Existing Conditions Report

Riverside Connect

Prepared by the Center for Transportation and the Environment
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List of Acronyms

ADA	American with Disabilities Act
AFLEET	Alternative Fuel Life-Cycle Environmental and Economic Transportation
ANL	Argonne National Lab
BEB	Battery Electric Bus
CARB	California Air Resources Board
CEC	California Energy Commission
CI	Carbon Intensity
COA	Comprehensive Operations Analysis
CRT	Charge Ready Transport
CTE	Center for Transportation and the Environment
DAR	Dial-A-Ride
EV	Electric Vehicle
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicles
FTA	Federal Transit Administration
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GVWR	Gross Vehicle Weight Rating
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
ICT	Innovative Clean Transit
kW	Kilowatt
kWh	Kilowatt Hour
kWh/mi	Kilowatt-hour/mile
LA Metro	Los Angeles County Metropolitan Transportation Authority
LCFS	Low Carbon Fuel Standard
MOU	Memorandum of Understanding
MW	Megawatt
MWh	Megawatt-hours
NOx	Nitrogen Oxides
OCTA	Orange County Transportation Authority
OEM	Original Equipment Manufacturer
RCTC	Riverside County Transportation Commission
RTA	Riverside Transit Agency
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SRTP	Short Range Transit Plan
TBW	Tire and Brake Wear
TTW	Tank-To-Wheel
WTT	Well-To-Tank
WTW	Well-To-Wheel
YTD	Year-to-date
ZEB	Zero-Emission Bus

Glossary of Terms

Auxiliary Loads: Power consumed (usually as a by time measure, such as "x" kW/hour) by support systems for non-drivetrain demands, such as HVAC and interior lighting.

Battery Electric Bus: Zero-emission bus that uses onboard battery packs to power all bus systems.

Battery Usable Capacity: The portion of the battery that is usable by the vehicle. The top 10% and the bottom 10% of a battery are typically not used to extend the life of the battery. The usable capacity therefor typically represents 80% of the nameplate capacity.

Block: Refers to a vehicle schedule, the daily assignment for an individual bus. One or more runs can work a block. A driver schedule is known as a "run."

Charging Equipment: The equipment that encompasses all the components needed to convert, control and transfer electricity from the grid to the vehicle for the purpose of charging batteries. May include chargers, controllers, couplers, transformers, ventilation, etc.

Cutaway: Cutaways are typically smaller than conventional buses, measuring less than 30 ft. long and weighing less than 30,000 lbs. and more that 14,000 lbs., seating about 15 or more passengers and may accommodate some standing passengers, while providing more space – particularly for wheelchairs – compared to other small-to-medium- sized vehicle options, forming a critical component of paratransit service in the United States.

Depot Charging: Centralized BEB charging at a transit agency's garage, maintenance facility, or transit center. With depot charging, BEBs are not limited to specific routes, but must be taken out of service to charge.

Energy: Quantity of work, measured in kWh for ZEBs.

Energy Efficiency: Metric to evaluate the performance of ZEBs. Defined in kWh/mi for BEBs, mi/kg of hydrogen for FCEBs, or miles per diesel gallon equivalent for any bus type.

Fuel Cell Electric Bus: Zero-emission bus that utilizes onboard hydrogen storage, a fuel cell system, and batteries. The fuel cell uses hydrogen to produce electricity. Its waste products are heat and water. The electricity powers the batteries, which powers the bus.

Gasoline Gallon Equivalent (GGE): A unit equal to the amount of energy contained in one gallon of gasoline that can be used to compare the fuel consumption, efficiency, and emissions across vehicles with different fuel types.

Greenhouse Gas Emissions: Common GHGs associated with diesel combustion include carbon dioxide (CO2), carbon monoxide (CO), nitrous oxides (Nox), volatile organic compounds (VOCs), and particulate matter (PM). These emissions negatively impact air quality and contribute to climate change impacts. Zero-emission buses have no harmful emissions that result from diesel combustion.

Gross Vehicle Weight Rating (GVWR): The maximum amount of weight that a vehicle can handle safely, which includes the vehicle weight and its payload capacity.

Hydrogen Fueling Station: The location and equipment that houses the hydrogen storage, compression, and dispensing equipment to support fuel cell electric buses. If hydrogen is produced onsite, it will also include this equipment.

Nameplate Capacity: The maximum rated output of a battery under specific conditions designated by the manufacturer. Battery nameplate capacity is commonly expressed in kWh and is usually indicated on a nameplate physically attached to the battery. It includes the unusable top and bottom portion of the battery's total energy.

Nominal Efficiency/Nominal Energy: Nominal load conditions assume average passenger loading and a moderate temperature over the course of the day, which places marginal demands on the motor and the heating, ventilation, and air conditioning (HVAC) system. These conditions are then used to define the nominal operating efficiencies in kWh/mi and energy requirements per vehicle, per route.

On-route Charging/Opportunity Charging: The behavior of using on-route located charging equipment to charge a BEB in-service. With proper planning, on-route charged BEBs can operate indefinitely, and one charger can charge multiple buses.

Operating Range: Driving range of a vehicle using only power from its electric battery pack or on-board hydrogen storage, fuel cell, and battery to travel a given driving cycle.

Route Modeling: A cost-effective method to assess the operational requirements of ZEBs by estimating the energy consumption on various routes using specific bus specifications and route features.

Strenuous Efficiency/Strenuous Energy: Strenuous load conditions assume high or maximum passenger loading and near-maximum output of the HVAC system. These strenuous loading conditions represent a hypothetical and unlikely worst-case scenario, but one that is necessary to establish an outer bound for the analysis, and are expressed as strenuous operating efficiencies in kWh/mi and energy requirements per vehicle, per route.

Tractive Efficiency: The tractive efficiency refers to the energy required to drive the motors, which can be impacted by passenger loading, topography, and speed of the cutaway.

Useful Life: FTA definition of the amount of time a transit vehicle can be expected to operate based on vehicle size and seating capacity. The useful life defined for transit buses is 12-years. For cutaways, the useful life is 7 years.

Validation Procedure: Confirms that the demonstrated bus performance is in line with expected performance. Results of validation testing can be used to refine bus modeling parameters and to inform deployment plans. Results of validation testing are typically not grounds for acceptance or non-acceptance of a bus.

Well-to-Tank (WTT) Emissions: Quantity of greenhouse gas, criteria pollutants, and/or other harmful emissions that takes into account the carbon intensity of the grid used to charge the buses. For FCEBs, well-to-tank emissions would take into account the energy to produce, transport, and deliver the hydrogen to the vehicle.

Well-to-Wheel (WTW) Emissions: Quantity of greenhouse gas, criteria pollutants, and/or other harmful emissions that includes emissions from energy use and emissions from vehicle operation. For BEBs, well-to-wheel emissions would take into account the carbon intensity of the grid used to charge the buses. For FCEBs, well-to-wheel emissions would take into account the energy to produce, transport, and deliver the hydrogen to the vehicle.

Zero-Emission Bus (ZEB): A heavy-duty bus that emits no tailpipe emissions from the onboard source of power.

Zero-Emission Vehicle: A vehicle that emits no tailpipe emissions from the onboard source of power. This is used to reference battery-electric and fuel cell electric vehicles, exclusively, in this report.

Introduction

Executive Summary

Riverside County Transportation Commission (RCTC) awarded a contract to the Center for Transportation and the Environment (CTE) to develop the Riverside County Zero-Emission Bus Rollout and Implementation plans on behalf of transit agencies and municipal transportation services in the cities of Banning, Beaumont, Corona and Riverside; and the Palo Verde Valley Transit Agency. The **Zero-Emission Bus** (ZEB) rollout plans must be compliant with the California Air Resources Board (CARB) Innovative Clean Transit (ICT) Regulation and also with Federal Transit Administration (FTA) requirements in applying for federal grant funds.

CTE is a non-profit zero-emission transportation planning and engineering firm that has partnered with IBI Group, a leading international architecture, planning, and engineering services company, to support planning the approach to achieve RCTC's zero-emission goals. Riverside Connect provides paratransit service in and around the City of Riverside, the largest city within Riverside County, located 50 miles southeast of Los Angeles.

The Existing Conditions Report is the first step in the development of Riverside Connect's ZEB Rollout Plan and serves as a foundation and baseline scenario from which the transition to zero-emission buses will begin. CTE and IBI Group surveyed Riverside Connect's existing conditions including any relevant demographics, service area characteristics, existing fleet sizes and service conditions, and location and status of fueling and maintenance infrastructure in the project area. To process and verify this information, CTE compiled Riverside Connect's data into a standard template and conducted thorough reviews of its content. As a product of this effort, CTE created this comprehensive Existing Conditions Report that compiles this information and summarizes baseline conditions for Riverside Connect.

Reverence to the state of affairs of an agency's operations is paramount for maintaining the service the agency provides to the community as well as leveraging the progress each agency has made to supply transportation services. This report establishes detailed baseline operations, service, and conditions as of November 2022.This report catalogs Riverside Connect's existing vehicles and infrastructure assets, as well as outlines the route energy consumption and expected monetary expenditures for future procurements of the existing vehicle type. By the conclusion of this report, the project team will convey the current service provided by Riverside Connect, their assets, and provide a starting point for endeavoring on a zero-emission fleet transition, to comply with the ICT regulation.

The most notable findings from the analyses performed to create this report are as follows. According to CTE's models, based on a generic electric **cutaway** combining the market averages for battery **nameplate capacities**, none of Riverside Connect's Dial-A-Ride (DAR) service today can be performed solely by overnight **depot-charging** of a battery-electric cutaway. By 2040, despite projected improvements in battery capacities, neither the maximum mileage nor average day can be completed by a depot-charged battery-electric cutaway. Thus, a transition to zero-emission sooner than 2040 would require either **on-route charging**, midday charging at the depot, or to be served by a fuel cell electric vehicle. Moreover, Riverside Connect could restructure their paratransit service to accommodate zero-emission service, however service restructuring is not a component of this project. According to IBI's in-depth analysis overlaying Riverside Connect's service area and 2021 census track data for disadvantaged communities (DAC) based on CalEnviroScreen 4.0, nearly 44% (35.64 square miles) of the agency's service area is designated as a DAC. Over the transition period, Riverside Connect would be projected to spend approximately $20M in cutaway capital costs to replace their fleet with similar CNG cutaways. This will serve as the baseline expected expenditure from which CTE will calculate the delta cost of the zero-emission transition in later reports.

California Air Resources Board Innovative Clean Transit Regulation

On December 14, 2018, California Air Resources Board (CARB) enacted the Innovative Clean Transit (ICT) regulation as part of a statewide effort to reduce emissions from the transportation sector, which accounts for 40 percent of climate-changing gas emissions and 80-90 percent of smog-forming pollutants. The ICT regulation requires all California public transit agencies to submit a rollout plan demonstrating how it will achieve a 100% zero-emission fleet by 2040. The plans include zero-emission bus purchasing schedules, infrastructure developments, and workforce training programs and are due in 2023 for small transit agencies.

The only commercialized technologies that CARB qualifies as zero-emission are **battery-electric buses** (BEB) and **hydrogen fuel cell electric buses** (FCEBs). BEBs and FCEBs have similar electric drive systems that feature a traction motor powered by a battery. The primary differences between BEBs and FCEBs are the respective amount of battery storage and the method by which the batteries are recharged. The energy supply in a BEB comes from electricity provided by an external source, typically the local utility's electric grid, which is used to recharge the batteries. The energy supply for an FCEB is completely on-board, where hydrogen is converted to electricity within a fuel cell. The electricity from the fuel cell is used to recharge the batteries. The electric drive components and energy source for a BEB and FCEB are illustrated in **Figure 1**.

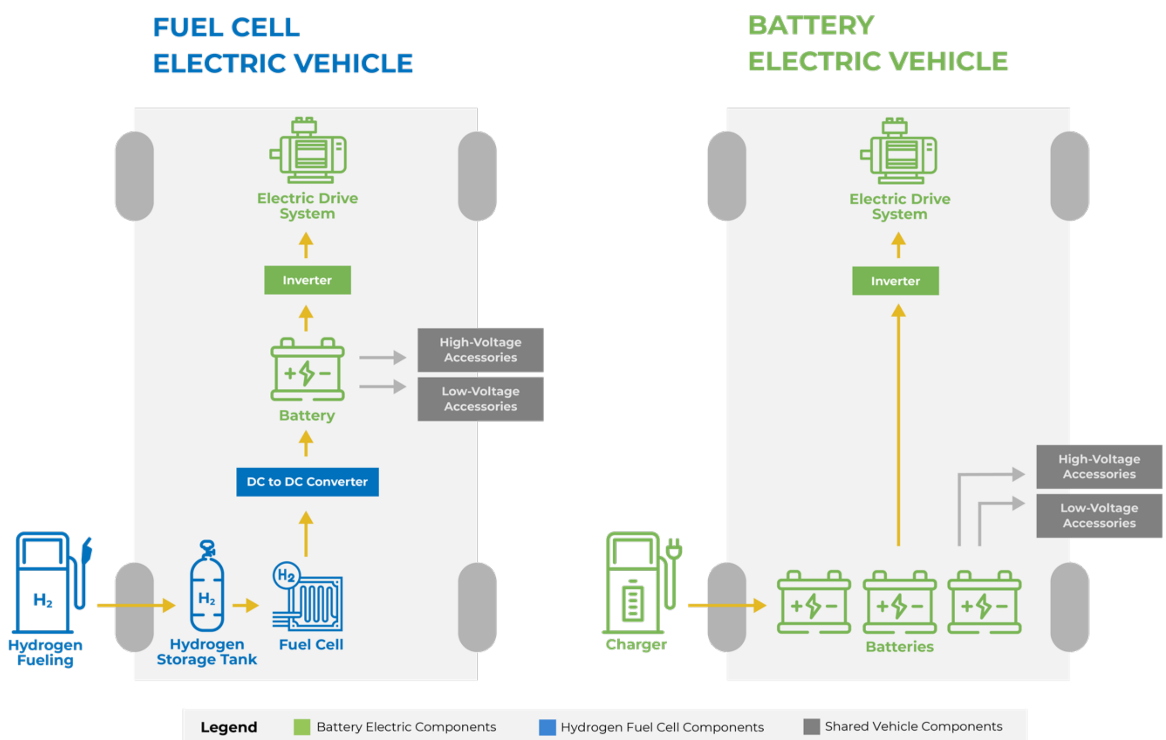

Figure 1 – Battery and Fuel Cell Electric Bus Schematic

ZEB Purchase Requirements

CARB's ICT regulation requires all transit agencies to purchase only ZEBs from 2029 onward. Partial ZEB purchasing requirements begin in 2023 for large agencies and in 2026 for small agencies with the goal of transitioning all public fleets to a 100% ZEB fleet by 2040.

CARB designates Riverside Connect as a small fleet because the transit agency operates less than 100 vehicles at peak pullout. For small agencies, the ICT regulation requires that all new bus purchases include a specified percentage of ZEBs in accordance with the following schedule in **Table 1**.

Table 1 – CARB ICT ZEB Transition Timeline for Small Agencies

Starting January 1	ZEB Percent Requirement of New Bus Purchases
2026	25%
2027	25%
2028	25%
2029	100%

Agencies can defer the purchase of a cutaway bus, over-the-road bus, double-decker bus, or articulated bus until either January 1, 2026 or until a model of a given type has passed the Altoona bus testing procedure and obtained a Bus Testing Report, regardless of purchasing milestones. At the time of writing this report, two cutaway vehicles (GreenPower's EV Star and Forest River's Battery Electric Ford E-450 Cutaway Shuttlebus) have passed Altoona testing but CARB has not revised its regulation regarding cutaways. Additionally, Riverside County agencies can defer the purchase of zero-emission vehicles, based on RCTC Capital Justification Policy, which encourages agencies to consider technology retrofits prior to new procurements.

CARB offers transit agencies certain flexibility in complying with ZEB purchase requirements; two or more agencies may work together to collectively comply with the ZEB purchase requirements, so long as they share the use of infrastructure, function in the same air basin, are located in the same air district, are under the same Metropolitan Planning Organization, or are under the same Regional Transportation Planning Organization. These are referred to as Joint Groups in the regulation.

Agencies may request exemptions from ZEB purchase requirements in a given year due to circumstances beyond the transit agency's control. Acceptable circumstances include:

- Delay in bus delivery caused by setback of construction schedule of infrastructure needed for the ZEB;
- Market-available depot-charged BEBs cannot meet a transit agency's daily mileage needs;
- Market-available ZEBs do not have adequate gradeability performance (i.e., unable to climb a slope at efficient speed) to meet the transit agency's daily needs;

- When a required ZEB type for the applicable weight class based on gross vehicle weight rating (GVWR) is unavailable for purchase because the ZEB has not passed the Altoona bus test; cannot meet the Americans with Disabilities Act (ADA) requirements; or would violate any federal, state, or local regulations or ordinances;
- When a required ZEB type cannot be purchased by a transit agency due to financial hardship.

ZEB Bonus Credits

To recognize and incentivize early adopters of ZEBs, the ICT regulation has a credit system, which gives credits to agencies that deployed ZEBs before the regulation was enacted in 2018. Agencies are eligible for two credits for each fuel cell electric bus and one credit for each battery electric bus that was in their fleet as of January 1, 2018. Agencies may apply these credits to their future ZEB purchase requirements. Each credit has the same value as having one ZEB in their fleet but must be used by December 31, 2028. Riverside Connect does not have any ZEB Bonus Credits available from early adoption; however, two or more agencies may share credits for joint ZEB procurements.

Riverside Connect

Riverside Connect Service Area Characteristics

Riverside Connect operates paratransit transportation services providing for seniors and disabled residents in the City of Riverside. It is a division within the City of Riverside's Parks, Recreation and Community Services Department. Riverside Connect offers service within an 81 square mile area within the city limits of the City of Riverside. Riverside Connect is operated by the City of Riverside under a Memorandum of Understanding (MOU) in order to provide solely paratransit, demand response services. Riverside Transit Agency (RTA) provides fixed route service to the area.

Riverside Connect's DAR service is reserved for seniors of age 60 and older and people with disabilities, including those covered by the Americans with Disabilities Act (ADA). The DAR service may be primarily used for rides to grocery stores and medical facilities, however, as the COVID-19 infection rates decrease, Riverside Connect anticipates that workshops, senior centers, and other programs will reopen and service will eventually return to pre-COVID levels. Riverside Connect's service map is shown in **Figure 2.**

As a transit operator in California, Riverside Connect is subject to the Innovative Clean Transit (ICT) regulation, requiring all California transit agencies to develop a plan to achieve a zero-emission fleet by 2040. This Existing Conditions Report summarizes the service data for the agency and describes a baseline scenario that accounts for a plan without a zero-emission fleet transition.

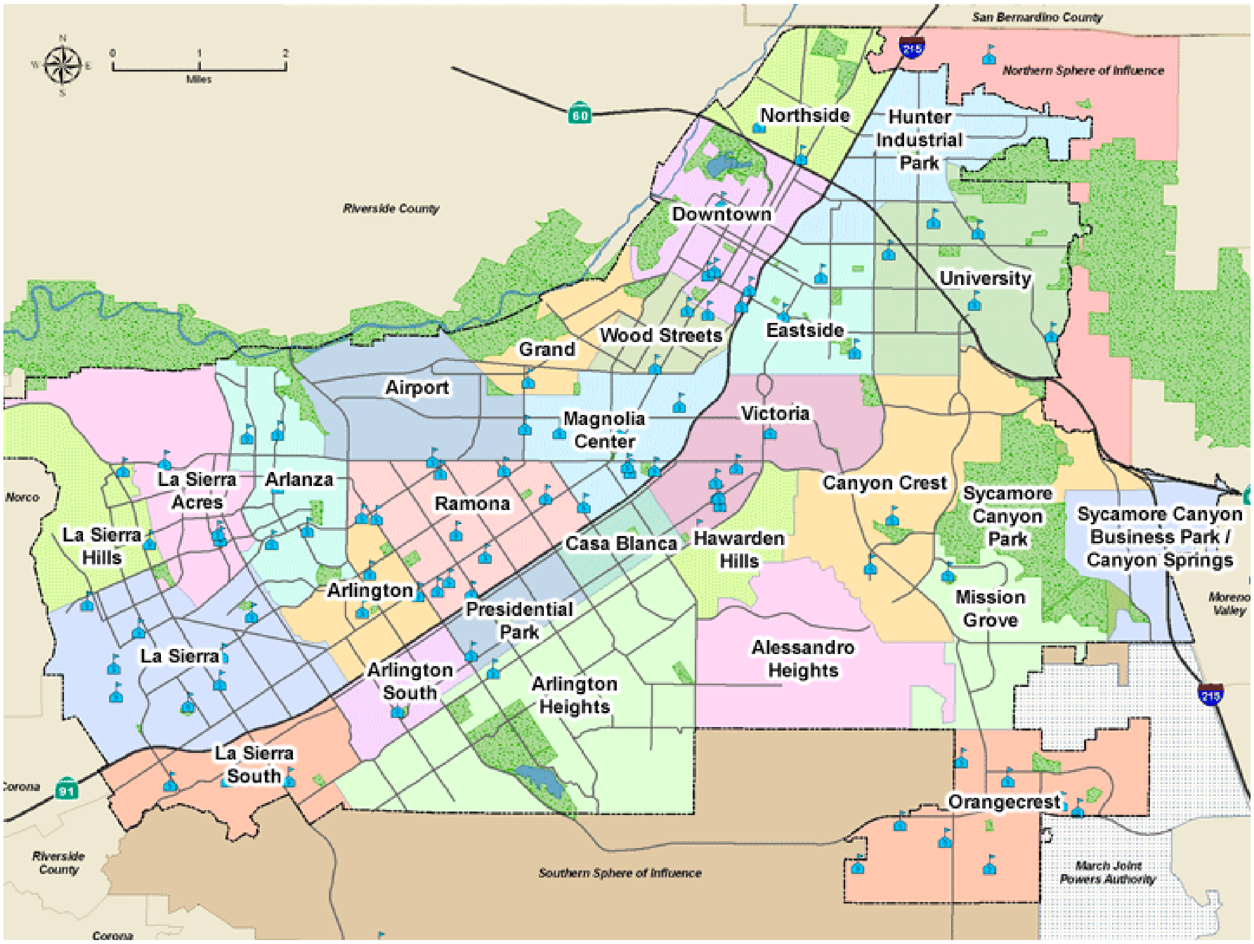

Figure 2 – Riverside Connect Service Map

Topography and Climate

The geographical coordinates of Riverside, California are 33.9533 deg latitude, -117.3961 deg longitude and the city sits at 827 feet above sea level[1]. Riverside Connect operates its vehicles across primarily flat terrain. CTE utilizes topography information to define the **nominal** and **strenuous energy** requirements on a vehicle in this region to inform the battery-electric bus service feasibility analysis; steeper grades and longer elevation routes will require significantly more energy, thereby defining strenuous energy requirements. Riverside, California, experiences hot, arid, clear summers between June and September, recording an average high of 90° F in July and August[2]. Riverside experiences long, cool, partly cloudy winters between November and March, recording an average low of 48°F in December. These operational conditions affect the HVAC loads onboard the vehicles, particularly below 50°F and above 80°F, which in turn have a seasonal impact on the energy requirements. Energy requirements are also affected by precipitation, as regenerative braking is deactivated under slippery road conditions. Riverside experiences minimal precipitation, recording an average of 2.8 inches of rain in December; the lack of rain and snow implies minimal impact on the regenerative braking functionality of the vehicles.

[1] https://edits.nationalmap.gov/apps/gaz-domestic/public/summary/1661315
[2] https://www.worldweatheronline.com/riverside-weather-averages/california/us.aspx

Population Demographics

Located about fifty miles southeast of Downtown Los Angeles, The City of Riverside is the most populous city in Riverside County and the Inland Empire. Demographic data for the City of Riverside can be found in **Table 2** below.

Table 2 - Demographics of Riverside, CA[3] [4]

City of Riverside	
Total Population	317,261
Population per Sq. Mile	3,891
Race	
Hispanic or Latino, percent	53.6%
White alone, Hispanic or Latino, percent	52.8%
White alone, not Hispanic or Latino, percent	28.9%
Black or African American alone, percent	5.9%
Asian Alone	8.7%
Two or More Races, percent	7.3%
Median Age	32
Median Household Income	$72,738
Average Commute Time (minutes)	36

[3] https://www.census.gov/quickfacts/fact/table/riversidecountycalifornia/PST045221
[4] https://datausa.io/profile/geo/riverside-ca

Disadvantaged Communities Service

CalEnviroScreen is a tool created by the California Office of Environmental Health Hazard Assessment (OEHHA) to help identify communities disproportionately burdened by pollution and with population characteristics that make them more sensitive to pollution. Using this tool, specific disadvantaged communities (DACs) can be identified. DACs are classified as areas representing the 25% highest scoring census tracts in CalEnviroScreen, census tracts with high amounts of pollution and low populations, or federally recognized tribal areas as identified by the Census in the 2021.[5]

DACs represent key focus areas for ZEB rollout and could be prioritized in transition planning based on their current and historical pollution burden. The City of Riverside includes 38 distinct census tracts designated as DACs. In addition, nearly 44% (35.64 square miles) of the city's land area is designated as a DAC. **Figure 3** below shows Riverside's city boundaries relative to DACs.

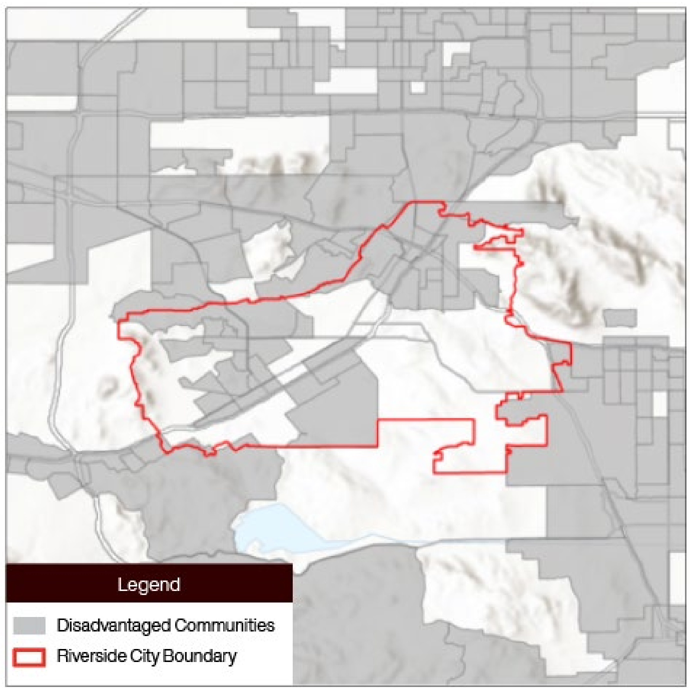

Figure 3 - City of Riverside and Disadvantaged Communities

The City of Riverside's Special Transportation Division provides dial-a-ride (DAR) service within the city boundaries for seniors 60 and older, persons with disabilities, and other persons certified under the Americans with Disability Act (ADA). Some of the Riverside dial-a-ride service area falls within the DAC zones but specific trips may start and/or end outside of the DAC designated areas. Unlike fixed-route service, dial-a-ride does not operate on a set route, so a single vehicle may provide trips both within and outside of a DAC during a single day.

Existing Fleet Overview

As of July 2022, Riverside Connect's bus fleet included thirty-four (34) 26-ft CNG cutaways, all of which are allocated for paratransit service. Riverside Connect also has two (2) transit vans, however, they are light duty vehicles which are not subject to ICT regulations and will not be considered for this analysis. CTE's vehicle classification adheres to FTA's definition of a cutaway, see glossary.

[5] https://experience.arcgis.com/experience/1c21c53da8de48f1b946f3402fbae55c

Riverside Connect's entire fleet of thirty-four (34) cutaways consists of Glaval Bus Type C Ford E-450 vehicles. The transition to zero-emission will be agnostic to vehicle Original Equipment Manufacturer (OEM), however. A summary of the 2022 fleet by vehicle size, first service year, fuel type, and OEM is shown in **Table 3**.

Table 3 - Fleet Summary by Depot, Length, Fuel Type, and OEM

Depot	Vehicle Length	Fuel Type	OEM	First Service Year	Quantity
8095 Lincoln Avenue	26’	CNG	Ford	2010	4
				2011	3
				2013	7
				2014	9
				2017	8
				2019	3
Total					**34**

Fleet Purchase Pricing

Recent transit vehicle capital costs reported by Riverside Connect are listed below in **Table 4.** These prices represent Riverside Connect’s most recent purchases, adjusted for inflation. CTE applied a historical cumulative inflation rate of 27% based on the Producer Price Index (PPI) for transportation equipment[6], in order to account for pandemic pricing fluctuations between 2019 and 2022. In addition, CTE applied an annual inflation rate of 2% from 2022 onward, to inform vehicle pricing in future procurements across the entire 18-year period.

[6] U.S Bureau of Labor Statistics, PPI Commodity Data: https://data.bls.gov/PDQWeb/wp

Table 4 – 2022 Adjusted Fleet Costs based on Most-Recent Pricing Reported by Agency

Reported Base Vehicle Price by Vehicle Length and Fuel Type		
Length	**Fuel Type**	**Single Vehicle Capital Cost**
26' Cutaway	CNG	$157,537

Existing Fleet Mileage and Fuel Consumption

Riverside Connect's existing fleet fuel consumption data was used to estimate energy costs throughout the transition period.

Riverside Connect provided annual fleet mileage by vehicle type and service year of introduction. The annual fleet mileage, fuel consumption, and fuel economies, are listed in **Table 5**, **Table 6**, and **Table 7** respectively.

Table 5 - Average Annual Service Miles by Vehicle Length

Average Annual Mileage Per Vehicle Type, Age, and Fuel Type (mi)			
Vehicle Length	**First Service Year**	**Fuel Type**	**Annual Mileage Traveled by a Single Bus**
26' Cutaway	2010	CNG	19,973
	2011		32,087
	2013		23,219
	2014		28,178
	2017		24,938
	2019		31,969
Weighted Average for Total Annual Service Miles for Full Fleet			**26,109**

Table 6 - Annual Fuel Consumption by Vehicle Length

Average Annual Fuel Consumption Per Vehicle Type, Age, and Fuel Type (GGE)			
Vehicle Length	**First Service Year**	**Fuel Type**	**Avg. Annual Fuel Consumption per Bus (GGE)**
26' Cutaway	2010	CNG	2,320
	2011		
	2013		
	2014		
	2017		
	2019		
Weighted Average for Total Annual Fuel Consumption for Full Fleet			**2,320**

Table 7 - Calculated Fuel Economy by Vehicle Length

Calculated Fuel Economy Per Vehicle Type, Age, and Fuel Type (MPGGE)			
Vehicle Length	**First Service Year**	**Fuel Type**	**Avg. Fuel Economy (MPGGE)**
26' Cutaway	2010	CNG	8.61
	2011		13.83
	2013		10.01
	2014		12.14
	2017		10.75
	2019		13.78
Weighted Average for Total Annual Fuel Consumption for Full Fleet			**11.25**

Annual GHG Emissions

Riverside Connect's fleet of thirty-four (34) CNG vehicles operate for approximately 887,698 miles per year, consuming 78,888 Gasoline Gallons Equivalent (GGE) of fuel per year. In order to demonstrate the benefits of transitioning from a fossil fuel fleet to a zero-emission one, CTE examined the well-to-wheel

greenhouse gas emissions (GHG) for Riverside Connect's existing fleet, using Argonne National Lab's (ANL) Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool[7].

Current Well-to-Wheel Emissions

Well-to-tank (WTT) emissions are emissions associated with the production of fuel. In the case of a battery electric vehicle, this would encapsulate the carbon content of the electric grid and will vary regionally. For example, in the case of a fuel cell vehicle, this would be a factor in the emission calculation based on the hydrogen production method and feedstock. **Tank-to-wheel** (TTW) emissions are emissions associated with operating the fleet. Zero-emission vehicles will only produce emissions from particle offing at the tire-road interface and brake wear (TBW), whereas traditional combustion engine transit vehicles will expel pollutants directly from the tailpipe. **Well-to-wheel** (WTW) emissions take into account both the well-to-tank and the tank-to-wheel emissions. By differentiating between emission sources, CTE can more accurately assess the criteria pollutants associated with each zero-emission bus based off regional electricity and hydrogen supply. Riverside Connect's existing fleet is responsible for an estimated 670 metric tons in overall well-to-wheel (WTW) emissions annually, including 44.40 lbs. of particulate matter under 2.5 micrometers (PM2.5), which has a considerable health impact on the local community. CTE also analyzed the social costs of the greenhouse gas emissions, which capture the environmental impacts that are borne by society. The cost of each ton of GHG emissions is estimated at $40.76. The AFLEET tool estimates the total social costs of emissions from the existing fleet at $30,101 annually. Riverside Connect's particulate emissions are summarized in **Table 8.**

[7] AFLEET Tool: https://afleet-web.es.anl.gov/afleet

Table 8 - Annual Vehicle Operation Pollutants by Fuel Type

Overall Annual Vehicle Operation Pollutants (lbs.)									
Bus Group	CO	NOx	PM10	PM10 (TBW)	PM2.5	PM2.5 (TBW)	VOC	VOC (Evap.)	SOx
CNG	39,541.72	1,352.97	48.60	189.09	44.40	23.48	132.32	-	5.24

Existing Facility and Infrastructure Overview

Riverside Connect's entire DAR paratransit fleet operates out of 8095 Lincoln Avenue, within the City of Riverside's Corporation Yard. The administrative facility includes administrative offices, a dispatch area, restrooms, and a break room. The facility also includes a parking lot for the agency's fleet, a CNG slow fill station, and a CNG Maintenance Bay. The Maintenance Bay facility has five maintenance bays for CNG vehicles, an administrative office, and multiple storage compartments for vehicle parts and equipment. A map of the Corporation Yard is shown in **Figure 4**. These facilities offer a starting point for the consideration of viable locations for zero-emission fueling infrastructure, chargers and/or a **hydrogen fueling station**.

Figure 4 – Fueling, Administrative, and Storage Facility Overview

Transition Planning Requirements Analysis

Understanding present operations and capital costs of Riverside Connect's service is essential to evaluating the energy requirements costs for a complete transition to a zero-emission fleet. Beginning the transition to zero with the assumption that all transit services will remain intact throughout the transition ensures that no disruptions occur for the community. Riverside Connect's staff provided key data on current service including:

- Current fleet composition including vehicle propulsion types and lengths
- Paratransit service information including distances and trip frequency
- Mileage and fuel consumption

CTE prepared Riverside Connect's Agency Data Collection template and distributed to the agency to collect the aforementioned data and to begin the Requirements Analysis & Data Collection stage of the project which forms the foundation for the rest of the transition analyses. Riverside Connect self-assigned topography and speed characteristics to each service day, which were utilized to better define efficiencies. Quantitatively, CTE classified a route as predominantly flat, if the average magnitude of the grade of the terrain was lower than 1%, and fast or slow depending on whether the route involved highway or urban (city) driving, and its average speed was over or under 17 mph, respectively.

CTE then used component-level specifications for a generic battery electric cutaway with a 110-kWh nameplate capacity, representative of the average vehicle available in the market today, and a library of route data from years of historical deployments to develop a baseline performance model, by simulating the operation of an electric bus using Autonomie. Autonomie is a powertrain simulation software program developed by Argonne National Lab (ANL) for the heavy-duty trucking and automotive industry[8]. CTE modified pertinent software parameters in Autonomie to assess energy efficiencies, energy consumption, and range projections for several ZEBs. The energy requirements of the sample routes were then applied to all service days that share similar characteristics to Riverside Connect's service.

CTE's analysis provides an understanding of vehicle efficiencies based on varied loading conditions. Nominal Loading conditions assume average passenger loading and a moderate temperature over the course of the day, which places marginal demands on the motor and heating, ventilation, and air conditioning (HVAC) system. Strenuous Loading conditions assume high or maximum passenger loading and near-maximum output of the HVAC system. These strenuous load conditions represent a hypothetical but possible worst-case scenario, and one that is necessary to establish an outer bound for the analysis. This nominal/strenuous approach offers a range of operating efficiencies—measured in kilowatt-hour/mile (kWh/mi)—to use for estimating average annual energy use (nominal) or planning maximum service demands (strenuous). The estimated **nominal** and **strenuous efficiencies** will eventually be used to predict if ZEB technologies will be able to complete all service days in subsequent assessments.

Demand Response Service

CTE obtained information regarding Riverside Connect's DAR service from the agency data collection form and Riverside Connect's SRTP. Riverside Connect operates their DAR program from 8:00 AM to 5:30 PM on weekdays, with additional service on Saturdays and Sundays from 9:00 AM to 4:00 PM. The service operates year-round with the exceptions of Thanksgiving, Christmas Day, and New Year's Day. Riverside Connect's fleet of 26-ft cutaways performing DAR service drove over 887,000 miles annually. This represents a 50% reduction in service compared to pre-pandemic service levels, with an average of 14-17 vehicles deployed in service on any given day. The on-demand nature of the DAR service made it impractical to categorize the trips into discrete blocks. Instead, CTE calculated the average mileage for the service days that Riverside Connect provided, as well as the maximum mileage that a vehicle was expected to perform.

[8] https://vms.taps.anl.gov/tools/autonomie/

CTE also used Riverside Connect's classification of their service days as flat and low speed. CTE used various performance data, including Altoona tests (for flat terrain), Autonomie simulations, and real-world deployments to generate a library of data, grouped by similar operating conditions (speed, terrain, and vehicle type). This data informed Riverside Connect's vehicle efficiencies as performed by an equivalent battery-electric cutaway, specifically on flat terrain and at low speeds. The calculated nominal efficiency for Riverside Connect's DAR service is listed in **Table 9** below.

Energy efficiency and **operating range** are primarily driven by vehicle specifications. CTE's nominal and strenuous efficiency calculations for Riverside Connect's fleet are based on a generic 25-ft. battery-electric cutaway. Efficiency and range metrics can be impacted by a number of variables including the route profile (i.e., distance, dwell time, acceleration, sustained top speed over distance, average speed, traffic conditions, deadhead), topography (i.e., grades), climate (i.e., temperature), driver behavior, and operational conditions (e.g., passenger loads and **auxiliary loads**). As such, the efficiency and range of a given ZEB model can vary from one agency to another. CTE utilizes a library of varied performance data from multiple agencies, topographies, energy demands, and other operating conditions to create a customized and realistic service scenario representative of anticipated conditions for Riverside Connect. This prevents an operator from assigning vehicles to a route or service day that requires more energy than the vehicle is capable of performing.

Table 9– Cutaway Energy Usage

Route	Bus Length	Nominal Efficiency (kWh/mi)
Dial-A-Ride	Cutaway	1.55

Once the energy demand for the average and maximum service day was known, it was compared to the **usable capacity** of a market-representative battery-electric cutaway (99 kWh) to determine whether that service day would be feasible or infeasible with a single, overnight depot-charged battery-electric cutaway vehicle.

It was assumed that the observed trend of a 5% improvement on battery capacity every two years will continue. **Figure 5** shows that the average service day from 2022 is infeasible, given currently available battery capacity. The average and maximum service days are similarly infeasible throughout the transition period, despite the projected improvements in battery capacity.

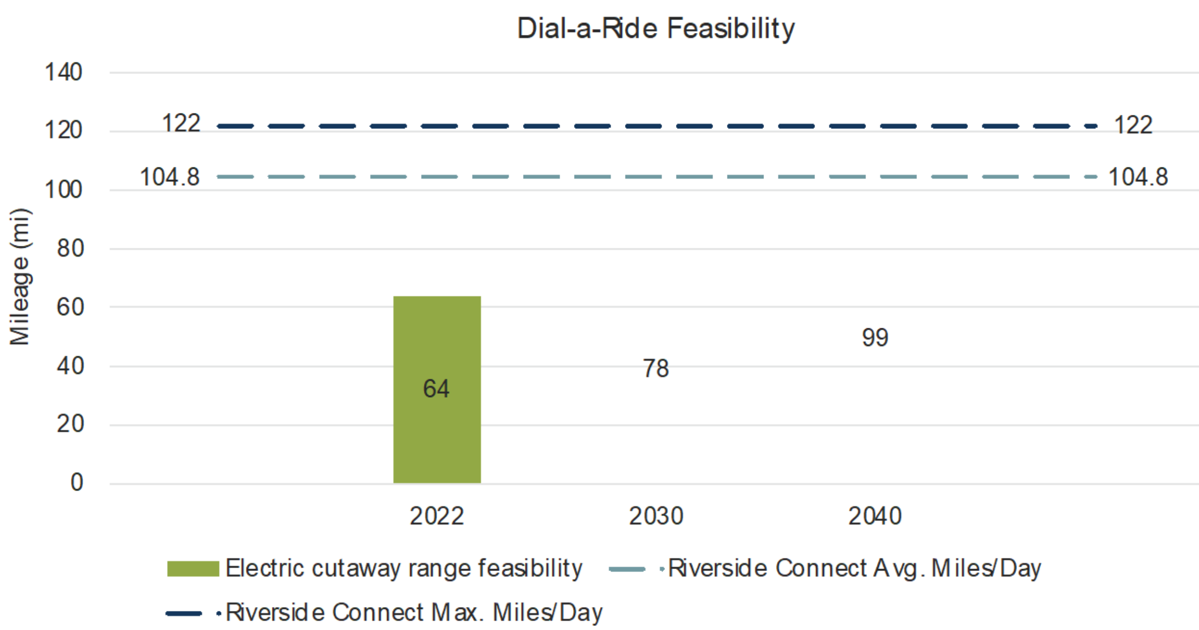

Figure 5 – Dial-A-Ride Feasibility

These results mean that Riverside Connect will need to consider other zero-emission technology solutions to meet the agency's service requirements, which we will explore in subsequent reports. Riverside Connect could consider upsizing their vehicles to transit buses which have more available service energy on-board; current 30-ft transit buses have battery capacities that far exceed the capacity of cutaways, and DAR service could be feasible sooner with these vehicles. Riverside Connect could also utilize equivalent battery-electric cutaways sooner, if the service days are capped by milage or duration congruent with today's battery-electric cutaway performance and the fleet is expanded. Vehicle swapping is feasible with Riverside Connect's current fleet size because their service is being run at 50% of their pre-pandemic levels with an average of approximately half of their vehicles in service every day. If their service returns to its pre-pandemic levels, however, vehicle swapping will require increase in the size of their fleet.

Other solutions include upsizing to a fleet of FCEBs (given that there is no 25-ft. equivalent market-ready fuel cell electric cutaway), on-route charging, re-blocking existing routes, and/or adding additional battery-electric buses. These alternative zero-emission technology solutions will be required to complete Riverside Connect's service and some will be explored in subsequent reports. DAR feasibility models are not generated for FCEBs, because it is assumed that today's model of the 40-ft transit FCEB can accomplish any block under 350 miles. Given that Riverside Connect's DAR service days range between 82 and 122 miles, the agency's DAR service would be feasible with an upsized fleet of 40-ft FCEBs.

Baseline Vehicle Procurement Schedule

Riverside Connect's fixed-route fleet today is comprised of 26-ft CNG cutaways. For the purpose of this analysis, CTE does not consider the contingency fleet or their fleet of light-duty vehicles in the baseline procurement schedule. In their SRTP, Riverside Connect included future replacements of three cutaways that have reached the end of their service lives. Two cutaways will be replaced with equivalent CNG cutaways, while the other one will be replaced with an equivalent battery-electric cutaway. Based on this schedule, Riverside Connect will have replaced their existing fleet of vehicles with service entry years of 2010 through 2014 by 2026. Beyond this, CTE projects that Riverside Connect will replace their 26-ft cutaways on a 7-year cycle, based on FTA minimum service-life categories determined by seating capacities, vehicle lengths, and the manufacturer's selection for federal transit bus tests[9]. While transit agencies may have their own guidelines for service life, FTA funds may not be used to procure a bus in an application requiring a higher service-life category than the highest service-life category tested by the manufacturers on a particular vehicle. Aligning procurement schedules accordingly will prove important in providing a baseline against which to compare future zero-emission capital investments in subsequent reports.

For the purposes of establishing a baseline scenario, CTE projected vehicle procurements and costs over an 18-year period, based on the fleet composition as of September 2022. To estimate procurement costs for the entire transition period through 2040, CTE utilized an annual inflation rate of 2%, to inform vehicle pricing across the entire 18-year period, as well as a 27% cumulative inflation rate between the last bus purchase in 2019 and 2022, based on the truck and bus Producer Price Index (PPI). **Figure 6** depicts the number of CNG vehicles purchased each year through 2040 in this scenario. The subsequent graphics demonstrate a business-as-usual operation, as the foundation for understanding cost impacts to transition to zero-emission technology. Over the transition period, Riverside Connect would spend approximately $20M in bus capital costs to replace their existing fleet with CNG cutaways. Table 10 – Annual Procurements, Baseline Scenario outlines the annual procurement costs, through 2040.

Table 10 – Annual Procurements, Baseline Scenario

Purchase Year	Purchased Quantities		
	CNG	Electric	Total Costs

[9]Federal Transit Administration Useful Life of Transit Buses and Vans; https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Useful_Life_of_Buses_Final_Report_4-26-07_rv1.pdf

2023	2	1	$ 612,926
2024	12	-	$ 2,005,569
2026	10		$ 1,773,090
2027	9		$ 1,643,654
2030	2	1	$ 753,821
2031	12	-	$ 2,466,596
2033	10	-	$ 2,180,677
2034	9	-	$ 2,021,487
2037	2	1	$ 927,105
2038	12	-	$ 3,033,603
2040	10	-	$ 2,681,957
Total	**90**	**3**	**$ 20,100,485**

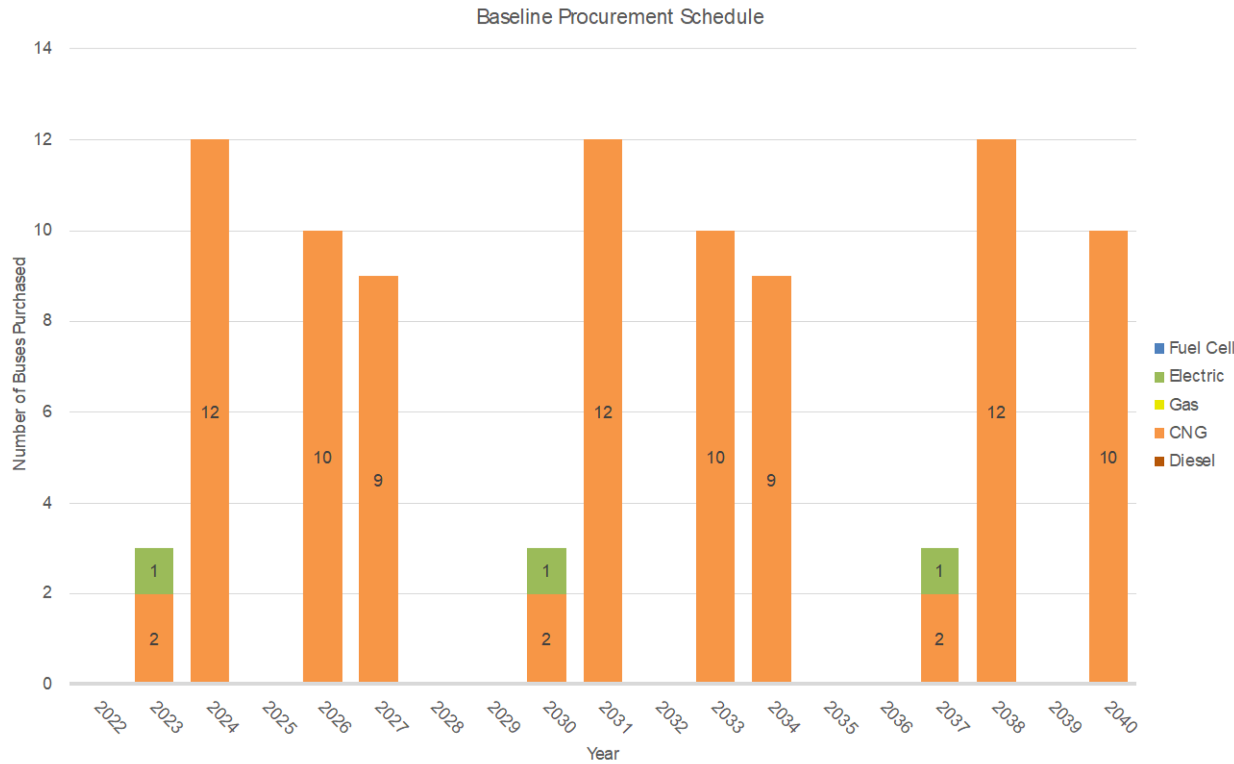

Figure 6 - Projected Bus Purchases, Baseline Scenario

Figure 7 depicts the annual fleet composition through 2040 for the *Baseline Scenario*; the fleet remains composed of 26-ft CNG cutaways over the 18-year period.

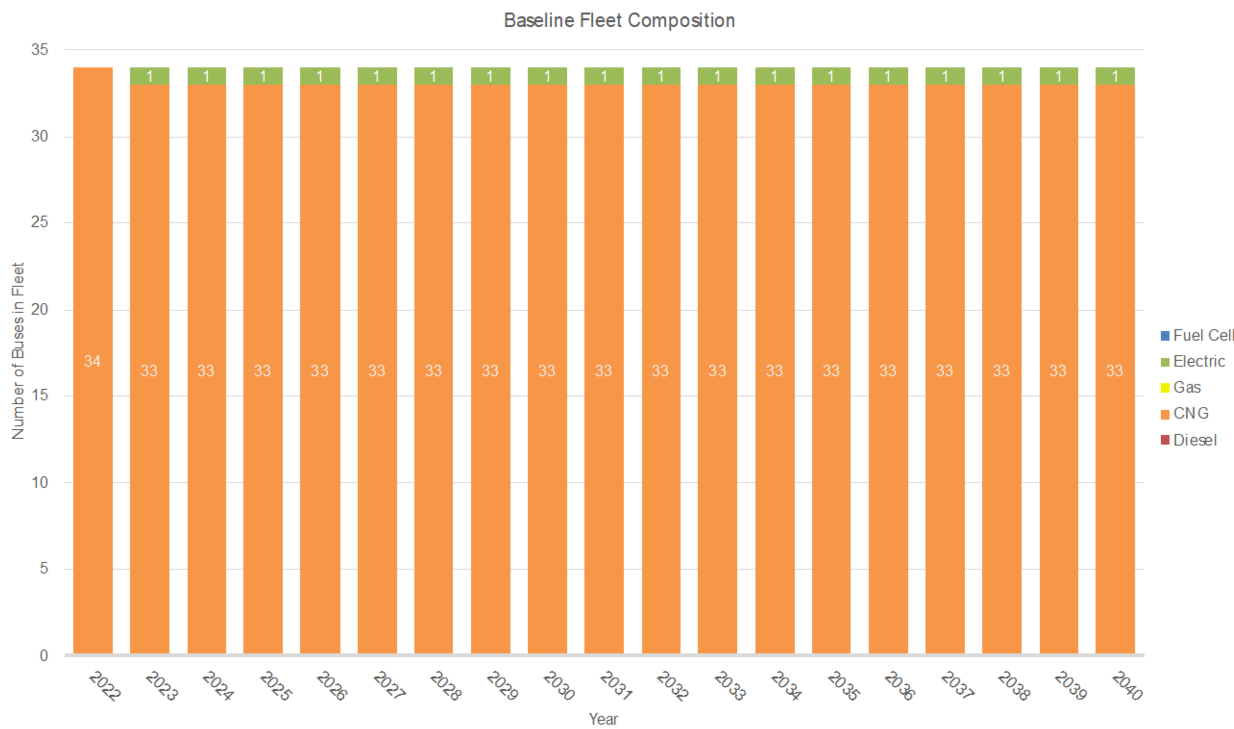

Figure 7 - Annual Fleet Composition, Baseline Scenario

Figure 8 shows the annual total bus capital costs for the cutaways purchased in each year in the Baseline Scenario.

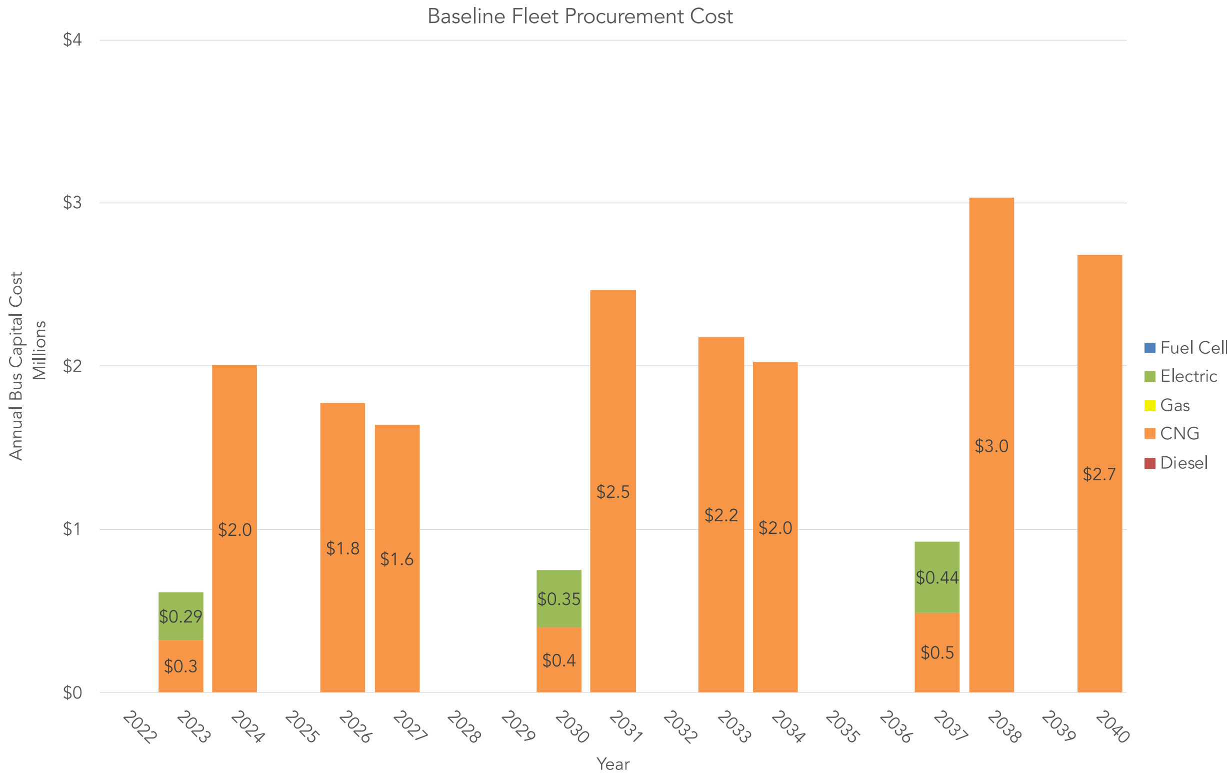

Figure 8 - Annual Capital Costs, Baseline Scenario

Riverside Connect Sustainability Goals

Per their City Strategic Plan, Envision Riverside 2025[10], the City of Riverside has dedicated themselves to both Environmental Stewardship and Infrastructure, Mobility & Connectivity. The City of Riverside defines Environmental Stewardship as "Champion proactive and equitable climate solutions based in science to ensure clean air, safe water, a vibrant natural world, and a resilient green new economy for current and future generations." To this end, relevant goals that they are working to fulfill are to "rapidly decrease Riverside's carbon footprint by acting urgently to reach a zero carbon electric grid with the goal of reaching 100% renewable energy production by 2040 while continuing to ensure safe, reliable and affordable energy for all residents," "implement proactive policies and inclusive decision-making processes to deliver environmental justice and ensure that all residents breath healthy and clean air with the goal of having zero days of unhealthy air quality per the CalEnviroScreen by 2030," and "implement the requisite measures to achieve citywide carbon neutrality no later than 2040." The City's goals within their Strategic Priority of Infrastructure, Mobility & Connectivity are to "provide, expand and ensure equitable access to sustainable modes of transportation that connect people to opportunities such as employment, education, healthcare, and community amenities," "maintain, protect and improve assets and infrastructure within the City's built environment to ensure and enhance reliability, resiliency, sustainability, and facilitate connectivity," "Identify and pursue new and unique funding opportunities to develop, operate, maintain, and renew infrastructure and programs that meet the community's needs," and "Incorporate Smart City strategies into the planning and development of local infrastructure projects."

[10] https://www.riversideca.gov/sites/default/files/City%20Strategic%20Plan_Digital_2021_Spreads.pdf

California's plan to address public health, air quality and climate protection goals includes the Innovative Clean Transit (ICT) regulation, which aims to reduce greenhouse gas (GHG), nitrogen oxide (NOx), and diesel particulate emissions, with which Riverside Connect will be compliant at the conclusion of this project. To accomplish its sustainability goals, Riverside Connect is working to replace its CNG fleet with 100% zero-emission vehicles by 2040 in accordance with ICT regulations.

Regional Zero-Emission Market & Deployment Ecosystem

Regional Hydrogen Production and Distribution

California has one of the most mature hydrogen fueling networks in the nation. The state legislature has fostered growth in zero-emission fuels through the state's Low-Carbon Fuel Standard (LCFS) program, which incentivizes the consumption of fuels with a lower carbon intensity than traditional combustion fuels. Recently, the California Energy Commission (CEC) announced in late 2021 that $77 million in funding was allocated for hydrogen fueling infrastructure projects. The California Air Resources Board and the California Energy Commission (CEC) have set a target of 100 publicly available light-duty hydrogen fueling stations operational by 2023. Also in 2021, the CEC released a grant funding opportunity that is intended to stimulate developments in renewable hydrogen transportation fuel production [3]. Earlier this year, SoCalGas proposed the Angeles Link, a large-scale green hydrogen infrastructure system for Southern California, that is expected to utilize 25-35 GW of curtailed or new solar, wind, or battery output to power electrolyzers that produce 'clean hydrogen'. The hydrogen would then be delivered to industrial customers in California via a new hydrogen pipeline system spanning 200 to 750 miles.

California has at least seven heavy-duty and transit-operated fueling stations in operation and at least four more in development[11]. Additionally, the number of hydrogen production and distribution centers is growing to meet increased hydrogen demand as it gains popularity as a transportation fuel. At present, there are two operating heavy-duty and transit-operated hydrogen fueling station in the neighboring San Bernadino and Orange counties, two planned transit-operated hydrogen fueling station in Los Angeles County and Pomona. In addition, private hydrogen fueling stations by First Element Fuels and Stratosfuel are in development and should be commissioned before the end of the fleet transition timeline.

In the region, Omintrans, a public transit agency serving the San Bernadino Valley recently received $9.3 million from the Federal Transit Administration (FTA) under the FY2022 Low-No Emission Vehicle Program to develop hydrogen refueling infrastructure and launch a workforce development program. Similarly Sunline Transit Agency has received $7.8 million to upgrade their liquid hydrogen refueling infrastructure. Riverside Transit Agency has also received $5.2 million to procure hydrogen fuel cell buses. The presence of hydrogen fueling infrastructure projects, especially in the counties of Riverside and San Bernadino, demonstrates the feasibility of fuel cell electric technology for transit in the region.

Regional BEB Deployments & Market Access

The BEB market has the benefit of greater maturity and more available products. Three of the major BEB OEMs manufacture buses in California with two manufacturing sites located in Southern California. Nearby agencies such as Long Beach Transit, LA Metro, and Foothill California have some of the most mature BEB deployments in the country. This year, the FTA also awarded battery-electric bus and charging infrastructure projects under the FY2022 Low-No Emission Vehicle Program. In Los Angeles County, Los Angeles County

[11] Hydrogen Refueling Stations in California, California Energy Commission: https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/hydrogen-refueling

Metropolitan Transportation Authority (LA Metro) was awarded $104.2 million, and the City of Gardena was awarded $2.22 million to procure battery-electric buses and charging equipment. In Riverside County, Sunline Transit Agency was awarded an additional $7.15 million to procure battery electric buses and charging stations, and in Orange County, Orange County Transportation Authority (OCTA) was awarded $2.51 million to purchase zero-emission buses to improve air quality and paratransit service.

Utility Programs and EV Incentives

Riverside Public Utilities is a consumer-owned utility that provides both water and electricity to Riverside. Riverside Public Utilities is a founding member of the Southern California Public Power Authority (SCPPA), enjoying the benefits of joint action through cost-effective planning, construction, management, and operations of electrical energy resources. Riverside Public Utilities currently offers several EV incentives and rebates, although none of them are catered toward public transit applications[12]. Riverside Connect may be able to leverage their relationships with other agencies in the Commission to develop and maintain shared electric vehicle charging infrastructure by locating sites within Southern California Edison (SCE) territory.

Riverside Connect may also have access to local incentive programs aimed at reducing air pollution in Southern California; as the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties, the South Coast Air Quality Management District (SCAQMD) provides a variety of financial incentives to encourage the immediate use of commercially available, low- or zero-emission technologies[13]. Of note is the Carl Moyer Program, that provides funding for alternative fueling infrastructure and heavy-duty vehicle replacement/conversion projects.

Challenges to ZEB Transition

In addition to the uncertainty of technology improvements, there are other risks to consider in trying to estimate costs over the 18-year transition period. Although current BEB range limitations may be improved over time as a result of advancements in battery energy capacity and more efficient components, battery degradation may re-introduce range limitations, which is a cost and performance risk to an all-BEB fleet over time. While this can be mitigated by on-route charging, there may be emergency scenarios where the buses are expected to perform off-route or atypical service. In these emergency scenarios that require use of BEBs, agencies may face challenges performing emergency response roles expected of them in support of fire and police operations. Furthermore, fleetwide energy service requirements, power redundancy, and resilience may be difficult to achieve at any given depot in an all-BEB scenario. Although FCEBs may not be subject to these same limitations, higher capital equipment costs and availability of hydrogen may constrain FCEB solutions. RCTC, BCTS, CTE and IBI Group will expand upon challenge mitigation and adaptation in the ZEB Implementation Plan deliverable component of this project.

Benefits of Zero-Emission Transition

Despite the challenges associated with zero-emission transitions, there are also a myriad of benefits that Riverside Connect can realize. The most obvious is the reduction in greenhouse gas production associated with transitioning from ICE to zero-emission vehicles. The transportation sector is the largest contributor to greenhouse gas emissions in the United States, accounting for more than 30% of total emissions, and within this sector, 25% of these emissions come from the medium- and heavy-duty markets, yet these markets account for less than 5% of the total number of vehicles. Electrifying these vehicles can have an outsized impact on pollution, fossil-fuel dependency, and climate change.

[12] https://riversideca.gov/utilities/residents/rebates/electrify-riverside
[13] http://www.aqmd.gov/home/programs/business

Under-resourced urban communities often rely on transit bus systems for community mobility, yet have also borne the brunt of pollution-emitting industries and local diesel pollution. Zero-emission transitions of public transit systems thus not only provide pollution reduction broadly but provide it more equitably by focusing efforts in historically overlooked communities. An increased commitment to electrifying public transit helps metropolitan areas, including under-resourced communities, meet national air quality standards by reducing overall vehicle emissions and the pollutants that create smog.

In addition to the emissions benefits, there are operational benefits to using zero-emission buses. ZEBs are four times more fuel efficient than comparable new diesel buses. Better fuel efficiency means less waste when converting the potential energy in the fuel to motive power. Less waste not only means less pollution, but it also results in more efficient use of natural resources. This fuel efficiency improvement also results in cost savings for operators.

Finally, support from the federal government has enabled transit agencies to successfully test new zero-emission vehicle technologies without passing the entire cost of these pilots onto the end-user. The federal government covers between 80 and 90 percent of the capital cost of a typical 40' transit bus in exchange for the transit agency agreeing to operate the bus for 12 years. Without such federal assistance, a technology shift of this scale would be financially infeasible for fleet operators.