Infrastructure Study" goods-movement analysis to identify areas with electrical capacity constraints and pinpoint the best corridors and clusters for shared sites, if possible, then screen a shortlist of candidate depots and corridor locations for charging and hydrogen. This effort can also help identify areas with joint demand from transit and truck fleets that can align utility upgrades to substations and energy distribution circuits that will meet future demand from both parties. SCAG can convene transit, utilities, and freight partners to align on technology pathways, regional utility infrastructure planning, and interoperability.

Goal 5 Action Plans

Near-Term

For the near-term, SCAG can focus on identifying shared ZEB and ZET opportunities that are easy to implement and do not create service risk for transit.

Define Low-Risk, High-Value Shared Opportunities: Leading transit agencies and municipal fleet partners, SCAG can coordinate and assist to identify workforce opportunities and pinpoint where shared charging or hydrogen fueling could improve utilization and lower unit costs while keeping transit operations protected first. Involving local community college trade programs, unions that represent the region's skilled workforce, and potential funding partners would strengthen the partnership, support comprehensive program design, and help fill workforce gaps with a trainee-to-technician pipeline.

Mid-Term

As interest grows, state agencies can shift from concept to execution by organizing coordination and creating tools that make partnerships repeatable.

Partner Coordination and Pilot Documentation: Utilities, transit agencies, and municipal and freight stakeholders can align timelines and operational assumptions and document pilot structures. This coordination can include planning for aggregated demand, parking needs, and early utility engagement to secure alignment on infrastructure requirements and service expectations.

Cross-Sector Collaboration: Transit agencies and municipal fleet operators can work together to clarify roles, governance, and cost allocation concepts. They can draft templates that reduce transaction costs for future shared projects. They can also work with state agencies and training providers to develop a workforce model that defines shared core competencies and safe cross-training expectations for bus and truck technicians, as well as installation and maintenance for charging equipment and distribution infrastructure.

Long-Term

In the long-term, following testing with municipal fleet partners and transit agencies, SCAG can embed coordination and collaboration that works the near- and mid-term into regional planning and keep it current as conditions change. Coordination may now begin with private truck fleet owners, depot operators, or other heavy-duty vehicle operators.

Integrate Findings into Corridor Strategies: SCAG can coordinate with transit agencies and truck fleet owners to document pilot results and integrate lessons learned into planning documents, such as Connect SoCal, SCAG's Comprehensive Sustainable Regional Freight Plan, and other mode specific efforts. Over time, these insights can help inform or prioritize funding programs. State agencies can identify opportunities to build one workforce pipeline for both buses and trucks to reduce duplication in training programs and help streamline funding needs. State agencies can also support intentional cross-training that reflects differences in vehicle designs and maintenance cycles, while building a more flexible workforce as both markets mature.

Influence Market Policies in Sustainable Energy and Procurement: SCAG's convening and summary of findings and outcomes through the short- and medium-term action plans can support policy changes in the utility space around rate setting, transit- or truck-specific policy and program design from the CPUC, utilities, regulators and local jurisdictions. SCAG can also convene transit and truck fleet partners to strengthen customer connections and encourage more standardized OEM equipment models that meet the common sector needs, which could reduce costs and shorten lead times for vehicles or infrastructure that are often custom ordered. This coordination may begin at the local level, where jurisdictions, transit agencies, truck fleet owners, utilities, and infrastructure providers can work together to establish operating agreements and implementation approaches for shared infrastructure.

7 Conclusion

Transit agencies in the SCAG region have made significant progress in the transition to zero-emission buses (ZEBs) by deploying battery-electric buses and fuel cell electric buses. They are also building charging and hydrogen fueling infrastructure and preparing staff for new operating and maintenance needs. At the same time, research has shown how complex implementation can be. Vehicle procurement, infrastructure delivery, permitting, funding, workforce training, and daily operations must be closely aligned.

This study developed a deeper understanding of regional ZEB readiness through best practice research, existing conditions analysis, surveys, and interviews. The findings show strong policy alignment, early deployment momentum, and a growing base of agency experience across the region. However, readiness varies. Larger agencies are advancing multi-depot programs and mixed-technology strategies. Smaller operators often face greater constraints with staffing, funding, and technical capacity. Infrastructure readiness remains one of the most important factors affecting deployment timelines.

Transit agencies remain at the center of successful ZEB implementation. They define fleet and facility needs. They select technology pathways, pursue funding, coordinate with utilities and vendors, train staff, and maintain reliable service. SCAG can continue to support ZEB implementation through its regional planning and convening role. This role is most useful when it complements, rather than replaces, transit agency-led implementation. SCAG can help create space for peer learning, connect ZEB planning with broader regional priorities, share practical tools, and support coordination and funding advocacy. The next phase of the ZEB transition will require continued partnership across multiple stakeholders.

8 Appendices

Appendix A Summary of ZEB Rollout Plan and Deployment

Agency Name	County	Agency Size	Total Buses (2025 Reporting)	Rollout Plan Accessibility/Data Sources	ZEB Technology Pathway	Electric Utility
City of Santa Clarita	Los Angeles	Large	111	CARB website	Both	SCE
City of Santa Monica	Los Angeles	Large	193	CARB website	BEBs	SCE
Foothill Transit	Los Angeles	Large	355	CARB website	Both	SCE
Long Beach Transit	Los Angeles	Large	242	CARB website	Both	SCE
Los Angeles County Metropolitan Transportation Authority	Los Angeles	Large	2179	CARB website	BEBs	LADWP/SCE
Los Angeles Department of Transportation	Los Angeles	Large	538	CARB website	BEBs	LADWP
Montebello Bus Lines	Los Angeles	Large	68	CARB website	FCEBs	SCE
Omnitrans	San Bernardino	Large	245	CARB website	Both	SCE
Orange County Transportation Authority	Orange	Large	764	CARB website	Both	SCE
Riverside Transit Agency	Riverside	Large	224	CARB website	FCEBs	Riverside Public Utilities
Access Services	Los Angeles	Small	49	Agency website	Not specified	SCE
Anaheim Transportation Network	Orange	Small	82	CARB email communication	BEBs	Anaheim Public Utilities
Antelope Valley Transit Authority	Los Angeles	Small	104	N/A - 100% already	BEBs	SCE
Arcadia Transit	Los Angeles	Small	10	No	N/A	SCE
ARC of Imperial Valley	Imperial	Small	6	No	N/A	Imperial Irrigation District

Agency Name	County	Agency Size	Total Buses (2025 Reporting)	Rollout Plan Accessibility/Data Sources	ZEB Technology Pathway	Electric Utility
Camarillo Area Transit	Ventura	Small	4	CARB website	BEBs	SCE
City of Alhambra	Los Angeles	Small	8	No	N/A	LADWP
City of Artesia	Los Angeles	Small	1	No	N/A	SCE
City of Avalon	Los Angeles	Small	0	N/A - 100% already	BEBs	SCE
City of Azusa	Los Angeles	Small	4	No	N/A	Azusa Light & Water
City of Baldwin Park	Los Angeles	Small	7	No	N/A	SCE
City of Banning (Banning Connect)	Riverside	Small	10	CARB website	BEBs	City of Banning Electric Utility
City of Beaumont	Riverside	Small	22	CARB website	Both	SCE
City of Bell Gardens	Los Angeles	Small	6	No	N/A	SCE
City of Bellflower	Los Angeles	Small	2	No	N/A	SCE
City of Beverly Hills	Los Angeles	Small	5	No	N/A	SCE
City of Burbank	Los Angeles	Small	26	CARB website	BEBs	Burbank Water and Power
City of Calabasas	Los Angeles	Small	13	Agency website	BEBs	SCE
City of Carson	Los Angeles	Small	3	No	N/A	SCE
City of Cerritos	Los Angeles	Small	3	No	N/A	Cerritos Electric Utility
City of Commerce	Los Angeles	Small	24	CARB email communication	Not specified	SCE
City of Corona	Riverside	Small	20	Agency website	Both	Corona Utilities Department
City of Culver City	Los Angeles	Small	57	Agency website	Both	SCE
City of Downey	Los Angeles	Small	9	Agency website	BEBs	Liberty Utilities
City of El Monte	Los Angeles	Small	17	CARB website	BEBs	SCE
City of Gardena (GTrans)	Los Angeles	Small	91	CARB email communication	BEBs	SCE
City of Glendale (Glendale Beeline)	Los Angeles	Small	46	CARB website	BEBs	Glendale Water and Power

Agency Name	County	Agency Size	Total Buses (2025 Reporting)	Rollout Plan Accessibility/Data Sources	ZEB Technology Pathway	Electric Utility
City of Glendora	Los Angeles	Small	3	CARB website	BEBs	SCE
City of Inglewood	Los Angeles	Small	0	No	N/A	SCE
City of La Canada Flintridge	Los Angeles	Small	3	No	N/A	SCE
City of La Mirada	Los Angeles	Small	10	Agency website	BEBs	SCE
City of Lakewood DASH Transit	Los Angeles	Small	6	CARB website	BEBs	SCE
City of Lawndale	Los Angeles	Small	3	No	N/A	SCE
City of Manhattan Beach	Los Angeles	Small	4	No	N/A	SCE
City of Monterey Park	Los Angeles	Small	8	No	N/A	SCE
City of Norwalk	Los Angeles	Small	44	Agency website	Both	SCE
City of Pasadena	Los Angeles	Small	56	CARB website	BEBs	Pasadena Water and Power
City of Pico Rivera	Los Angeles	Small	0	No	N/A	SCE
City of Redondo Beach	Los Angeles	Small	20	Agency website	BEBs	SCE
City of Riverside Special Transportation	Riverside	Small	44	Agency website	Both	
City of San Clemente	Orange	Small	5	No	N/A	SDG&E
City of San Fernando	Los Angeles	Small	4	No	N/A	LADWP
City of Santa Fe Springs	Los Angeles	Small	3	Agency website	BEBs	SCE
City of Simi Valley Transit	Ventura	Small	19	CARB email communication	BEBs	SCE
City of South El Monte	Los Angeles	Small	1	No	N/A	SCE
City of South Gate (Get Around Town Express)	Los Angeles	Small	9	Agency website	BEBs	SCE
City of South Pasadena	Los Angeles	Small	3	No	N/A	Pasadena Water and Power
City of West Covina	Los Angeles	Small	11	No	N/A	SCE
City of West Hollywood	Los Angeles	Small	11	No	N/A	SCE
City of Whittier	Los Angeles	Small	3	No	N/A	SCE

Agency Name	County	Agency Size	Total Buses (2025 Reporting)	Rollout Plan Accessibility/Data Sources	ZEB Technology Pathway	Electric Utility
Claremont Dial-a-ride	Los Angeles	Small	8	No	N/A	SCE
Compton Renaissance Transit	Los Angeles	Small	3	No	N/A	SCE
County of Ventura	Ventura	Small	3	No	N/A	SCE
Gold Coast Transit District	Ventura	Small	75	CARB website	FCEBs	SCE
Imperial County Transportation Commission	Imperial	Small	62	Agency website	FCEBs	Imperial Irrigation District
La Campana Transit (City of Bell)	Los Angeles	Small	0	No	N/A	SCE
Laguna Beach Transit	Orange	Small	25	Agency website	BEBs	SCE
Los Angeles County Public Works	Los Angeles	Small	38	No	N/A	LADWP
Moorpark City Transit	Ventura	Small	5	No	N/A	SCE
Morongo Basin Transit Authority	San Bernardino	Small	28	CARB website	BEBs	SCE
Mountain Area Regional Transit Authority	San Bernardino	Small	38	Agency website	BEBs	SCE
Needles Area Transit	San Bernardino	Small	4	CARB website	BEBs	Needles Public Utility Authority
Ojai Trolley Service	Ventura	Small	5	Agency website	BEBs	SCE
Palo Verde Valley Transit	Riverside	Small	8	CARB website	Both	SCE
Palos Verdes Peninsula Transit Authority	Los Angeles	Small	26	Agency website	BEBs	SCE
Pomona Valley Transportation Authority	Los Angeles	Small	18	Agency website	BEBs	SCE
Sunline Transit Agency	Riverside	Small	113	CARB website	Both	Imperial Irrigation District
Thousand Oaks Transit	Ventura	Small	15	CARB email communication	BEBs	SCE

Agency Name	County	Agency Size	Total Buses (2025 Reporting)	Rollout Plan Accessibility/Data Sources	ZEB Technology Pathway	Electric Utility
Torrance Transit	Los Angeles	Small	0	CARB email communication	Both	SCE
Ventura County Transportation Commission	Ventura	Small	57	CARB website	Both	SCE
Victor Valley Transit Authority	San Bernardino	Small	115	CARB email communication	Both	SCE

Source: ICT Rollout Plan, CARB; ICT Reporting Tool & Data, CARB (2025)

Note: Inglewood, Torrance Transit and La Campana Transit (City of Bell) registered under the ICT reporting, yet no bus inventories were reported. Pico Rivera reported two buses, yet both were retired. Avalon did not report any buses under the ICT reporting database, but its website shows seven buses in total, all of them battery electric.

Appendix B Summary of Existing Charging and Hydrogen Infrastructure

Table 13. Charging Infrastructure for ZEBs in the SCAG Region

Transit Agency	Site Name	Chargers Installed	Charger Type	Status
Anaheim Transportation Network	Claudina Site	46	Depot Plug-in Charging	Operational
Antelope Valley Transit Authority	Antelope Valley College	2	On-Route Wireless Charging	Operational
Antelope Valley Transit Authority	AVTA base	1	Depot Wireless Charging	Operational
Antelope Valley Transit Authority	Operations & Maintenance Facility (Depot)	112	Depot Plug-in Charging	Operational
Antelope Valley Transit Authority	Palmdale Transportation Center	3	On-Route Wireless Charging	Operational
Antelope Valley Transit Authority	Scott Thomas Wilk Transit Center	3	On-Route Wireless Charging	Operational
Antelope Valley Transit Authority	Sgt. Steve Owen Memorial Park	3	On-Route Wireless Charging	Operational
Antelope Valley Transit Authority	Tom Lackey Transit Center	3	On-Route Wireless Charging	Operational
City of Artesia	City of Artesia Electric Bus & Vehicle Charging Facility	1	Depot Plug-in Charging	Operational
City of Culver City	Culver CityBus Transportation Facility	3	Depot Plug-in Charging	Operational
City of Gardena (Gtrans)	GTrans O&M Facility	3	Depot Plug-in Charging	Operational
City of Norwalk	Norwalk Transit System Operations Facility	4	Depot Plug-in Charging	Operational
City of Norwalk	Norwalk Transit System Operations Facility	4	Depot Plug-in Charging	Under Construction
City of Pasadena	Pasadena Transit Operations and Maintenance Facility	2	Depot Plug-in Charging	Planned
City of Santa Monica	BBB Depot	20	Depot Plug-in Charging	Operational
Foothill Transit	Arcadia Bus Yard	16	Depot Plug-in Charging	Operational
Foothill Transit	Azusa Intermodal Transit Center	2	On-Route Overhead Charging	Non-operational
Foothill Transit	Pomona Transit Center	2	On-Route Overhead Charging	Non-operational
Long Beach Transit	Headquarters Depot	10	Depot Plug-in Charging	Operational
Long Beach Transit	Long Beach Convention Center Stop	1	On-Route Wireless Charging	Operational

Transit Agency	Site Name	Chargers Installed	Charger Type	Status
Los Angeles County Metropolitan Transportation Authority	Airport Connector	7	On-Route Overhead Charging	Under Construction
Los Angeles County Metropolitan Transportation Authority	Airport Connector	6	On-Route Overhead Charging	Proposed
Los Angeles County Metropolitan Transportation Authority	Artesia Station Layover Opportunity Chargers	2	On-Route Overhead Charging	Proposed
Los Angeles County Metropolitan Transportation Authority	Canoga Station (G Line)	2	On-Route Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Central Maintenance Facility (CMF) Opportunity Chargers	1	On-Route Overhead Charging	Proposed
Los Angeles County Metropolitan Transportation Authority	Chatsworth Transportation Center (G Line)	2	On-Route Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Division 15 Layover Opportunity Chargers	2	On-Route Overhead Charging	In Design
Los Angeles County Metropolitan Transportation Authority	Division 18 (Carson) Depot Charging	TBD	Depot Overhead Charging	In Design
Los Angeles County Metropolitan Transportation Authority	Division 7 (West Hollywood) Depot Charging	TBD	Depot Overhead Charging	In Design
Los Angeles County Metropolitan Transportation Authority	Division 8 Bus Depot	10	Depot Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Division 8 Layover Opportunity Chargers	2	On-Route Overhead Charging	In Design
Los Angeles County Metropolitan Transportation Authority	Division 9 (El Monte Depot)	4	On-Route Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Division 9 (El Monte Depot)	120	Depot Overhead Charging	Under Construction
Los Angeles County Metropolitan Transportation Authority	El Monte Transit Center (EMTC)	4	On-Route Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Harbor Gateway Transit Center (J Line)	8	On-Route Overhead Charging	Operational
Los Angeles County Metropolitan Transportation Authority	North Hollywood Station (G Line)	4	On-Route Overhead Charging	Operational

Transit Agency	Site Name	Chargers Installed	Charger Type	Status
Los Angeles County Metropolitan Transportation Authority	North Hollywood Station Layover Opportunity Chargers	4	On-Route Overhead Charging	Under Development
Los Angeles County Metropolitan Transportation Authority	Portable Chargers - Divisions 1, 2, 3, 9, 15, 18, and CMF	33	Depot Plug-in Charging	Operational
Los Angeles County Metropolitan Transportation Authority	Universal Station Layover Opportunity Chargers	4	On-Route Overhead Charging	In Design
Los Angeles Department of Transportation	Compton Yard (Lease)	10	Depot Plug-in Charging	Operational
Los Angeles Department of Transportation	Downtown (Commercial) Yard	13	Depot Plug-in Charging	Operational
Los Angeles Department of Transportation	Downtown (Commercial) Yard	22	Depot Plug-in Charging	Under Construction
Los Angeles Department of Transportation	Mid-Cities (Washington) Yard	20	Depot Plug-in Charging	Operational
Los Angeles Department of Transportation	Mid-Cities (Washington) Yard	110	Depot Plug-in Charging	Under Construction
Los Angeles Department of Transportation	North (Sylmar) Yard	50	Depot Plug-in Charging	Proposed
Los Angeles Department of Transportation	South (Harbor) Yard	50	Depot Plug-in Charging	Proposed
Omnitrans	East Valley Maintenance Facility (sbX Project)	5	Depot Plug-in Charging	Operational
Omnitrans	East Valley Maintenance Facility (sbX Project)	16	Depot Plug-in Charging	Proposed
Omnitrans	Kendall/Palm Transit Station	3	On-Route Overhead Charging	Proposed
Omnitrans	Pomona Trans Center	2	On-Route Overhead Charging	Under Construction
Omnitrans	West Valley Maintenance Facility	5	Depot Plug-in Charging	Operational
Omnitrans	West Valley Maintenance Facility	18	Depot Overhead Charging	Under Construction

Transit Agency	Site Name	Chargers Installed	Charger Type	Status
Orange County Transportation Authority	Garden Grove Bus Base	10	Depot Plug-in Charging	Operational
Orange County Transportation Authority	Santa Ana Bus Base	10	Depot Plug-in Charging	Under Construction
Sunline Transit Agency	Indio Facility	3	Depot Plug-in Charging	Operational
Sunline Transit Agency	Thousand Palms Facility	3	Depot Plug-in Charging	Operational
Victor Valley Transit Authority	Barstow Area Facility	4	Depot Plug-in Charging	Operational
Victor Valley Transit Authority	Hesperia Operations & Maintenance Facility	7	Depot Plug-in Charging	Operational

Source: Transit agency-provided data and ICF research

Table 14. Hydrogen Refueling Infrastructure for ZEBs in the SCAG Region

Transit Agency	Hydrogen Type at Storage	Compression Level at Dispensing	Capacity (kg/day)	Operation Status	Station Details	Scalability
Foothill Transit (Pomona Deport)	Liquid (cryogenic)	350 bar	~1,800–2,000 kg/day (25,000 gal ≈ 2,100 kg LH_2; sized for daily refills)	In Operation	One of the earliest transit hydrogen fueling depots in Los Angeles County; supports a growing fleet of FCEBs. Operational at Pomona Operations and Maintenance facility and fuels 33 FCEBs.	Can expand via additional liquid storage tanks and dispensers. Will be fueling 52 FCEBs by end of first quarter 2026.
OCTA (Santa Ana Bus Base)	Liquid (cryogenic)	350 bar	~1,500 kg per 8 hours	Decommissioned**	Largest U.S. transit hydrogen fueling station; multiple fueling lanes support ~50 buses/day; designed for large-scale fleet growth.	Built for modular expansion; additional compressors/dispensers can be added.
OCTA (Garden Grove Base)	Liquid (cryogenic)	350 bar	~3,000 kg per day	Under Construction	OCTA's second hydrogen fueling station; will support 50 FCEBs with a capacity to support up to 100 FCEBs.	Build for modular expansion; addition equipment can be added.
SunLine Transit Agency (Headquarters)	Liquid + on-site production (electrolyzer)	Dual hose: 350 bar & 700 bar	~900 kg/day electrolyzer; ~ 4,400 kg/day LH2 station	In Operation	Longest-operating U.S. transit hydrogen fueling station (since 2000); hybrid system with delivered LH_2 and renewable H_2 from on-site solar-powered electrolyzers.	Modular system, scalable via additional liquid storage tanks and dispensers.
Riverside Transit Agency (RTA)	Liquid (cryogenic)	350 bar	~3,300 kg per day (peak) based on 8 hour fueling window	Under Construction	The agency has awarded a contract to Clean Energy to design and construct a purpose-built hydrogen fueling station. The facility	Can expand via additional dispenser.

Transit Agency	Hydrogen Type at Storage	Compression Level at Dispensing	Capacity (kg/day)	Operation Status	Station Details	Scalability
			(25,000 kg tank)		will initially support 5 fuel cell electric buses, and the agency plans to grow its hydrogen fleet to over 100 buses over the next decade. The project includes hydrogen supply and maintenance services. RTA has secured a $5.1 million federal grant from FTA's Low-No program toward purchasing the initial buses.	
Pasadena Transit	Liquid (cryogenic)	350 bar	~425 kg/day	Under Construction	Pasadena has secured over $100 million in grant funding toward its ~$150.7 million ZEB program, including a $14.4 million TIRCP award. A dedicated hydrogen station at 159 S. Kinneloa Avenue is in design and expected to be operational by fall 2027, supporting up to 45 FCEBs. As of August 2025, the City Council approved a $32 million contract for 17 new FCEBs to enter service in spring 2027.	Can expand via additional liquid storage tanks and dispensers.
Victor Valley Transit	Liquid (cryogenic)	dual-pressure dispensing	Unknown	Under Construction	This station will be accessible for both public	

Transit Agency	Hydrogen Type at Storage	Compression Level at Dispensing	Capacity (kg/day)	Operation Status	Station Details	Scalability
Authority (VVTA)		(350 and 700 bar)			and fleet fueling. VVTA has received a $12 million FHWA Charging and Fueling Infrastructure grant to support the hydrogen station and co-located DC fast charging equipment.	
Gold Coast Transit District (GCTD)	Unknown	Unknown	Unknown	On hold*	Agency was awarded approximately $12.1 million under the FTA Low-No program to deploy five FCEBs and construct a hydrogen fueling station. The project will support fueling for up to 50 buses per day and includes maintenance facility upgrades and workforce training. Completion is targeted for 2026.	
Omnitrans	Compressed gas	350 bar	Trailer holds 500kg	Operational	Small scale unit for pilot buses. Operational December 2025. 1 Hydrogen compression and dispensing unit with GTL Leasing tandem tube storage trailer.	
Omnitrans	Liquid (cryogenic)	Dual hose: 350 bar & 700 bar		Proposed	Agency is working on the purchase of property nearby for that station	Working with STV on a fueling facility scalable to 90 buses

Transit Agency	Hydrogen Type at Storage	Compression Level at Dispensing	Capacity (kg/day)	Operation Status	Station Details	Scalability
					pending CEQA, NEPA and Geotech studies.	
Santa Clarita Transit	Liquid (cryogenic)	350 bar	400 kg per day	Under Construction	This station will initially support transit fleet fueling only. Located at the city's Transit Maintenance Facility, the station is designed to produce up to approximately 400 kg of hydrogen per day, with initial utilization expected to be around 50-60 percent of capacity based on the city's near-term fuel cell bus fleet size. The city is also evaluating a future phase to expand the existing public CNG station at the Transit Maintenance Facility to include a public hydrogen dispenser.	

**GCTD put this project on hold given the cancellation of ARCHES hydrogen bubs; currently the agency is contacting the FTA about options in amending their Low-No federal grant.*

***OCTA decommissioned this hydrogen station in 2026 after Air Products removed its leased equipment. OCTA plans to rebuild the station.*

Source: ICF research and transit agency provided.

Appendix C Federal ZEB Related Regulations

Federal Agency	Regulation or Guideline Name	Description
U.S. Environmental Protection Agency	National Ambient Air Quality Standards (NAAQS)	Establishes national air quality standards for six criteria pollutants harmful to health and the environment.
	Transportation Conformity	Ensures federally funded transportation projects do not worsen air quality and comply with NAAQS.
	Heavy-Duty Engine and Vehicle Standards	Updates emissions standards to reduce air pollution from heavy-duty commercial vehicles, including transit vehicles, that create ozone and particulate matter.
	GHG Standards for Heavy-Duty Vehicles – Phase 3	Establishes GHG emissions standards from heavy-duty commercial vehicles, including transit vehicles, by up to 60% by 2032.
U.S. Department of Transportation	49 CFR Part 38	Provides accessibility requirements for transit vehicles under the Americans with Disabilities Act (ADA).
	49 CFR Part 39	Prohibits disability discrimination by transit operators and requires accessible vessels, facilities, and accommodations.
	49 CFR Part 661	FTA Buy America requirements for rolling stock and other procurements, mandating U.S. final assembly and minimum domestic content for vehicles and certain products purchased with FTA funds.
	Transitioning to Zero-Emission Bus Operations Toolkit	Offers federal guidance for planning, procuring, and deploying zero-emission buses.
Access Board	ADA/Architectural Barriers Act Accessibility Guidelines – EV Charging	Proposes updates to ensure electric vehicle (EV) charging stations are accessible under ADA guidelines.
	Accessible EV Charging Design Recommendations	Provides recommended design practices for constructing EV charging stations usable by people with disabilities.

Source: ICF research

Appendix D Summary of Key Planning Programs

Zero-Emission Fleet Transition Plans (ZEFTP): A ZEFTP is a federally required document for transit agencies seeking funding under FTA's Buses and Bus Facilities Competitive Program (49 U.S.C. §5339(b)) and Low or No Emission Program (49 U.S.C. §5339(c)). It outlines how an agency will transition to zero-emission technologies and demonstrates readiness for large-scale deployment. The plan must address long-term fleet management, financial resources, applicable policies and regulations, facility upgrades, utility or alternative fuel coordination, and workforce impacts such as training needs. Agencies may submit an existing plan or provide an addendum to fill gaps. Serving as the "master readiness document" for FTA evaluators, zero-emission fleet transition plans (ZEFTPs) directly support federal decarbonization mandates under the Infrastructure Investment and Jobs Act (2021). At the local level, ZEFTPs integrate seamlessly with city Climate Action Plans, e.g., San Diego's net-zero-by-2035 target or New York City's PlaNYC, ensuring that fleet electrification strategies reinforce broader community climate priorities.

California's Zero-Emission Bus Rollout Plan: A ZEB rollout plan is a mandated planning document required under CARB's ICT regulation. All public transit agencies in California must prepare and submit a ZEB rollout plan that outlines how they will transition their fleets to 100 percent zero-emission technologies by 2040. The plan details the agency's implementation strategy, including projected fleet replacement schedules, facility and charging or fueling infrastructure needs, utility coordination, workforce development, financial planning, and risk mitigation approaches. It also requires agencies to demonstrate how ZEB adoption aligns with service needs. Rollout plans function as the foundation of the ICT compliance document. Beyond regulatory compliance, ZEB rollout plans are closely linked with regional and local policy frameworks. They support air quality requirements under state implementation plans, advance greenhouse gas (GHG) reduction commitments adopted by metropolitan planning organizations (MPOs), and reinforce local climate action plans that prioritize clean transportation investment. In practice, these plans help agencies secure funding, sequence capital projects, and coordinate interagency actions necessary for a structured and reliable transition.

Short-Range Transit Plans (SRTP): SRTPs are five- to seven-year planning documents required by MPOs to maintain federal funding eligibility. They provide detailed operational, financial, and capital planning, including bus replacement schedules, depot upgrades, and early ZEB targets. As the first formal venue for introducing ZEB strategies, SRTPs are essential for ensuring agencies remain eligible for both formula and discretionary funding, while defining near-term vehicle orders, pilot deployments, block assignments, and facility needs critical to scaling electrification. By integrating ZEB projects into the transportation improvement program, SRTPs embed regional climate goals, air quality conformity requirements, and local climate action commitments.

> Sacramento County's SRTP integrates ZEB bus procurement with depot upgrades and charging infrastructure, while San Luis Obispo's joint SRTP outlines fleet transition strategies and a five-year electrification roadmap aligned with regional climate goals.

Capital Improvement Programs (CIP): CIPs are multi-year budgeting documents that allocate funding for major capital projects such as depot electrification, hydrogen fueling stations, chargers, substations, solar and storage systems, land acquisition, and bus procurement. Typically spanning five to 10 years, they establish the financial framework for infrastructure critical to bus transition. CIPs guide agency capital spending, ensure transparency, and support eligibility for federal and state funding programs. By directing investment toward decarbonization projects, they connect long-term financial planning to climate mandates.

LA Metro's adopted CIP embeds ZEB projects in its Capital Program section with funding for depot electrification, charging infrastructure and bus procurement. Similarly, Denver Regional Transportation District's adopted CIP includes ZEB investments in its Facilities Projects and Fleet Replacement, programming charging depot retrofits, utility upgrades, and phased bus purchases.

Climate Action Plans (CAPs): CAPs and sustainability plans are municipal or agencywide strategies that set long-term emissions reduction targets. Covering sectors such as transportation, buildings, energy, and waste, they consistently identify zero-emission transit as a core strategy for meeting GHG goals. CAPs establish legally or politically binding communitywide climate commitments and align with federal priorities, statewide climate statutes, regional clean air plans, and local sustainability policies. Transit electrification is typically highlighted as a high impact measure. By elevating ZEB investments as essential climate strategies, CAPs make ZEB deployment eligible for climate funding, resilience dollars, and municipal capital prioritization. They also help transit agencies justify investments, coordinate with local partners, and secure political support for electrification.

San Diego's 2022 CAP commits the city to net-zero emissions by 2035 and highlights zero-emission transit as a central strategy, prioritizing bus electrification and clean mobility investments. Washington Metropolitan Area Transit Authority (WMATA)'s Zero-Emission Bus Transition Plan advances the region's climate framework by setting a goal of 100% ZEBs by 2042, directly supporting the District's Clean Energy DC Climate and Energy Action Plan, which targets a 50 percent reduction

Fleet Electrification Master Plans: Fleet electrification master plans are usually agency initiated, long-range strategies that translate climate commitments (e.g., under CAPs) into operational roadmaps for bus fleet conversion. Unlike federally required ZEFTPs, these master plans are voluntary documents over 10–20 years.

Chicago Transit Authority's Fleet Electrification Strategy supports the City of Chicago's Climate Action Plan, which sets a goal of cutting greenhouse gas emissions by 62% by 2040 and reaching carbon neutrality by mid-century.

Appendix E NLR Trial and Evaluation Examples

Several agencies have undertaken multi-year trials and evaluations. For example, Foothill Transit's battery-electric bus (BEB) program has been documented in successive NLR reports from its 2010 pilot through at least 2020, enabling side-by-side comparisons across charging architectures and overtime. SunLine's fuel cell electric bus (FCEB) program has been evaluated repeatedly since the early 2000s, with published results spanning 2009-2014 and new fleet studies in 2020–21 that included on-site hydrogen production. These multi-year evaluation programs provide long-term operational insights and practical lessons. Selected trial cases are summarized below.

- **Foothill Transit** - BEB on-route overhead charging vs. depot plug-in charging
  - **Test focus:** Side-by-side comparison of on-route overhead charging (Pomona) and primarily depot plug-in charging (Arcadia) against a common CNG baseline.
  - **Lesson learned:** Charging architecture is an operational design choice, with protecting layover windows and right-sizing power at terminals stabilizes fast charge fleets, while depot charging simplifies infrastructure but reduces mid-day flexibility.

- **Long Beach Transit** - BEB depot plug-in charging with optional inductive backup
  - **Test focus:** Energy use, availability, and duty-cycle fit for a low-speed circulator supported mainly by depot charging, with an on-route inductive pad as insurance.
  - **Lesson learned:** For short, predictable circulators, depot charging is sufficient; early availability dips can be mitigated through warranty and battery upgrades without relying on on-route charging.

- **County Connection -** BEB with inductive boost serving short-route
  - **Test focus:** Efficiency, availability, and on-route WAVE inductive "top-ups" on a downtown circulator, comparing against matched diesel baselines.
  - **Lesson learned:** BEBs deliver excellent efficiency on low-speed circulators, and modest on-route opportunity charging effectively protects schedule and range margins.

- **SunLine Transit Agency** - FCEB with on-site electrolysis

    - **Test focus:** Fuel economy, availability, and depot fueling performance using ~900 kg per day in-house hydrogen production integrated with the CNG island.
    - **Lesson learned:** Reliable depot hydrogen is the lever for scaling; fleet availability is more often constrained by non-stack systems (HVAC, batteries, low-voltage) than by the fuel cell stack itself.
- **OCTA** - FCEB with liquid hydrogen

    - **Test focus:** Comparative fuel economy, operating cost, and subsystem availability versus CNG, supported by a high-capacity liquid hydrogen station with pre-cooling.
    - **Lesson learned:** FCEBs can be more than double CNG fuel equivalent efficiency, but overall uptime hinges on conventional bus subsystems; hydrogen price is the dominant driver of fuel $/mile.
- **Stark Area Regional Transit Authority (SARTA), Ohio** - FCEB in a cold-weather context

    - **Test focus:** Reliability, availability, and maintenance cost in winter operations, with attention to HVAC and technician/operator acceptance.
    - **Lesson learned:** Fuel cell stacks and balance-of-plant can meet reliability targets; building workforce proficiency and tuning HVAC/low-voltage systems are key to improving whole-bus availability in cold climates.

Across evaluated sites, the research shows that BEBs excel on short, low speed, long dwell service (especially with opportunity charging), while FCEBs perform better on longer blocks that benefit from quick refueling and consistent range. Uptime is most often constrained by conventional subsystems, such as HVAC, low-voltage electronics, and batteries, rather than the core electric or fuel cell stacks, so maintenance focus, spare parts, and staff training are as important as propulsion choice.

To choose the right ZEB technologies, agencies should not only analyze service patterns (block length, speeds, dwell, climate, loads) but also need to select the matching infrastructure. In addition, it is essential to set availability targets, particularly tied to subsystem reliability, stock critical spares, train staff, and run measured before scaling procurements and facilities upgrades.

Appendix F ZEB Technology Selection Criteria Framework

Criterion	Decision Questions	Typical BEB Fit	Typical FCEB Fit	What to Collect
Body Type & Capacity	What vehicle lengths and axle loads are needed?	Broad 30 to 40-ft and 60-ft	Mature 40-ft with growing 60-ft offers	OEM spec sheets; bridge and yard constraints
Range & Duty Cycles	What is the max block miles including reserve? Average speeds? Dwell? Grades?	100-150 miles per charge; short–medium, urban routes with stop-and-go; medium to long dwell; moderate grades	250-370 miles per refuel; longer, regional, interlined, or hillier routes; fewer/shorter layovers	Block miles, dwell/layover windows, AVL speeds, elevation profiles
Refueling / Charging Time	Can dwell/layovers reliably support energy events?	Depot: 2–6 hours; On-route Direct Current Fast Charge (DCFC): <15 min top-ups if layovers protected	Depot H2: <10 minutes full refill with pre-cooling	Schedules and run-cuts; terminal dwell logs or telematics data
Infrastructure & Energy Needs	What can the site and utility support in near-term and long-term?	Chargers (depot and/or on-route); possible updates of transformer, panel and switchgear; managed charging; on-site solar optional	hydrogen station (delivered or on-site production), compression/storage, pre-cooling; dispenser placement	Utility capacity evaluation; tariffs analysis; yard layout plan; hydrogen supply plan
Capital & Operating Cost (TCO)	Vehicle + infrastructure capex? Opex with fuel/energy and maintenance?	Lower charger capex/port; $/mile sensitive to demand charges but very low on right routes	Higher station capex; $/mile dominated by $/kg H2; improves with low-cost to scale up supply	Vendor quotes, tariffs, demand profiles, $/kg pathways, CMMS data
Reliability & Maintenance Complexity	What subsystems will drive uptime and spares?	Simpler drivetrain; uptime hinges on battery thermal/HVAC/low-voltage	More systems (stack/balance of plant (BOP)/H2); FC subsystem often high uptime	Failure modes/miles between road calls, parts lead times, technician skills
Scalability	How quickly must the fleet grow?	Scales incrementally with depot power and stalls; constrained by space and grid capacity	Scales efficiently with hub throughput and shared fueling; station headroom is the lever	Utility roadmaps, station throughput modeling
Workforce Skills	What training exists?	EV safety, HV batteries, DC equipment, software	High-pressure H2, leak testing, pre-cooling, stack/BOP diagnostics	Training plans; local partners
Funding Eligibility	Which grants/rebates align with timing?	Often strong utility/make-ready + voucher support	Hydrogen hub programs and clean fuel grants can be decisive	Funding matrix and timelines

Appendix G Innovative Charging Technologies and Solutions

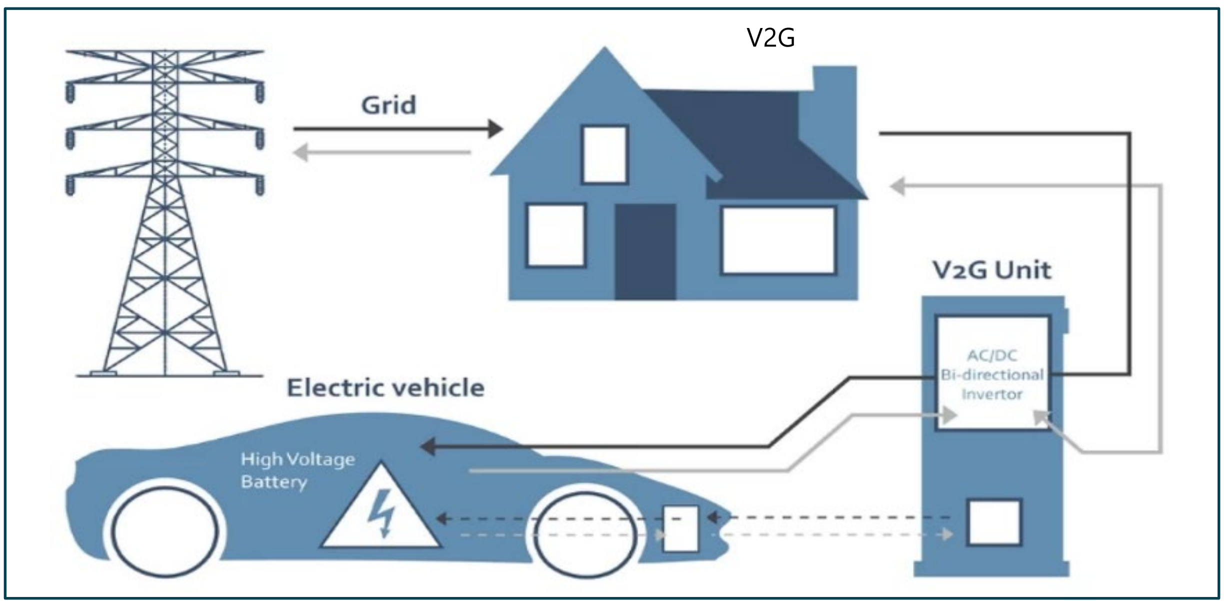
Transit agencies are increasingly using these technologies to reduce energy and demand costs, improve charging efficiency, and strengthen operational resilience, although deployment remains more common in larger or early-adopter fleets.

Advanced Charging Management Systems

Charging management systems (CMS) are essential for large-scale battery-electric bus BEB deployments. These platforms optimize how and when buses charge by controlling load, scheduling charging events, managing power draw, and enabling automated diagnostics. By intelligently coordinating charging across dozens or hundreds of buses, CMS solutions help agencies avoid costly demand charges, reduce peak load stress on distribution systems, and maintain high operational uptime. Common vendors include the Mobility House, ABB, Siemens, Heliox, and ChargePoint, which are widely used by transit agencies.

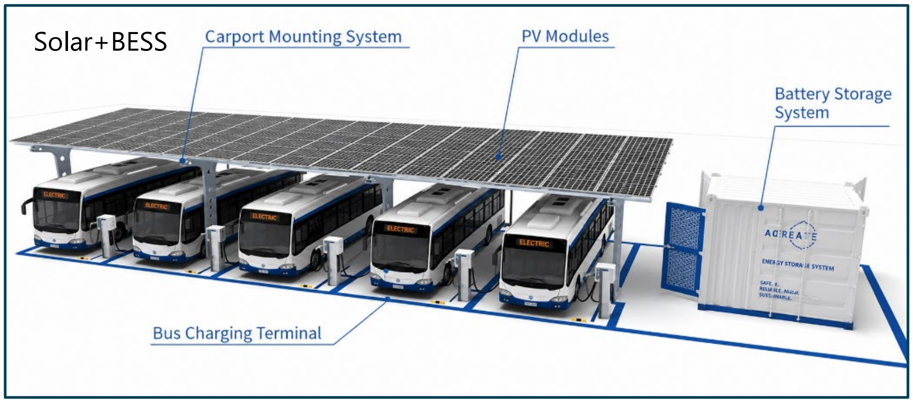
Vehicle-to-Grid (V2G) Technology

Vehicle-to-Grid (V2G) technology enables bi-directional power flow between a bus and the electric grid, allowing BEBs to act as distributed energy resources. When properly integrated, buses can provide grid support, supply backup power during outages, and help agencies offset energy costs by exporting power when market prices are high. V2G is particularly useful in school districts and smaller transit systems with long vehicle dwell times. These applications demonstrate how zero-emission bus (ZEB) fleets can contribute to grid resilience while improving their own cost efficiency. For example, Fremont Unified School District deployed a V2G school bus project in partnership with PG&E and the Mobility House.



Solar and Battery Energy Storage Systems (BESS)

To reduce operational costs and improve resilience, many agencies are investing in solar photovoltaic systems paired with battery energy storage. These hybrid systems generate renewable energy onsite, manage peak demand, shift load to off-peak hours, and provide backup power in the event of grid outages. Transit agency examples include Los Angeles Department of Transportation, Long Beach Transit, and Victor Valley Transit Authority. These agencies have implemented solar canopies, battery storage systems, and microgrid ready infrastructure to support depot electrification and enhance the resilience and efficiency of their ZEB operations.



Appendix H ZEB and Infrastructure Costs

Bus Costs

Zerto-emission bus ZEB costs include both capital and operations and maintenance (O&M), as summarized in Table 15. As shown in the Public Transportation Vehicle Database 2023-25, capital costs are significantly higher than diesel buses: battery-electric buses (BEBs) typically range from about $650,000 to $1,350,000 per bus, compared with $125,000 to $800,000 for Internal combustion engine (ICE) buses. These higher costs reflect limited production scale, specialized components, and ongoing technology development.

O&M costs, especially fuel, are major in terms of total cost. BEB electricity costs range widely, with an average of $0.13 per kWh, depending on utility rates, demand charges, and charging strategies. FCEB hydrogen prices also vary, ranging from $5.27/kg to $10.10/kg, based on production method, delivery logistics, and contract terms. Beyond fuel, many operating costs remain similar to ICE fleets, though maintenance practices differ. BEBs generally benefit from lower routine maintenance due to fewer moving parts but require specialized battery and high voltage system work. Fuel cell electric buses (FCEBs) require maintenance of fuel cell stacks and high-pressure hydrogen systems. Early deployments often rely on OEM support and extended warranties. Overall, ZEB maintenance costs typically fall in the $0.10-$0.50 per mile range, comparable to conventional buses, and long-term cumulative maintenance costs across bus types converge around $0.40–$0.46 per mile.

Table 15. Cost Comparison for BEB, FCEB, and Conventional Transit Buses

Bus Type	Technology Type	Average Capital Cost	Average Fuel Cost (regardless of bus type)	Average Maintenance Cost (regardless of bus type)
Cutaways	ICE	$125,000	ICE (CNG): $1.30/DGE BEB: $0.13/kWh FCEB: $7.79/kg	ICE(CNG): $0.85/mile BEB: $0.43/mile FCEB: $0.43/mile
	BEB	$650,000		
	FCEB	No Information		
Standard	ICE	$550,000		
	BEB	$890,000		
	FCEB	$1,520,000		
Articulated	ICE	$800,000		
	BEB	$1,350,000		
	FCEB	No Information		

Sources: Public Transportation Vehicle Database 2023-2025; NLR, 2022

Infrastructure Costs

A key element of any ZEB transition is the new infrastructure required to supply the energy needed to operate the fleet. These investments represent significant upfront costs and demand careful planning, coordination, and long-term financial commitment. Charging infrastructure costs typically include electric vehicle supply equipment (EVSE) hardware, installation, utility upgrades, and facility modifications:

- **EVSE hardware:** EVSE delivers electrical energy from the grid to the bus and includes components such as charging connectors and cables, control and safety systems, power electronics, and user interfaces. Costs vary by charger type and power level. For BEBs, common options include depot plug-in chargers, depot overhead systems, on-route overhead chargers, and on-route wireless charging.

- **EVSE installation:** Installation covers civil and electrical work, such as trenching, paving, conduit, engineering design, permitting, and inspections. Costs depend on site conditions, charger type, labor rates, and permitting timelines.
- **EVSE maintenance:** Agencies must budget for ongoing maintenance of charging equipment, software/network fees, warranties, and replacement parts.
- **Utility upgrades:** Additional charging demand may require utility "make-ready" work. Customer-side make-ready includes trenching, meters, electrical panels, step-down transformers, conduit, and cabling. Utility-side make-ready typically involves transformer installation and, in some cases, construction of new substations, which can be costly and time intensive.
- **Maintenance bays and facility updates:** Maintenance facilities require updated tools, safety equipment, and training to support work on high-voltage electric systems.

Based on studies in the past five years, Table 16 summarizes charging infrastructure costs for BEBs by charger type and power level, where available. In addition to traditional wired charging, agencies may also consider alternative technologies such as wireless charging and pantograph systems.

Table 16. BEB Charging Infrastructure Cost

Charger Type	Power Level	Charger Hardware Cost	Charger Installation Cost	Maintenance Cost
Depot Plug-In Charging	50kW	$35,800	$28,100	$800 per charger per year
	150kW	$100,000	$42,400	
	250kW	$125,000	$51,900	
	350kW	$150,000	$61,600	
	2MW	$600,000	$130,000	No Information
Depot Overhead Charging	300kW	$492,000	$328,000	No Information
On-Route Charging	150kW-450kW	$600,000	$400,000	No Information

Sources: SCAG Technology Compendium, 2024; CRC Infrastructure Assessment, 2023; CARB Comprehensive Review, 2022; USAID/NREL Electrifying Transit, 2021.

For hydrogen refueling infrastructure, costs generally fall into two categories: station capital cost and ongoing maintenance. In California, most hydrogen installations have been purchased with maintenance contracts that are either billed monthly or incorporated into overall station upkeep. Additional features, such as on-site hydrogen production via electrolysis or steam methane reforming, or enhancements like OCTA's added pre-cooling system, can increase capital costs but may be necessary to meet performance needs or regulatory requirements.

- **Station cost:** The California Air Resource Board's (CARB) "Hydrogen Self-Sufficiency Report" defines capital cost as the fully installed cost of developing a station. Installation costs vary by station capacity and network scale. CARB's cost curve, based on Assembly Bill 8-funded stations, assumes a power-law cost relationship for stations up to 600 kg per day, transitioning to a constant cost of $5,000 per kg of daily capacity for larger stations. Similar to BEB charging facilities, hydrogen stations require ongoing maintenance, including equipment servicing and safety system checks.
- **Maintenance bay and facility update**: Maintenance bays for gaseous-fuel vehicles must have gas detection and adequate ventilation. Facilities already equipped for CNG maintenance typically require minimal upgrades, while converting a diesel-only facility to support hydrogen entails significantly higher costs.

Table 17 shows how hydrogen refueling station costs could vary in California, ranging anywhere between $4 million to $8 million to build.

Table 17. Examples of Hydrogen Station Costs

Transit Agency	Station Capacity (kg/day)	Station Cost ($M)	Maintenance Cost	Year Built
AC Transit (Oakland, CA)	360	$6.3M	$15,500/month	2014
AC Transit (Emeryville, CA)	1,750	2011: $5.1M 2020: $4.4M	$11,800/month	2011 and 2020 upgrade
Foothill Transit, CA	NA	$6.6M	No Information	2022-2023
Sunline Transit Agency, CA	900	$8.3M (electrolyzer) $9.1 M (liquid)	$24,000/month (electrolyzer) $10,300/month (liquid)	2019 (electrolyzer) 2024 (liquid)

Sources: NRL, 2023; email communication in June 2026

Appendix I ZEB Deployment Toolkit

The toolkit developed as part of this study will help public transit agencies plan, procure, deploy, and operate zero-emission buses and support infrastructure in a way that is practical, cost-aware, and scalable. It translates complex technical, operational, and organizational considerations into step-by-step guidance, templates, and decision tools that agencies can apply across the full project lifecycle. It includes a series of focused factsheets designed to translate complex data, technologies, processes, and state policies into accessible, actionable information to guide zero-emission deployments across the SCAG region.

The toolkit will be published separately alongside the final report.

Abbreviations

Acronyms	Definition
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
ARCHES	Alliance for Renewable Clean Hydrogen Energy Systems
AHJ	Authority Having Jurisdiction
APTA	American Public Transit Association
AQMD	Air Quality Management District
AVTA	Antelope Valley Transit Authority
BEB	Battery Electric Bus
BESS	Battery Energy Storage System
CAA	Clean Air Act
CalSTA	California State Transportation Agency
CAPEX	Capital Expenditure
CCRTA	Cape Cod Regional Transit Authority
CCS	Combined Charging System
CCW	Complete Coach Works
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CFA	Cal Fleet Advisor
CIP	Capital Improvement Programs
CLCPA	Climate Leadership and Community Protection Act
CMS	Charging Management System
CNG	Compressed Natural Gas
CoEZET	Center of Excellence for Zero Emission Technology
CPUC	California Public Utilities Commission
CMAQ	Congestion Mitigation and Air Quality
CTA	Chicago Transit Authority
CTTC	California Transit Training Consortium
DC	Direct Current
DCFC	Direct Current Fast Charger
DGE	Diesel Gallon Equivalent
DGS	Department of General Services
DOT	Department of Transportation
EaaS	Energy-as-a-Service
EEC	Energy and Environment Committee
EPA	Environmental Protection Agency
EVCS	Electric Vehicle Charging Station
EVITP	Electric Vehicle Infrastructure Training Program
EVSE	Electric Vehicle Supply Equipment
FCEB	Fuel Cell Electric Bus
FAX	Fresno Area Express
FPH2	First Public Hydrogen

Acronyms	Definition
FTA	Federal Transit Administration
GCTD	Gold Coast Transit District
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HTA	Humboldt Transit Authority
HVAC	Heating, Ventilation, and Air Conditioning
HVIP	Clean Truck and Bus Voucher Incentive Project
LADOT	Los Angeles Department of Transportation
LADWP	Los Angeles Department of Water and Power
LA Metro	Los Angeles County Metropolitan Transportation Authority
ICA	Integration Capacity Analysis
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
IOU	Investor-Owned Utilities
IRA	Inflation Reduction Act
JPA	Joint Powers Authority
LCFS	Low Carbon Fuel Standards
LCTOP	Low Carbon Transit Operations Program
MBTA	Massachusetts Bay Transportation Authority
MPOs	Metropolitan Planning Organizations
MTA	Metropolitan Transportation Authority
NAAQS	National Ambient Air Quality Standards
NEPA	National Environmental Policy Act
NLR	National Laboratory of the Rockies
NOFO	Notice of Funding Opportunity
NYSERDA	New York State Energy Research and Development Authority
OCPP	Open Charge Point Protocol
OCTA	Orange County Transportation Authority
OEM	Original Equipment Manufacturer
O&M	Operation and Maintenance
PVVTA	Palo Verde Valley Transit Agency
RCTC	Riverside County Transportation Commission
RTA	Riverside Transit Agency
RTTAC	Regional Transit Technical Advisory Committee
SARTA	Stark Area Regional Transit Authority
SBCTA	San Bernardino County Transportation Authority
SCAG	Southern California Association of Governments
SCE	Southern California Edison
SOC	State-of-Charge
SRTP	Short-Range Transit Plans
STBG	Surface Transportation Block Grant
TC	Transportation Committee
TCO	Total Cost of Ownership
TIRCP	Transit and Intercity Rail Capital Program
TTTF	Transit Transformation Task Force

Acronyms	Definition
TWC	Transit Workforce Center
UCLA	The University of California, Los Angeles
V2G	Vehicle-to-Grid
VVTA	Victor Valley Transit Authority
WMATA	Washington Metropolitan Area Transit Authority
ZEB	Zero-Emission Buses
ZEBRA	Zero Emission Bus Resource Alliance
ZEFTP	Zero-Emission Fleet Transition Plan
ZET	Zero-Emission Truck
ZETCP	Zero-Emission Transit Capital Program
ZETI	Zero-Emission Truck Infrastructure Study
ZEV	Zero-Emission Vehicle

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