WHITE PAPER

CALIFORNIA TRANSIT AGENCIES CHART A COURSE TO ZERO EMISSIONS:

A REVIEW OF PROPOSED ZEB PATHWAYS UNDER THE INNOVATIVE CLEAN TRANSIT REGULATION

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ACKNOWLEDGMENTS

This report is derived from the Innovative Clean Transit Rollout Plans that were prepared by responding large transit agencies as required by the Innovative Clean Transit regulation, adopted in 2018 by the California Air Resources Board. Some large transit agencies have not submitted their Rollout Plans yet, and one additional smaller transit agency opted to submit a Rollout Plan, which is also used as reference material in this report. The authors would like to thank key CALSTART staff for their critical review of and additions to this report, including Emily Varnell, Mitul Arora, Chase LeCroy, Kevin Leong, and Justin Slosky. Any errors are the authors' own.

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LIST OF ACRONYMS

BEB	Battery Electric Bus
CARB	California Air Resources Board
EV	Electric Vehicle
FCEB	Fuel Cell Electric Bus
ICT	Innovative Clean Transit
ZEV	Zero-Emission Vehicle
ZEB	Zero-Emission Bus

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EXECUTIVE SUMMARY

The California Air Resources Board's (CARB) adoption of the Innovative Clean Transit (ICT) regulation requires transit agencies to transition to 100 percent zero-emission fleets by 2040. To achieve this goal, transit agencies are required to submit Rollout Plans that outline a gradual shift to zero-emission buses (ZEBs) over the next two decades. CALSTART analyzed key data found in Rollout Plans submitted by large transit agencies[1] as of May 2021 in efforts to develop a greater understanding of fleet conditions, timelines, trends, and costs (smaller agencies are obligated to submit Rollout Plans in 2023). The resulting figures and observations are valuable to advancing the ICT's zero-emission targets.

This report uses Rollout Plans submitted to CARB to provide summary statistics and simple observations on how large California transit agencies' planned migrations to zero-emission technologies. A few large transit agencies have not yet submitted their Rollout Plans and are therefore not represented in the summary analysis. Sunline, a smaller California transit agency that was not yet obligated to submit its Rollout Plan, opted to submit it plan by May 2021 and has also been used for reference.

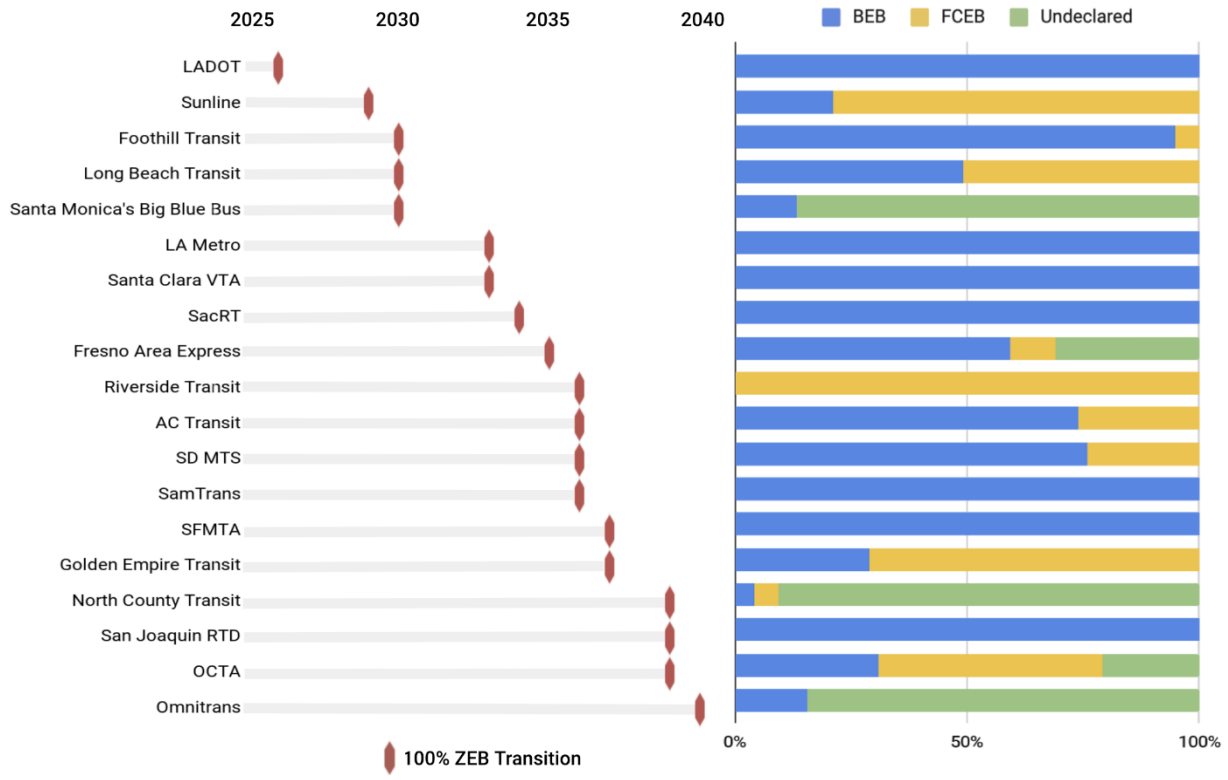
CALSTART aggregated ZEB acquisition schedules from 22 responding transit agencies (with ZEB and infrastructure cost data from 17 agencies, which was optionally submitted) as the basis of its calculations. Additional research, such as unique regional approaches to fuel types or why cost estimates may vary for infrastructure installments, could add supplemental value to the findings derived solely from the Rollout Plans. For more information on data sources, see Sections II and III.

For example, the Rollout Plans include the projected years when large transit agencies anticipate converting their entire fleets to ZEBs and the fuel types that will be used in the ZEBs: either battery electric buses (BEBs) or fuel cell electric buses (FCEBs). In cases where neither fuel type was identified, CALSTART categorized the choice as "undeclared." **Figure ES-1** uses these data points to track the timeline for each responding transit agency to reach 100 percent ZEB fleets and provide a snapshot of their ZEB technology choices at the time of reaching fully ZEB fleets. This chart lays out similarities and differences that inform when and how large California transit agencies plan to achieve zero emissions.

- Transit agencies appear to welcome both FCEBs and BEBs. One agency will exclusively deploy FCEBs, four agencies have opted for entirely BEB fleets, and every other responding agency anticipates a mix of technologies. More than half of responding agencies (10 out of 19) plan to purchase FCEBs, and two additional agencies will consider both FCEBs and BEBs in their undeclared acquisitions.
- The transition to 100 percent ZEBs (indicated by a red hexagon) is required by the ICT regulation to be completed by 2040. Most agencies that have submitted Rollout Plans will complete the transition ahead of schedule, with five agencies anticipating fleets composed entirely of ZEBs by 2030 or earlier.

[1] Of transit agencies that submitted Rollout Plans, 21 of 22 are considered to be "large" and were therefore obligated to submit their plans by May 2021. Sunline, a smaller transit agency, also submitted a Rollout Plan though it was not yet obligated - this plan is included in CALTART's calculations. Because every large transit agency submitted Rollout Plans, and only one responding agency of 22 is not considered large, this report will refer to projected trends among large transit agencies while referencing Sunline in its calculations.

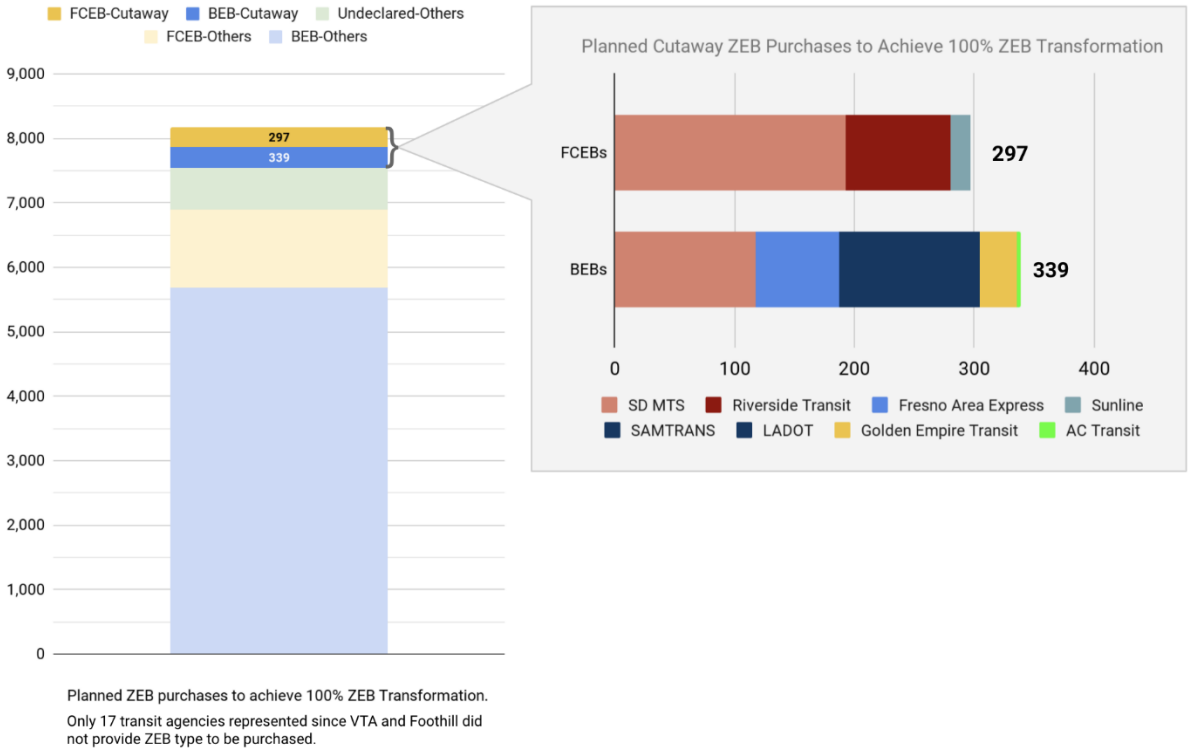
Figure ES-1. Responding Transit Agencies' Targeted Dates for Full ZEB Transformation with Proposed ZEB Technology Percentages at Time of Transition



Comparing procurement data across all submitted Rollout Plans also helps identify trends for multiple types of vehicles. **Figure ES-2** illustrates the number of cutaway vehicles relative to all purchases, fuel types, and operating agencies. Reporting transit agencies plan to use cutaway vehicles, for example, for approximately 10 percent of their vehicle fleets.

- More than 40 percent of responding transit agencies (eight out of 19) expect to operate cutaway ZEBs. These transit agencies anticipate that approximately 90 percent of their purchases will consist of standard long-body buses (>30 feet), with the remaining 10 percent consisting of cutaway buses.
- Cutaway buses are much more likely to be fueled by hydrogen than standard long-body buses. Transit agencies expect to purchase 339 cutaway BEBs and 297 cutaway FCEBs, creating a cutaway FCEB market share of 47 percent. By comparison, the entire declared ZEB market by 2040 is expected to consist of 15 percent FCEBs.

Figure ES-2. Anticipated Bus Count by Body Type, Fuel Type, and Transit Agency (Includes Rollout Plans Published as of May 2021)



Planned ZEB purchases to achieve 100% ZEB Transformation.

Only 17 transit agencies represented since VTA and Foothill did not provide ZEB type to be purchased.

These findings stand out among several other insights that CALSTART developed for "California Transit Agencies Chart a Course to Zero Emissions." These insights are laid out in Section I on ICT Rollout Plans. The following sections provide additional context for reporting agencies' plans to transition to ZEBs.

- **Section II: Observations** includes paraphrased comments taken from ICT Rollout Plans prepared by each transit agency. Comparative in nature, these takeaways are representative of different approaches to building out ZEB fleets and capture the decision-making processes behind Rollout Plan development.
- **Section III: Data Sources** details and compares the types of information within each Rollout Plan submitted as of May 2021, including ZEB count, ZEB costs, infrastructure costs, and submission date. Some discrepancies, which are noted in this section, occurred across the Rollout Plans that may affect the accurate forecasting of timing and costs for fleets to transition to ZEBs.

SECTION I

I. ROLLOUT PLANS FOR ZERO-EMISSION FLEETS

BACKGROUND

The California Air Resources Board (CARB) adopted the Innovative Clean Transit (ICT) regulation that became effective October 1, 2019. This regulation requires all public transit agencies to gradually transition their bus fleets to zero-emission technologies. All transit agencies that own, operate, or lease buses with a gross vehicle weight rating greater than 14,000 pounds, which covers all standard, articulated, over-the-road, double decker, and cutaway buses, must comply with the ICT regulation. This regulation requires a percentage of new bus purchases to be zero-emission buses (ZEBs) beginning in 2023, rising to 100 percent of all new bus purchases by 2029. The goal of the ICT is for all transit agency fleets to consist entirely of ZEBs by 2040.

The ICT regulation requires all transit agencies submit their Rollout Plans to CARB. Some key components of these plans include:

- Transit Agency Information
- Rollout Plan General Information
- Technology Portfolio
- Current Bus Fleet/Future Bus Purchases
- Facilities and Infrastructure Modifications
- Providing Service in Disadvantaged Communities
- Workforce Training
- Potential Funding Sources
- Start-up and Scale-up Challenges

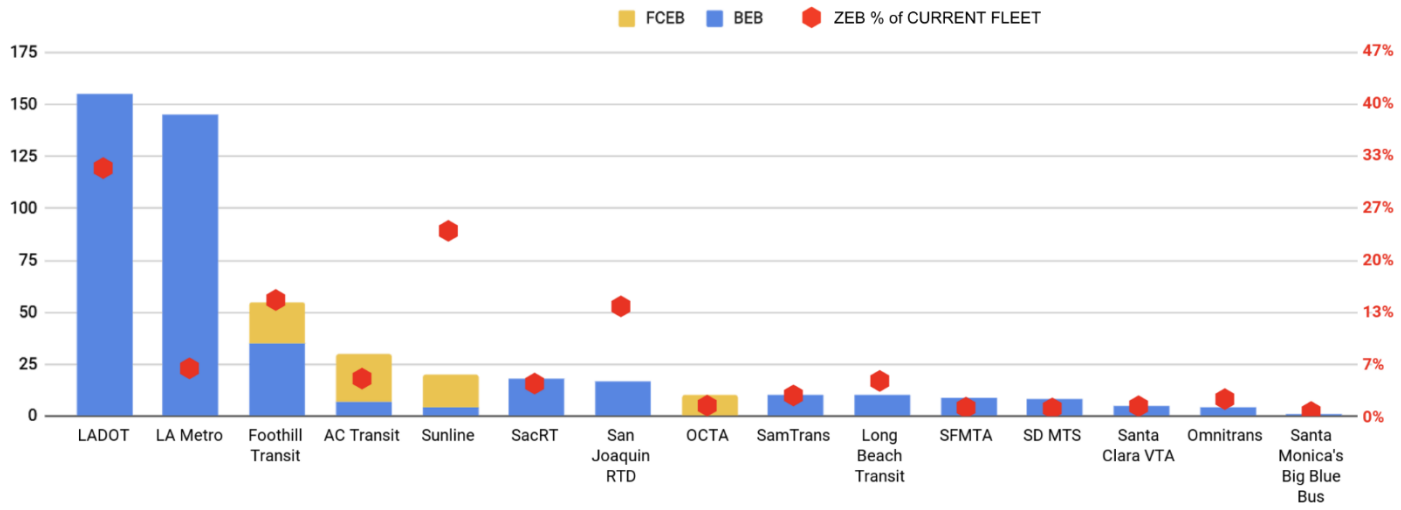
This report was created from 22 available Rollout Plans produced by each transit agency prior to May 2021, of which 19 submitted sufficiently detailed information to chart ZEB market progress. Some market data may be construed as partially complete because only large transit agencies were required to submit Rollout Plans by May 2021, a few large transit agencies have not yet submitted their plans, and some agencies chose to submit optional cost data. Some plans contained multiple scenarios or otherwise inconclusive information that were excluded from this analysis, which uses ZEB cost data and acquisition schedules from 17 agencies and infrastructure cost data from 13 agencies. These agencies that submitted Rollout Plans are referenced in this report as “responding” transit agencies. For more information on data management practices used in this report, see Section III.

CURRENT ZEBS DEPLOYED OR ON ORDER

The path to full ZEB deployments begins with fleets' current compositions. Some fleets have been more aggressive in adopting ZEBs during the early market and consequently have a head start, both in the total number of vehicles and the percentage of their fleets that are ZEBs. **Figure 1** shows all responding California transit agencies with confirmed ZEB deployments or purchases on order as of May 2021, according to the agencies' ICT Rollout Plans. These responding transit agencies' deployments or orders amount to 443 buses, or approximately 38 percent of the state's total 1,160 ZEBs deployed or on order (many ZEBs deployed in California that are not captured here were purchased by smaller transit fleets that are not yet required to submit Rollout Plans and non-transit fleets such as corporations, universities, airports, parking systems, and other private institutions).

- Two transit agencies, LADOT and LA Metro, account for approximately two-thirds of large transit agency ZEB deployments or orders. LADOT also stands out for having the highest percentage of ZEBs relative to its current fleet, with more than 40 percent of its buses running solely on electricity.
- The early ZEB market has purchased a greater number of BEBs than FCEBs. The two largest fleets based in and around Los Angeles operate BEBs exclusively, and BEBs represent the majority of ZEB purchases in 80 percent of fleets that submitted Rollout Plans.
- Most transit agencies will need to transform the great majority of their fleets. Only two fleets are currently comprised of at least 20 percent ZEBs, and only LADOT exceeds 40 percent. Nearly every transit agency will need to transform more than 85 percent of its fleet to ZEBs in the next 20 years.

Figure 1. Number of ZEBs and ZEB Percentage of Current Fleet (Deployed and/or Purchased)



THE ROAD TO ZERO EMISSIONS

Aggregating the Rollout Plans submitted by each transit agency leads to a greater understanding of ZEB trends among all responding agencies. **Figure 2** charts the timeline and technology choices by transit agencies, highlighting where both commonalities and important differences in how the transit sector will transition to ZEBs under the ICT.

- Transit agencies appear to welcome both battery electric buses (BEBs) and fuel cell electric buses (FCEBs). Four agencies have opted for entirely BEB fleets, one agency will exclusively deploy FCEBs, and every other responding agency anticipates a mix of technologies. The undeclared segments indicate that an agency has not yet decided which technology will best fit its needs for a particular number of vehicles. More than half of responding agencies (10 out of 19) plan to purchase FCEBs, and two additional agencies will consider both FCEBs and BEBs in their undeclared acquisitions.
- The transition to 100 percent ZEBs (indicated by a red hexagon) is required by the ICT regulation to be completed by 2040. Most agencies that have submitted Rollout Plans will complete the transition ahead of schedule, with five agencies anticipating fleets composed entirely of ZEBs by 2030 or earlier. Agencies expressed that the timing of transitions may be influenced by funding availability and model availability to meet all of their duty cycles.

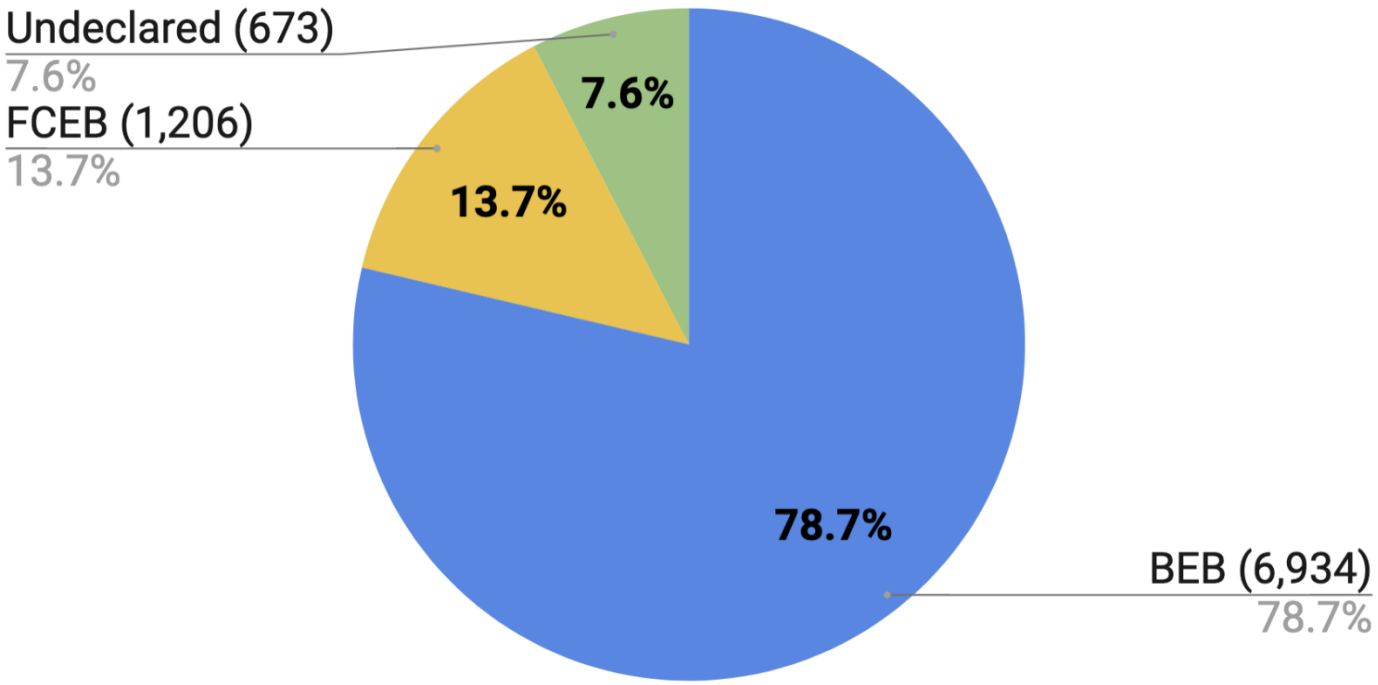
Figure 2. Responding Transit Agencies' Targeted Dates for Full ZEB Transformation with Proposed ZEB Technology Percentages at Time of Transition

PLANNED ZEB PROCUREMENTS

California's transit bus fleet is projected to transform completely to ZEBs by 2040. As **Figure 3** illustrates, the different paths that agencies undertake will result in a range of ZEB technologies and dates when full zero-emissions fleets are activated. Once the transition to full ZEB fleets has been achieved, California transit agencies that have submitted their Rollout Plans will operate a total of 8,207 ZEBs. **Figure 3** shows the totals and percentages by 2040.

BEBs will account for the great majority of deployments, with approximately three out of every four buses declared as running solely on electricity. That ratio could grow if the transit agencies that have not declared which technology they plan to purchase and operate skews toward BEBs. Alternately, FCEBs could account for one out of every four bus sales by 2040 if undeclared purchase orders skew toward fuel cell technologies.

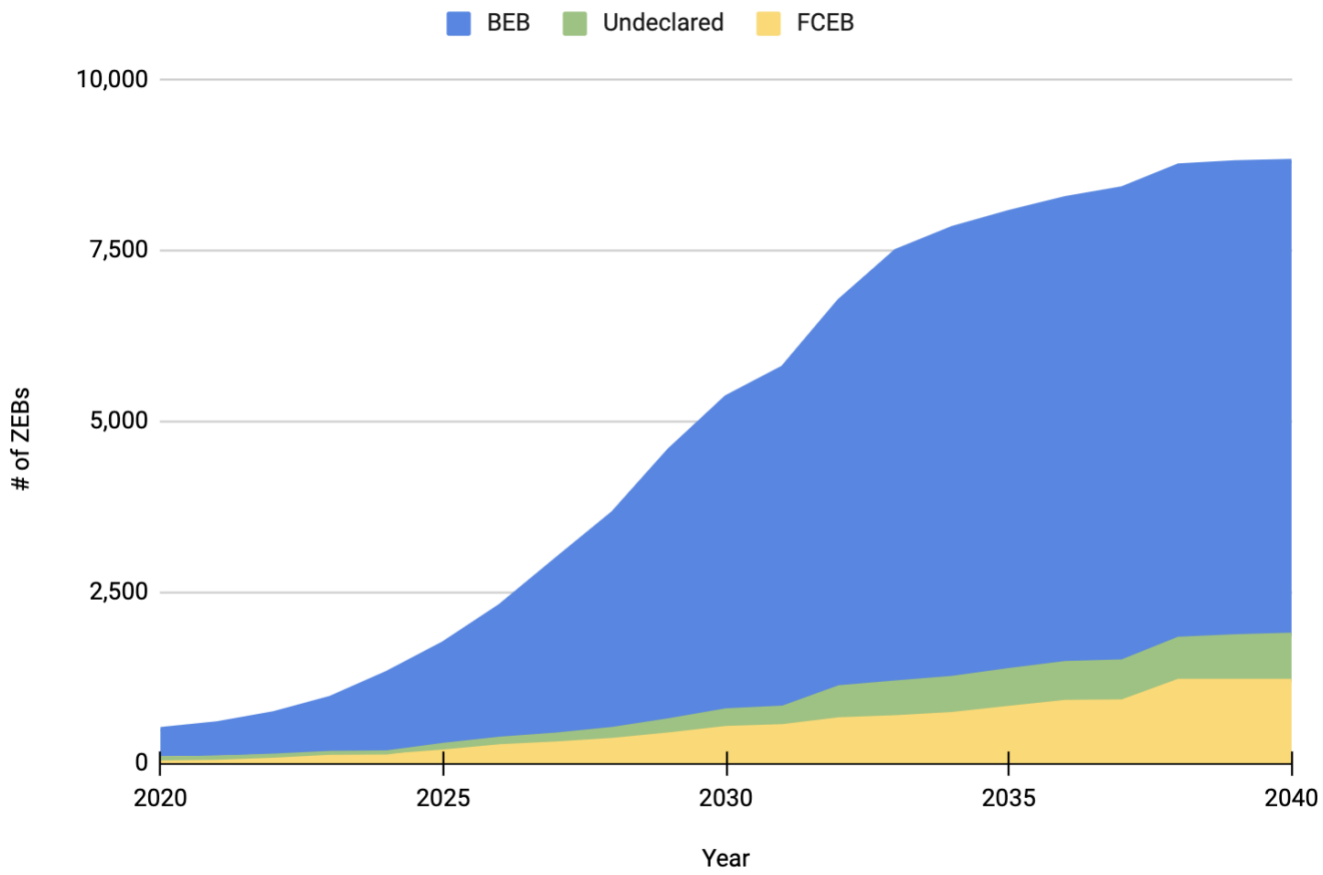
Figure 3. California ZEB Fleet Mix by Declared Technology (Includes Transit Agency Rollout Plans Up to 2040 Published as of May 2021)



The rate of ZEB adoption and technology types that each transit agency chooses will impact overall deployment figures over time. **Figure 4** charts responding California transit agencies' ZEB market growth over the 20-year transformational period by declared technology type.

- Transit agencies appear to prioritize BEB purchases in the near term. BEB growth scales up rapidly leading up to the 2029 deadline requiring exclusively ZEB purchases, with the rate of BEB adoption lowering during the years following the 2029 deadline. FCEB and undeclared technology adoptions ramp steadily up toward the end of the 20-year transformation.
- The 443 ZEBs that have been ordered or placed into service in California represent only 4 percent of the planned ZEB procurements by responding transit agencies, which will need approximately 8,000 additional ZEBs to transition entirely to zero-emission fleets by 2040.
- Near-term BEB adoption may reflect current market positioning, as shown in Figure 1. BEBs may be simpler for transit agencies to purchase and operate in the short term. Higher FCEB adoption rates in the long-term may indicate that the technology could fill duty cycles that BEBs do not meet in the short-term, or that additional infrastructure planning and familiarity with FCEBs could smooth transit agencies' transitions to the technology.

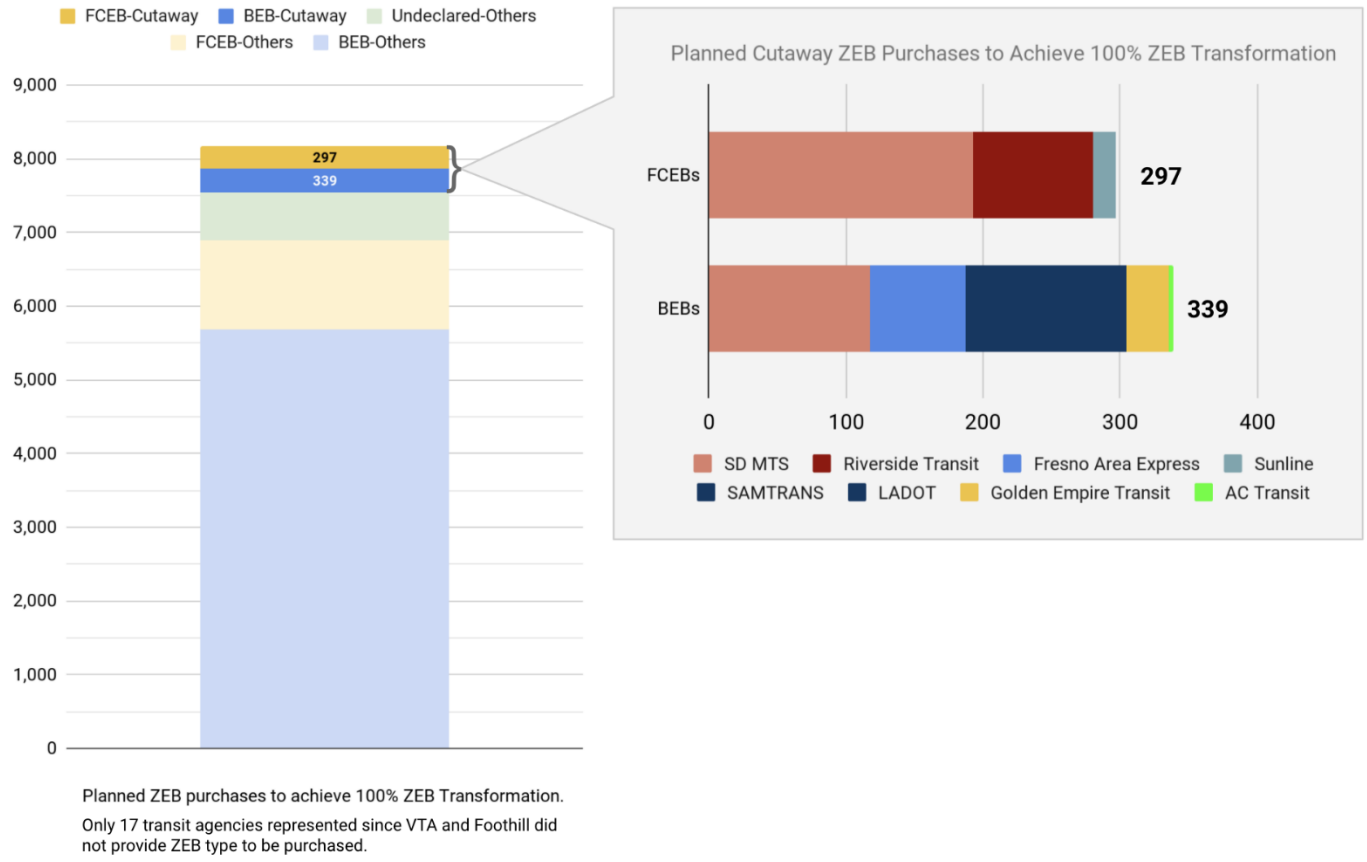
Figure 4. California ZEB Fleet Mix by Technology Over Time (Includes Transit Agency Rollout Plans Published as of May 2021)



Interestingly, projected deployment figures between FCEBs and BEBs are nearly equal for cutaway vehicle types, with a slightly higher planned rollout for cutaway BEBs. **Figure 5** shows the number of cutaway vehicles relative to all purchases, fuel types, and operating agencies (data excludes two transit agencies that did not specify body and fuel types).

- More than 40 percent of responding transit agencies (eight out of 17) expect to operate cutaway ZEBs. These transit agencies anticipate that approximately 92 percent of their purchases will consist of standard long-body buses (>30 feet), with the remaining 8 percent consisting of cutaway buses.
- Cutaway buses are much more likely to be fueled by hydrogen than standard long-body buses. Transit agencies expect to purchase 339 cutaway BEBs and 297 cutaway FCEBs, creating a cutaway FCEB market share of 47 percent. By comparison, the entire declared ZEB market by 2040 is expected to consist of 15 percent FCEBs.
- San Diego Metropolitan Transit System stands out for its large number of cutaways relative to other responding transit agencies, with plans to purchase more than 300 cutaways that include both FCEBs and BEBs (47 percent of all planned cutaway purchases).

Figure 5. Anticipated Bus Count by Body Type, Fuel Type, and Transit Agency (Includes Rollout Plans Published as of May 2021)



Planned ZEB purchases to achieve 100% ZEB Transformation.

Only 17 transit agencies represented since VTA and Foothill did not provide ZEB type to be purchased.

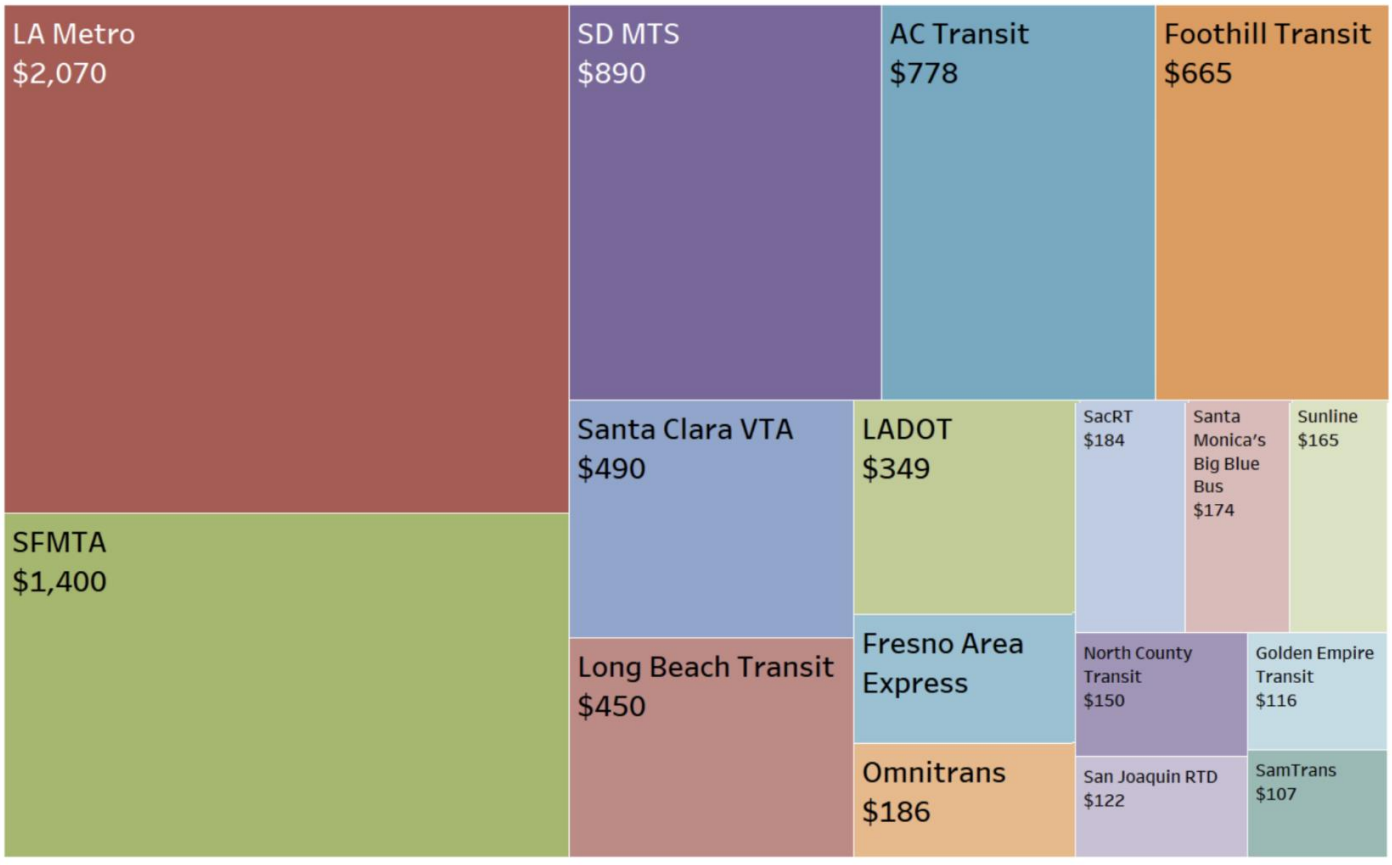
COSTS OF ZERO EMISSIONS TRANSFORMATION

Responding transit agencies were required to submit Rollout Plans with dates of anticipated ZEB acquisitions and, if applicable, the type of ZEB technology that would be adopted. Some of the responding agencies provided cost data for vehicle and infrastructure acquisitions, which was not required by CARB as part of Rollout Plan submissions. CALSTART used this data to provide estimated cost snapshots for responding agencies to transform their fleets to ZEBs.

Seventeen of the 22 transit agencies included optional projected cost data for acquiring ZEBs. The aggregated total cost estimated by these transit agencies amounts to $8.5 billion. **Figure 6** shows the cumulative costs to purchase ZEBs that each transit agency estimated, with size of rectangles representative of total costs.

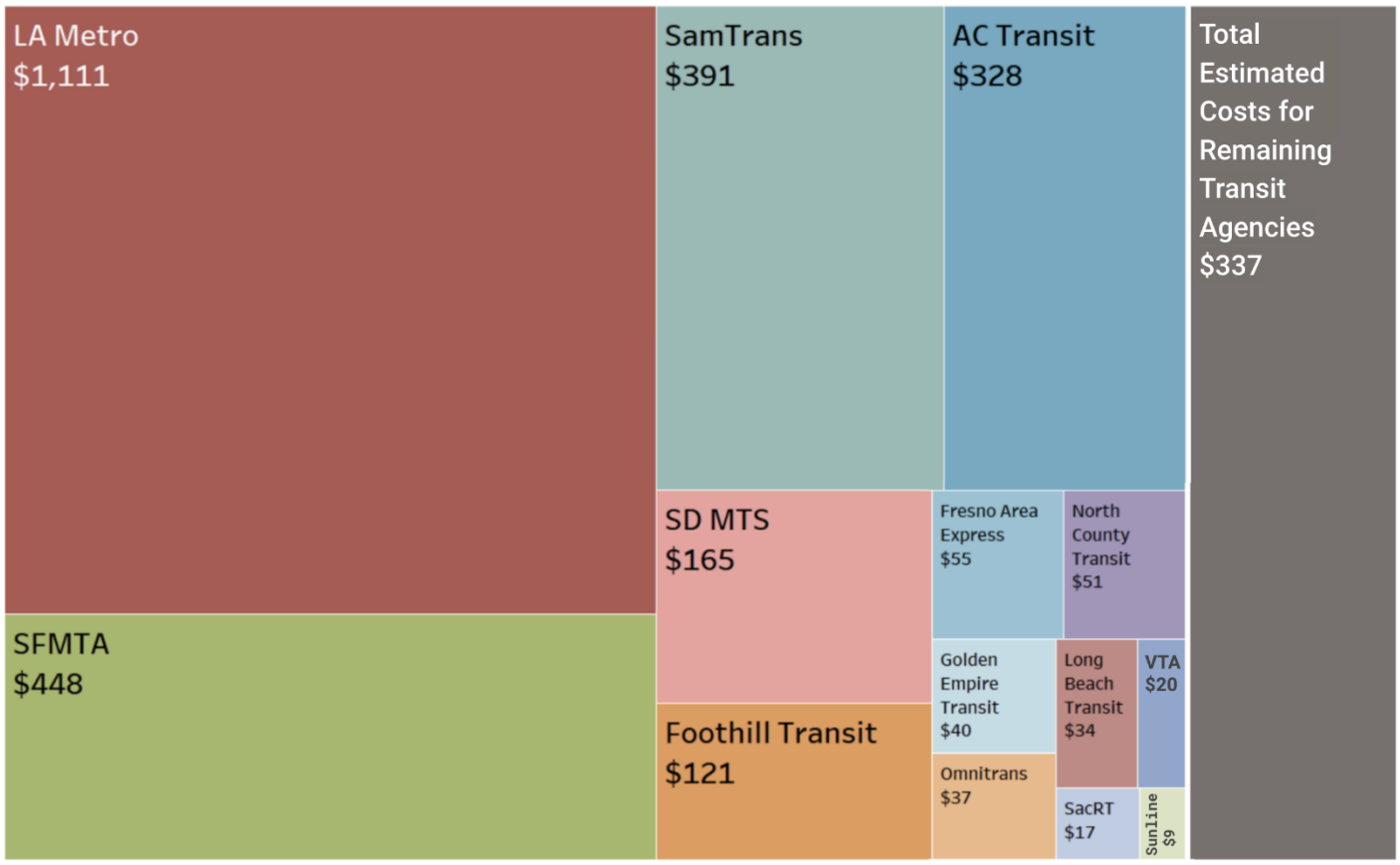
- The costs to each bus fleet roughly correspond to the number of buses each transit agency plans to purchase. LA Metro and SFMTA operate two of the largest fleets, whereas the smaller operators located in the bottom-right of Figure 6 will need to purchase fewer ZEBs to meet their zero-emission fleet targets.
- The total estimated costs may exceed the costs that will be needed to achieve fully zero-emission fleets. Some transit agencies included their planned acquisition schedules and associated costs through 2040, well beyond the dates when many transit agencies plan to achieve full zero-emission fleets, whereas other fleets only included purchase costs that would reach the threshold of fully zero-emission fleets. For example, LADOT includes ZEB purchase costs through 2040, even though the agency plans to achieve a zero-emission fleet well before 2030.

Figure 6. Cumulative Costs to Purchase ZEBs ($M) by Transit Agency (Responding Fleets as of May 2021)



Of the 14 transit agencies that provided infrastructure costs in the Rollout Plans, the aggregated total cost of electric and hydrogen fueling infrastructure amounts to $2.8 billion. **Figure 7** shows the aggregated breakdown of electric and hydrogen fueling infrastructure investment costs as estimated by each transit agency. The block that is separated and colored in gray represents CALSTART's estimated aggregated infrastructure investments for the three agencies that provided ZEB costs, but did not provide infrastructure costs.[2] The additional estimated infrastructure investments add over $300 million, bringing the total estimated infrastructure investments for the 17 responding agencies to approximately $3.2 billion.

Figure 7. Cost to Build Fueling Zero-Emission Infrastructure to Support ZEBs ($M) by Transit Agency (Responding Fleets as of May 2021)



- Some of these transit agencies have already made investments in BEB and hydrogen fueling infrastructure, which may impact the total cost that each agency may need to invest. Agencies that plan to invest more heavily in FCEBs, such as Sunline, may anticipate lower future infrastructure costs if hydrogen fueling stations have already been built and can service multiple FCEBs through existing infrastructure.

Larger transit fleets tend to have higher estimated infrastructure costs, which is to be expected because the infrastructure will service a great number of buses. Several other factors may impact the infrastructure costs that large fleets optionally estimated:

- LA Metro's infrastructure investment costs may be the highest for several reasons, most notably because it operates the largest fleet and will purchase the greatest number of ZEBs that require associated infrastructure investments. The four highest anticipated costs are located in California's two largest metropolitan areas, Los Angeles and the Bay Area, which are

[1] Three agencies provided optional vehicle cost data but did not provide optional infrastructure cost data. These agencies consist of LADOT, Santa Monica Big Blue Bus, and San Joaquin RTD. CALSTART estimated the generalized expected infrastructure costs for the three agencies that did not provide infrastructure cost estimates by calculating the average infrastructure investment cost estimated by the agencies that did provide infrastructure costs. This average infrastructure cost figure was then multiplied by the number of ZEBs that each agency plans to procure. These three agencies' calculated infrastructure investments are listed in a separate gray design to demonstrate that these agencies' investments are estimates derived by CALSTART.

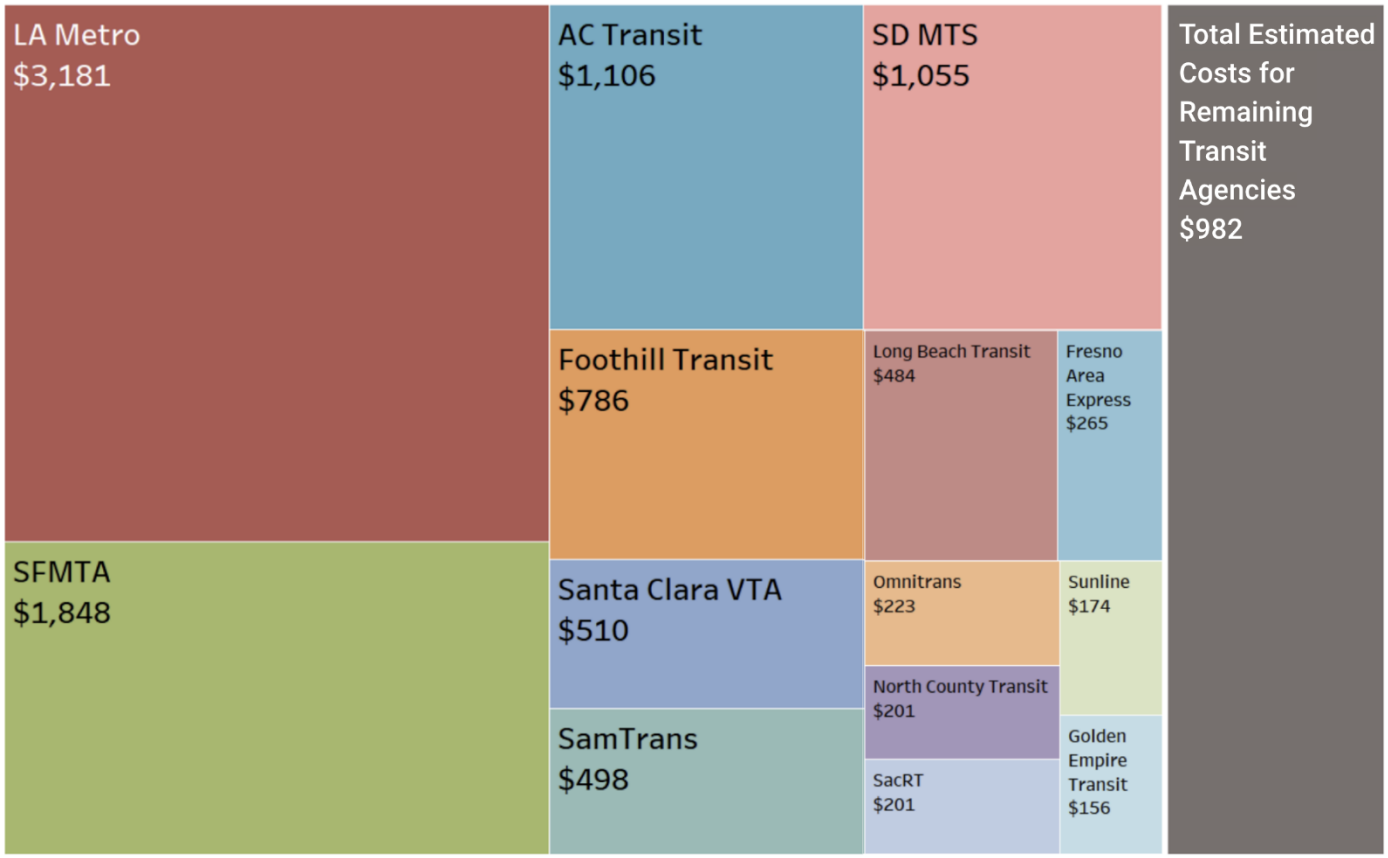
typically associated with large bus fleets that might require extensive upgrades and complex management systems.

- Larger fleets typically require expansive infrastructure investments to meet all operations and duty cycles. The complex array of planning and hardening infrastructure (such as trenching, transformer upgrades, and ensuring safe operations in public areas) for each bus route in dense urban areas may inflate costs quickly.
- Each transit agency approached its estimates differently (see Sections II and III for details). Larger transit agencies may have additional staff that were able to calculate targeted and highly specific "all-in" costs that added to projected infrastructure cost totals.

The total costs for transitioning responding agencies' fleets to ZEBs with associated infrastructure by 2040 amounts to $10.6 billion. Adding in agencies that included ZEB costs and using CALSTART estimates for infrastructure, the total investment costs rise to $11.6 billion. **Figure 8** shows the estimated combined ZEB and infrastructure costs by each transit agency.

- The 17 responding agencies that submitted Rollout Plans with optional cost data represent approximately two-thirds of California's transit fleet by bus count. The total cost for all transit agencies, therefore, could be extrapolated to exceed $17 billion. However, similar to the estimates for ZEB costs from Figure 6, the total costs to reach full ZEB fleets may be overrepresented because transit agencies submitted costs for vehicle acquisitions planned after achieving 100 percent ZEB fleet composition, at which point that would be replacing older ZEBs with newer ZEBs.
- The transit agencies with the highest total costs correspond to the agencies that manage large, urban fleets. As may be expected, these agencies will purchase large quantities of ZEBs relative to small transit agencies, and their associated infrastructure located in areas with higher real estate prices relative to agencies in areas with lower-cost real estate result in higher total expenditures.
- The total cost estimates reflect only the purchase costs of ZEBs and infrastructure, not the likely savings that transit agencies will achieve through ZEBs' reduced fueling and maintenance costs. Though transit agencies will need to make significant investments in the next two decades to fully transition to ZEBs, as shown in Figure 9, their total costs may be expected to be lower than the upfront investments indicate.
- Total investment costs also do not represent hidden savings, such as the value to residents of reduced air pollutants that negatively impact human health, particularly for disadvantaged communities that tend to live along roadways and suffer disproportionately from air pollution burdens (Tessum, 2021) and greenhouse gas emissions.

Figure 8. Total Cost to Transform Transit Agency Fleets ($M) to Zero Emissions by Transit Agency (Responding Fleets as of May 2021)



SECTION II

II. OBSERVATIONS

GENERAL OBSERVATIONS

- LA Metro plans to repower its conventionally fueled buses with zero-emissions drivetrains. Some transit agencies have said repowering vehicles would be more expensive than buying new buses.
- If BEB ranges do not increase significantly in the next few years, transit agencies will either need to buy extra BEBs to cover the routes or buy FCEBs.

OBSERVATIONS BY TRANSIT AGENCY

The following are paraphrased comments pulled from various ICT Rollout Plans that were prepared by each transit agency.

Fresno Areas Express

- Will replace its fleet on a 1:1 ratio: BEBs for shorter routes, FCEBs for longer routes.
- Is planning to refurbish some of their existing CNG fleet in 2021, which will extend the vehicles' lifespans and delay their replacement with ZEBs.
- Has partnered with Fresno City College to build a state-of-the-art training facility (Advanced Propulsion Training Campus) and will use this program to train its workforce.

Golden Empire Transit Bus (Bakersfield)

- May have to relocate its main facility by 2025, depending upon the final route of the High Speed Rail project.

LA Metro

- Expects to replace its buses with BEBs on a 1:1 ratio and will use on-route chargers to extend range if necessary.
- Will consider switching to FCEBs if battery range does not increase soon enough.

LA Metro (Continued)

- Plans to repower its CNG buses, turning them into BEBs (848 bus conversions) which are expected to be deployed in 2027 or 2028.
- Part of the justification for on-route charging is the expectation that midday power will become cheaper due to excessive solar electricity production during that period.
- On-route chargers will be DC inverted pantograph chargers with at least 150kW charging capacity.
- Expects to set up depot charging overhead on a one-to-many basis and will allow for fast charging lanes to top off or recharge at the end of the day.

North County Transit District (Northern San Diego County)

- Expects that BEBs will not be able to operate on 14 percent of their blocks by 2042, so FCEBs are strongly favored.

OCTA (Orange County)

- Views FCEBs as most comparable to CNG buses in a "business as usual" scenario.
- Feels that parking BEBs is more complicated and must be planned out well to ensure proper state of charge at the times needed.
- BEBs offer better energy efficiency in stop-and-go urban environments.
- A 100 percent BEB solution would require on-route charging.
- Lifecycle operating expenses are higher for BEBs.
- Hydrogen infrastructure costs are comparable to EV infrastructure costs for large quantities of ZEBs.
- Would prefer a single technology type (BEB or FCEB) because it would mean fewer spare parts and less staff training would be needed.

Riverside Transit

- Believes that a BEB-only fleet is not viable because certain routes in the large service area include significant deadheading (trips without paying passengers)
- Faces limited options for siting hydrogen infrastructure, as the Hemet facility is adjacent to the approach end of a runway of the Hemet airport.

Sacramento Regional Transit

- Has most of its bus parking located under an elevated freeway, making the site unsuitable for hydrogen infrastructure.
- Favors BEBs, and the utility (SMUD) is less exposed to wildfire-related blackouts than PG&E.
- Will put CNG buses purchased in 2027/2028 on the longest routes to comply with FTA's 500,000-mile rule.
- Needs another charging location for 51 BEBs, because of CALTRANS setback requirements of the chargers from the freeway pillars and the limits of the power available in the area from SMUD. The McClelland facility would be too expensive and cause excessive deadhead trips.

San Francisco Municipal Transit Agency (SFMTA)

- Justifies its focus on BEBs based on affordability, space constraints, low-cost electricity, and anticipated public resistance to FCEBs.
- It is difficult to assess how much additional power could be available to SFMTA due to the unusual way the municipalutilities are set up in San Francisco without service territory boundaries.

SFMTA (Continued)

- Is not eligible for PG&E's EV Fleet programs since SFMTA is not a PG&E customer.
- One particular block has an extreme duty cycle, climbing the equivalent of 2.2 miles in elevation per day.
- Uses renewable diesel for its entire diesel hybrid fleet.
- In the Green Zone in the city of San Francisco, diesel hybrid buses automatically switch to run in EV mode to minimize local air pollution.
- Is expecting a 1:1 BEB replacement of their current fleet.
- Will likely need on-route charging since 9 percent of existing blocks travel beyond 150 miles per day. The entire fleet contributes less than .01 percent of the city's overall greenhouse gas emissions.

San Diego MTS

- Favors FCEBs because they can negotiate hydrogen fuel prices, unlike electricity rates for BEBs.
- Is planning for backup power so buses will not have to shut down during a power outage.
- Would like to see communication protocols standardized between bus management and charging systems.
- Will not achieve full transition to ZEBs until 2042 because the final purchase of conventional buses in 2028 will not be retired until after 14 years of service.

SamTrans (San Mateo County)

- Is preparing for sea level rise by 2050 because two of their facilities that sit between one and three feet above sea level are likely to be impacted, raising its infrastructure costs to nearly triple the cost of ZEB purchases.
- Expressed that downtime for ZEBs is greater than conventional buses due to replacement parts scarcity and troubleshooting challenges.
- Sees ZEBs as having a steep learning curve because training manuals are not yet fully developed and the maintenance team needs to acquire new skill sets.

Santa Clarita

- Plans to install hydrogen production (steam reforming) on-site that will eventually produce 1,500 kg/H2/day to support 60 FCEBs.
- Rotates all buses through their network to equitably distribute new bus purchases.
- Requires its staff to complete 16 hours of its EV Transit Bus Safety Awareness and Familiarization course.

Sunline (Coachella Valley)

- Has been pursuing alternative fuel vehicles since 1993.
- Began operating a new electrolyzer for production of hydrogen in 2019 that produces 900 kg/H2 per day, enough to power 32 FCEBs.
- In 2020, decommissioned the steam reforming equipment, which produced hydrogen from methane.
- Will be refurbishing CNG buses to extend their lifespan by six years to spread out procurement costs.
- Has no plans to convert conventional buses to zero emissions.
- Is looking to diversify its hydrogen supply chain by trucking in liquid hydrogen from another supplier.

SECTION III

III. DATA SOURCES

Each of the 21 large transit agencies was required by the Innovative Clean Transit regulation to submit detailed information on their transition to 100 percent ZEBs, including vehicle acquisitions and associated dates. Costs for vehicle acquisitions and infrastructure were optional. **Table 1** describes the types of information provided in the Rollout Plans that were submitted as of May 2021, which were used as the basis for this report's quantitative analyses.

Table 1. Available ICT ZEB Rollout Plans by Transit Agency, Date Submitted, and Included Contents

		ZEB Counts	ZEB Counts by Bus Type	ZEB Costs	Infrastructure Costs	Report Date
1	LA Metro	✓	✓	✓	✓	Mar-2021
2	SFMTA	✓	✓	✓	✓	Feb-2021
3	OCTA	✓	✓	✗	✗	Jun-2020
4	AC Transit	✓	✓	✓	✓	Jun-2020
5	SD MTS	✓	✓	✓	✓	Sep-2020
6	Santa Clara VTA	✓	✗	✓	✓	Dec-2020
7	SamTrans	✓	✓	✓	✓	Dec-2020
8	LADOT	✓	✓	✓	✗	Nov-2020
9	Foothill Transit	✓	✗	✓	✓	Sep-2019
10	Riverside Transit	✓	✓	✗	✗	Dec-2020
11	Omnitrans	✓	✓	✓	✓	Apr-2020
12	SacRT	✓	✓	✓	✓	Mar-2021
13	Long Beach Transit	✓	✓	✓	✓	Jun-2020
14	Santa Monica's Big Blue Bus	✓	✓	✓	✗	Jun-2020
15	Santa Clarita	✗	✗	✗	✗	Jun-2020
16	North County Transit	✓	✓	✓	✓	Jun-2020
17	Golden Gate Bridge HTD	✗	✗	✗	✗	-----
18	San Joaquin RTD	✓	✓	✓	✗	Jun-2020
19	Fresno Area Express	✓	✓	✓	✓	Jun-2020
20	Golden Empire Transit	✓	✓	✓	✓	Aug-2020
21	Montebello	✗	✗	✗	✗	-----
22	Sunline	✓	✓	✓	✓	Aug-2020

There was some variability to the metrics used in each report. For example, when submitting optional cost information, some transit agencies counted the incremental cost of transitioning to a full zero-emissions fleet, while other agencies included costs they would have incurred anyway to acquire replacement conventional vehicles. These discrepancies may result in less reliable data forecasts in this report, and the latter practice could overstate the true cost of migrating transit fleets to zero-emission technologies.

- LA Metro – Excludes costs for solar+storage resources that are likely to be installed.
- SFMTA – Excludes solar+storage on-route charging resources and "make ready" costs.
- Santa Clara VTA – Multiple charging scenarios were proposed. Only the option deemed most likely, “Depot chargedBEBs,” was considered in this document.
- SacRT – Both BEB and FCEB scenarios were submitted. This document considered only the 100 percent BEB option because it cost $45M less than the FCEB option.
- Santa Clarita – Available data is insufficient to draw comparisons with other agencies, so it was not included.
- FAX – ZEB cost forecast includes costs for additional CNG buses. This practice was not consistently applied across transit agencies and may have added additional vehicle purchase costs to totals.

REFERENCES

Tessum, C., Paolella, D., Chambliss, S., Apte, J., Hill, J., & Marshall, J. (2021). Science Advances. PM2.5 Polluters Disproportionately and Systematically Affect People of Color in the United States. Retrieved from: https://advances.sciencemag.org/content/7/18/eabf4491