Existing Conditions Report

City of Corona Transit Service

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
BEB	Battery Electric Bus
CARB	California Air Resources Board
CCTS	City of Corona Transit Service
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
MW	Megawatt
MWh	Megawatt-hours
NOx	Nitrogen Oxides
OCTA	Orange County Transportation Authority
OEM	Original Equipment Manufacturer
PPI	Producer Price Index
RCTC	Riverside County Transportation Commission
SCE	Southern California Edison
TBW	Tire and Brake Wear
TTW	Tank-To-Wheel
WTT	Well-To-Tank
WTW	Well-To-Wheel

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., 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. City of Corona Transit Service (CCTS) provides transportation service in and around the City of Corona, a suburban community located southeast of Los Angeles in Riverside County.

The Existing Conditions is the first step in the development of CCTS's ZEB Rollout Plan to serve as the foundation from which CCTS will transition to zero-emission buses. CTE and IBI Group surveyed CCTS's existing conditions including relevant demographics, service area characteristics, operational fleet size and service conditions, and location and status of fueling and maintenance infrastructure in the project area. To process and verify this information, CTE compiled CCTS'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 CCTS.

This study reveals CCTS' current operational conditions and thus the paramount aim is to maintain the current level of service the agency provides to the community as well as to understand the resources CCTS consumes to supply existing transportation services. Although CCTS is currently in the midst of a Comprehensive Operations Analysis (COA), this report establishes detailed baseline conditions as of September 2022; any service changes as a result of the impending COA will not be reflected in the analysis of this report. This report catalogs CCTS's existing vehicles and infrastructure assets, as well as outlines the route energy consumption and expected monetary expenditures for future procurements to replace the existing vehicle types. The conclusion of the Existing Conditions Report will convey the current level of service provided by CCTS, their assets (capital and rolling stock), and provide a starting point for CCTS to begin the work for transitioning to a zero-emission fleet, 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 modeling efforts described in this report, based on a generic vehicle combining the market averages for battery **nameplate capacities**, none of CCTS's total fixed-route service today can be performed solely by overnight **depot-charging** a battery-electric bus. By 2040, only 50% of CCTS's total fixed-route service today can be performed solely by an overnight depot-charged battery electric bus. 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 bus. Similarly, only 49% of the typical Dial-A-Ride service days can be accomplished by a representative model cutaway vehicle and CCTS would need to consider midday depot charging or scheduling changes to perform all DAR service with a battery-electric cutaway or opt for fuel cell cutaway service. Moreover, CCTS could restructure their fixed-route blocks to accommodate zero-emission service but service restructuring is not a component of this project. According to IBI Group's in-depth analysis overlaying CCTS's fixed route service and 2021 census track data for disadvantaged communities based on CalEnviroScreen 4.0, 55% of stops on the Red Line serve disadvantaged communities and 53% of stops on the Blue Line serve disadvantaged communities. Over the transition period, CCTS would be projected to spend approximately $22.7M in bus capital costs to replace their fleet with similar CNG buses and 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**.

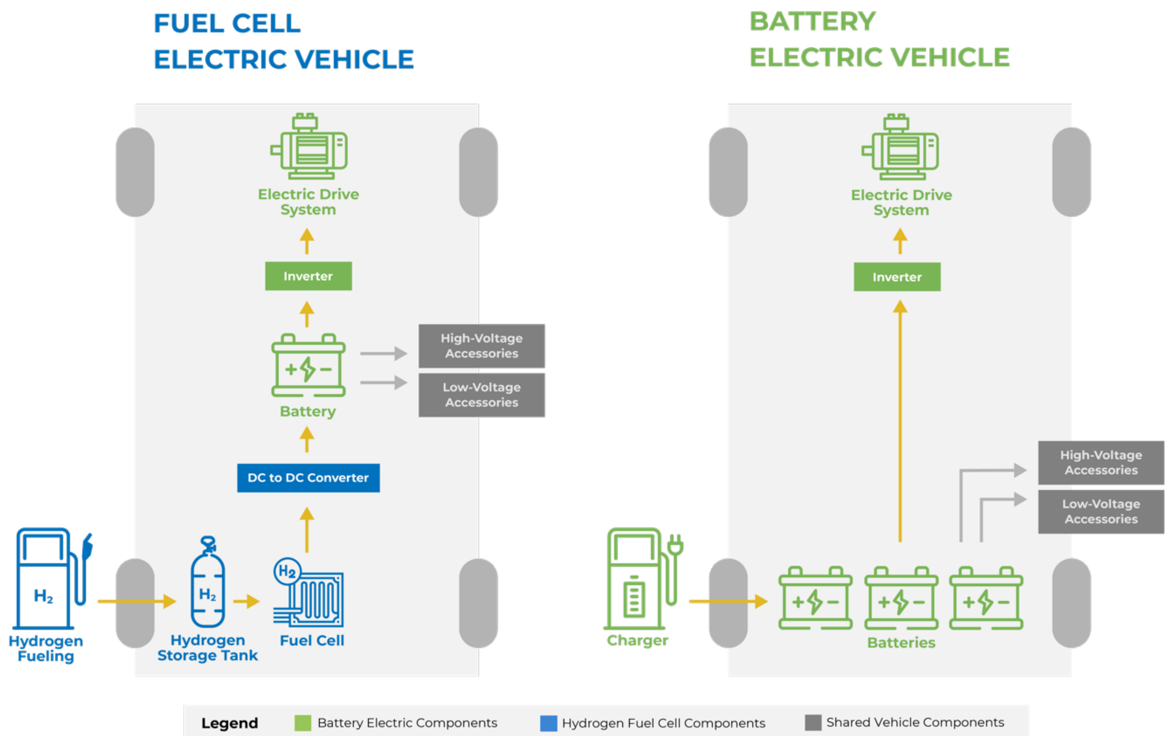

Figure 1 – Battery and Fuel Cell Electric Bus Schematic

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 the City of Corona Transit Service (CCTS) 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, a cutaway vehicle (GreenPower's EV Star) has 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, that 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. CCTS does not have any ZEB Bonus Credits available from early adoption; however, two or more agencies may share credits for joint ZEB procurements.

City of Corona Transit Service

CCTS Service Area Characteristics

The City of Corona operates a public transit system that provides services on two fixed routes in the city, Red Line, and Blue Line. The transit system transports passengers to Corona City Hall, Corona Public Library, major shopping centers and hospitals, the Senior Center, and more. Corona's bus routes connect with Riverside Transit Agency regional bus routes, North Main Metrolink Station, and Park and Ride Lots. The Red Line also provides extended service to the

Los Dagos shopping center on Saturdays, although both the Red Line and the Blue Line have a service frequency of 60-70 minutes.

The agency also provides DAR service, a specialized demand-responsive and ADA-compliant complementary paratransit service. Specialized demand-responsive service provides curb-to-curb transportation service to qualified individuals (seniors of 60 years and older, and persons with disabilities), while ADA complementary paratransit service provides door-to-door service upon request. DAR service is provided within the City of Corona and unincorporated communities of El Cerrito, Home Gardens, and Coronita. CCTS's service map is illustrated in Figure 2.

As a transit agency in California, the City of Corona 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 the current state of CCTS transit operation without a zero-emission fleet.

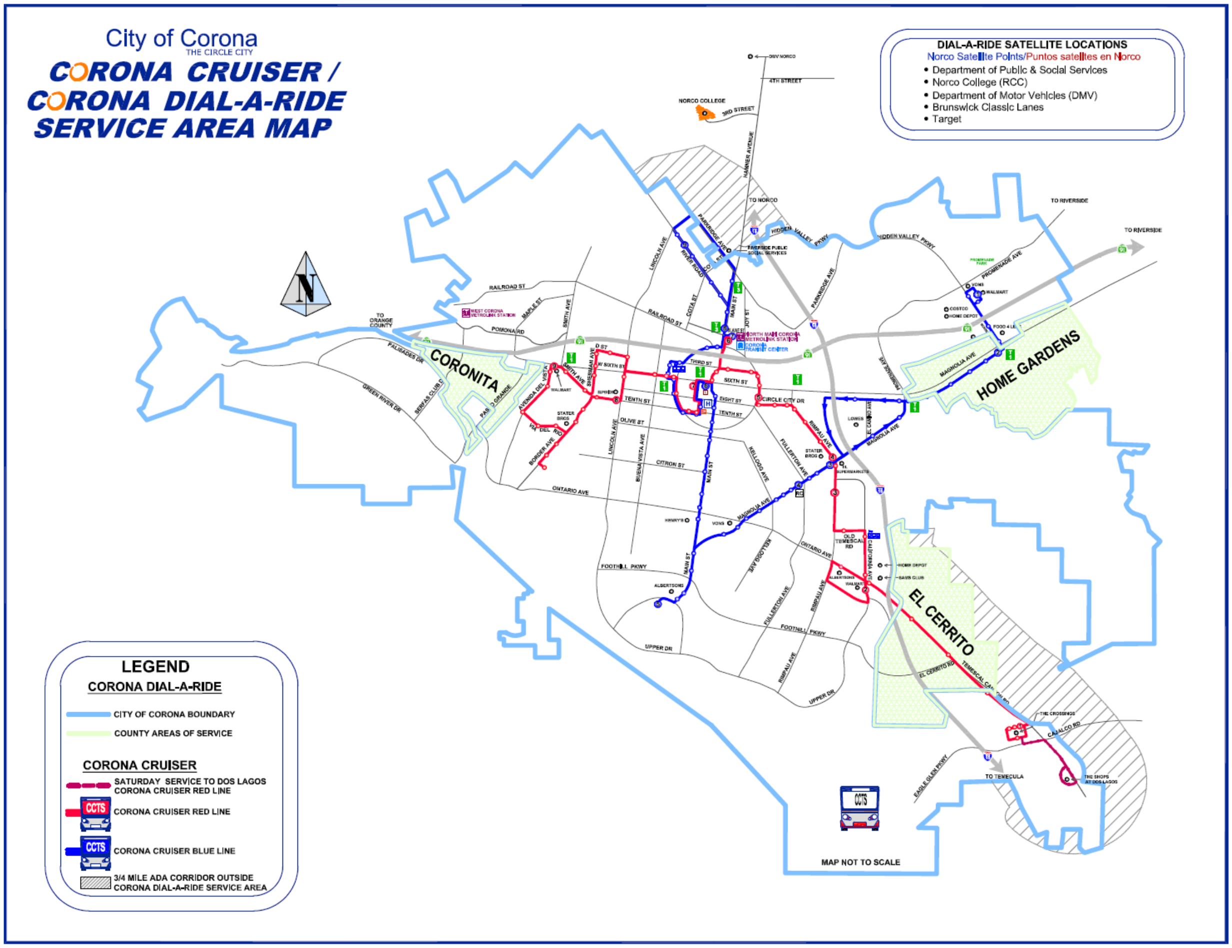

Figure 2 – City of Corona Transit Service Map

Topography and Climate

The geographical coordinates of Corona, California are 33.867 deg latitude, -117.567 deg longitude[1] and the city sits at 678 feet[2] above sea level. Corona Transit operates its vehicles across a mix of hilly and flat terrain through the city and the surrounding areas. 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. Using this methodology, CTE classifies all of CCTS's routes as hilly.

[1] https://www.latlong.net/place/corona-ca-usa-27924.html
[2] http://www.usacitiesonline.com/cacountycorona.htm#location

Corona, California experiences hot, arid, and mostly clear summers between May and October, recording an average high of 93°F in August[3]. Corona experiences cold, partly cloudy winters between November and April, recording an average low of 40°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. Corona experiences minimal precipitation, recording an average of 2.8 inches of rain in February[4]; the lack of rain and snow implies minimal impact on the regenerative braking functionality of the vehicles.

Population Demographics

The City of Corona has a population density of 3,934 residents per square mile[5]. Corona is home to a diverse population of residents; 47.9% of residents identify as Hispanic/Latino, while 31.7% identify as White alone, 10.5% identify as Asian alone, and 6.5% identify as Black alone. 0.6% of the community is American Indian and Alaska Native alone, and 0.6% identify as Native Hawaiian and Other Pacific Islander. According to the most recent census, 24% of Corona residents were born outside the United States. As of 2020, median household income was $88,434, and the poverty rate was 9.5%. The median age in Corona is 34.8 years old. The average travel time to work in Corona is 37.2 minutes. Primary modes of commuter transportation include driving alone (80.02%), carpool (10.04%), walking (1.12%), bus/trolley bus (0.77%) and other means (1.45%).[6]

Disadvantaged Communities Service

CalEnviroScreen is a tool created by the California Office of Environmental Health Hazzard 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 4.0, census tracts with high amounts of pollution and low populations, or federally recognized tribal areas as identified by the Census in the 2021.[7]

[3] https://www.usclimatedata.com/climate/USCA0075

[4] https://www.usclimatedata.com/climate/corona/california/united-states/usca0252

[5] https://www.census.gov/quickfacts/fact/table/coronacitycalifornia/RHI525221#RHI525221

[6]https://www.coronaca.gov/government/departments-divisions/economic-development/data-demographics

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

The City of Corona includes 10 different census tracts designated as DACs. DACs represent key focus areas for ZEB rollout and could be prioritized in transition planning based on their current and historical pollution burden. **Figure 3** below shows Corona's fixed routes and fixed route stops that are in and pass-through DACs.

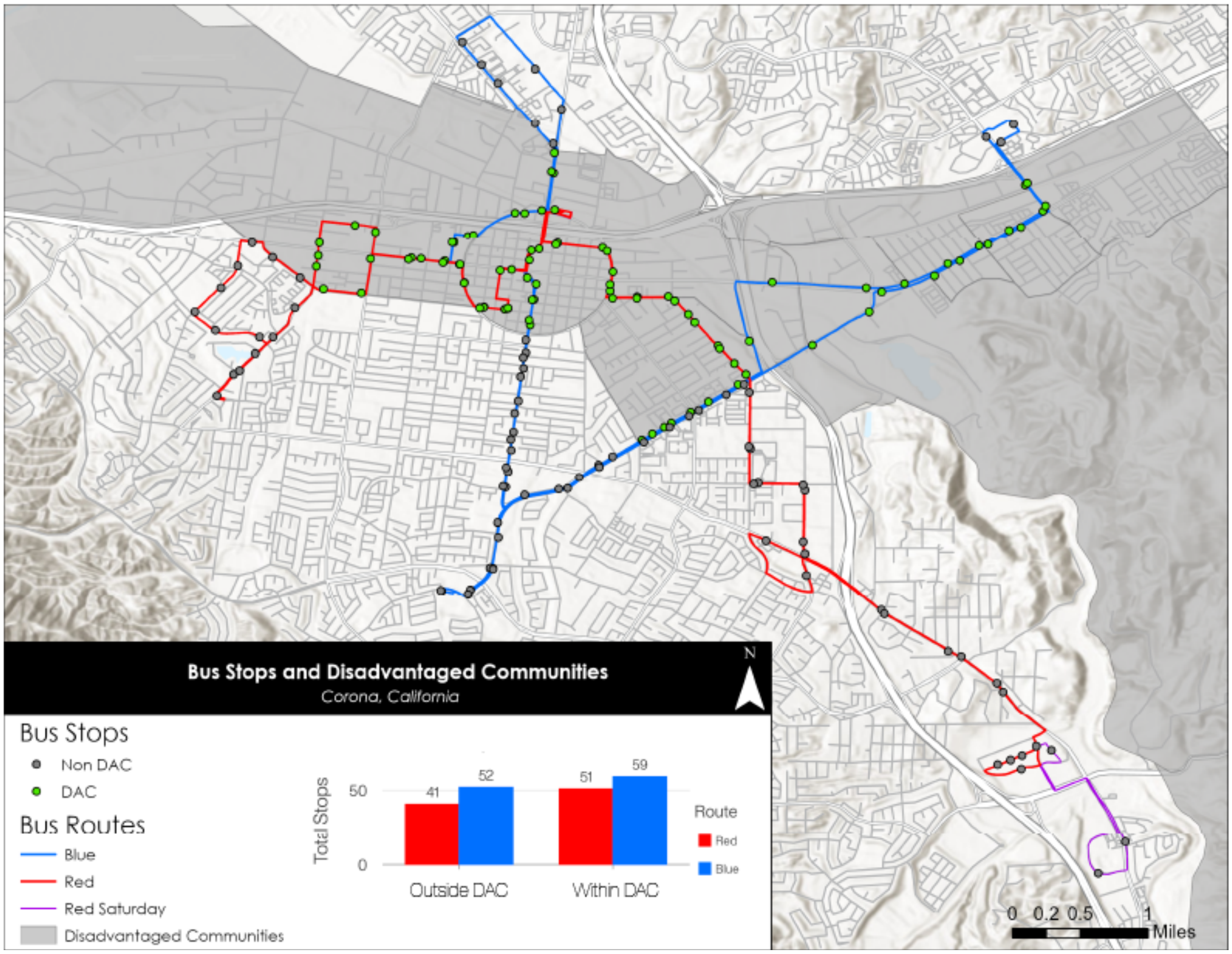

Figure 3 – Corona's Bus Service Relative to Disadvantage Communities

Of all the fixed-route stops, 110 (54%) are located within DACs. By line, 55% of the Red Line stops and 53% of the Blue Line stops fall within DACs. In terms of route length, 9 miles (40%) of the Red Line and 14 miles (59%) of the Blue Line lie within DACs.

In addition to fixed-route service, Corona Transit provides dial-a-ride (DAR) service. This service is provided for Seniors 60 and older; persons with disabilities; and persons certified under the Americans with Disability Act (ADA). Service is provided within the City of Corona and adjacent unincorporated communities of Coronita, El Cerrito, and Home Gardens, as well as several satellite locations. This includes ADA services within three-quarters of a mile of fixed-route service. Much of this area falls within DAC zones, but specific trips may start and/or end outside of DAC-designated areas. Unlike fixed-route service, the DAR service does not run a set route, and so a single vehicle may provide trips both within and outside of a DAC during a single day.

Existing Fleet Overview

In 2022, CCTS's bus fleet included eleven (11) 25-ft. Compressed Natural Gas (CNG) cutaways, two (2) 26-ft. CNG cutaways, and seven (7) 32-ft. CNG low-floor buses. The cutaways are allocated for DAR paratransit services, while the low-floor buses perform fixed-route service within the city limits, providing access to commercial and residential areas, schools, and medical facilities. CTE's vehicle classification adheres to FTA's definition of a cutaway, 'a bus-body attached to a small-to-medium- sized truck or van chassis[8].' Cutaways are typically smaller than a conventional bus, 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.

CCTS's transit fleet of twenty (20) total vehicles, thirteen (13) CNG cutaways, and seven (7) CNG 32-ft. buses have been summarized by vehicle size, first year in service, and fuel type as shown in **Table 2**.

[8] An Evaluation of the Market for Small-to-Medium-Sized Cutaway Buses: https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/AnEvaluationofMarketforSmalltoMediumSizedCutawayBuses.pdf

Table 2 – Fleet Summary by Depot, Length, and Fuel Type

Depot	Vehicle Length	First Service Year	Fuel Type
			CNG
735 Public Safety Way	Cutaway	2012	2
	Cutaway	2018	11
	32'	2016	7
	Total		20

CCTS's transit fleet consists of eleven (11) Glaval Universal E450 cutaways, two (2) El Dorado Aerotech 240 cutaways, and seven (7) El Dorado National EZ Rider buses. The transition to zero-emission will be agnostic to vehicle Original Equipment Manufacturer (OEM), however. A summary of the 2022 fleet by bus type, first service year, and OEM is shown in **Table 3.**

Table 3 – Fleet Summary by Depot, Length, and OEM

Depot	Vehicle Length	First Service Year	OEM		
			Glaval Universal	El Dorado National	Total
735 Public Safety Way	Cutaway	2012	-	2	2
	Cutaway	2018	11	-	11
	32’	2016	-	7	7
	Total		11	9	20

Fleet Purchase Pricing

Recent transit vehicle capital costs reported by CCTS are listed below in **Table 4.** It is important to note that CCTS’s past procurements from 2016 and 2018 informed the most recent vehicle prices. CTE applied a historical cumulative inflation rate of 40.34% based on the Producer Price Index (PPI) for transportation equipment[9], in order to account for pandemic pricing fluctuations between 2016 and 2022. To estimate procurement costs for the entire transition period through 2040, CTE utilized an annual inflation rate of 2% from 2022 onward, to inform vehicle pricing across the entire 18-year period.

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

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

2022 Base Vehicle Price by Length and Fuel Type	
Length	Single Vehicle Capital Cost in 2022
Cutaway	$172,766
32’	$ 658,037

Existing Fleet Mileage and Fuel Consumption

CCTS’s existing fleet fuel consumption data was used to estimate energy costs throughout the transition period.

It should be noted that the two (2) El Dorado cutaways and the eleven (11) Glaval Universal cutaways primarily perform DAR service, while the seven (7) buses perform fixed-route service within the city limits. In the event that the low-floor buses are down for repairs or planned maintenance, CCTS deploys cutaways on the fixed routes. For the purpose of this analysis and at the direction of CCTS, CTE has assumed that the fleet of cutaways perform DAR service only, and the low-floor buses perform solely fixed-route service.

CCTS provided annual mileage by vehicle type and service year of introduction, and totaled annual fuel consumption for the entire fleet, in FY 2021/22. In addition, CCTS provided fuel economies by service type (DAR or fixed route) for FY 2020/21. For purposes of the analysis, CTE assumed that the fuel economies remained consistent across the two fiscal years, and also assumed similar fuel economies across both service year cutaways. CTE then distributed the total fuel consumption data across each vehicle type, based on the mileage and fuel economy datasets described above. The annual fleet mileage, fuel consumption, and fuel economies, are shown in **Table 5, Table 6,** and **Table 7** respectively.

Table 5 – Average Annual Service Miles by Bus Length

Average Annual Mileage Per Bus Type and Age (mi)		
Vehicle Length	First Service Year	Annual Mileage Traveled by a Single Bus
Cutaway	2012	1,000
Cutaway	2018	13,664
32’	2016	23,693
Weighted Average for Total Annual Service Miles for Full Fleet		15,907

Table 6 – Annual Fuel Consumption by Bus Length

Average Annual Fuel Consumption per Bus Type and Age (GGE)		
Vehicle Length	First Service Year	Avg. Annual Fuel Consumption per Bus (GGE)
Cutaway	2012	184
Cutaway	2018	2,520
32’	2016	6,577
Weighted Average for Total Annual Fuel Consumption for Full Fleet		3,706

Table 7 – Calculated Fuel Economy by Bus Length

Calculated Fuel Economy by Vehicle Type and Age (MPGGE)		
Vehicle Length	First Service Year	Avg. Fuel Economy (MPGGE)
Cutaway	2012	5.42
Cutaway	2018	5.42
32'	2016	3.60

Annual GHG Emissions

CCTS's fleet of twenty CNG vehicles operate for approximately 318,150 miles per year, consuming 74,126 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 CCTS's existing fleet, using ANL's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) tool[10].

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),

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

whereas traditional combustion engine transit vehicles will expel pollutants directly from the tailpipe in addition to fuel vapor, particulate material (PM2.5) from tire wear and brakes friction material. **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. CCTS's existing fleet is responsible for an estimated 629.54 metric tons in overall well-to-wheel (WTW) emissions, including 2.49 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 $28,283.80 annually. CCTS's particulate emissions are summarized in **Table 8.**

Table 8 – Annual Vehicle Operation Pollutants by Fuel Type

Overall Annual Vehicle Operation Pollutants (lbs.)								
Bus Group	CO	NOx	PM10	PM2.5	VOC	SOx	PM10 TBW	PM2.5 TBW
CNG	13,477.13	80.56	2.49	2.49	28.69	4.92	71.54	9.12

Existing Facility and Infrastructure Overview

CCTS's entire transit fleet operates out of 735 Public Safety Way, termed the Corporation Yard, and is operated and dispatched by a transit operator contractor, MV Transportation. Maintenance is also performed independently by the contractor at an offsite facility located at 1930 S. Rochester Ave., in Ontario, CA, approximately 13 miles from the administrative building and bus garage. The City owns and operates a public CNG fueling station at 430 Cota Street; however, the transit fleet primarily fuels overnight at the slow-fill CNG fueling station located within the Corporation Yard at 740 Public Safety Way. A map of the facilities and fueling locations are provided below, in **Figure 4** and **Figure 5**, to understand the locations of CCTS's properties in relation to one another, as well as to routes and service areas. 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 – Administrative Facility Overview

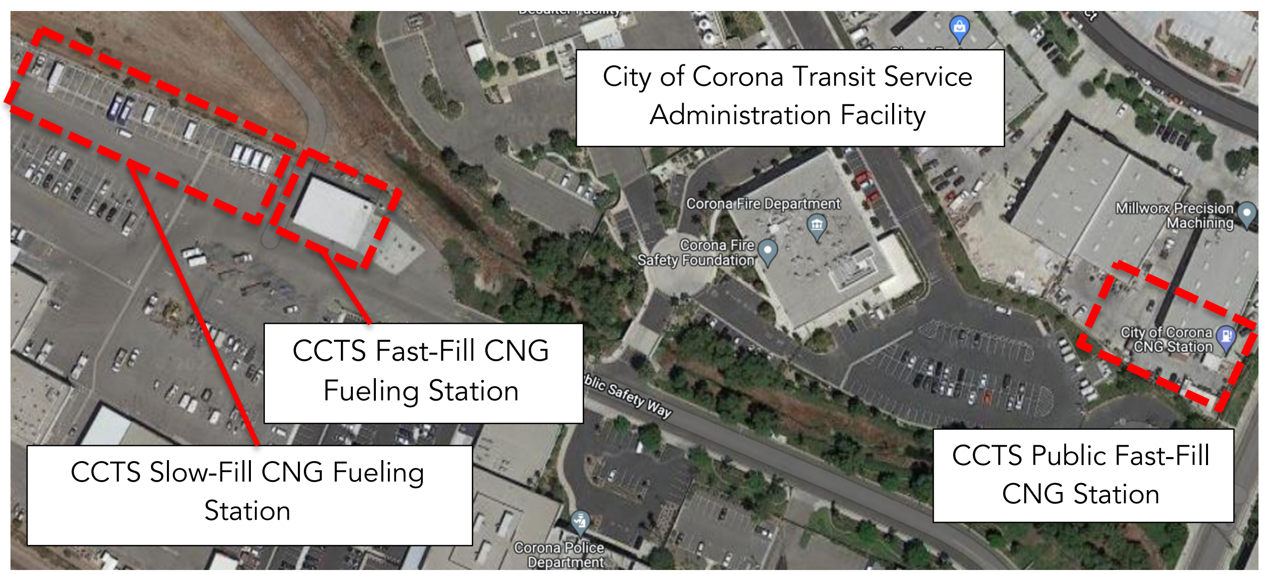

Figure 5 – Fueling Facility Overview

Transition Planning Requirements Analysis

Understanding present operations and capital costs of Corona'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. CCTS staff provided key data on current service including:

- Current fleet composition including vehicle propulsion types and lengths
- Route and block information including distances and trip frequency
- Nominal and strenuous passenger loading conditions
- Mileage and fuel consumption

CTE prepared CCTS'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. CCTS self-assigned topography and speed characteristics to each route, which were utilized to better define block 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 17 mph, respectively.

CTE then used component-level specifications for a generic 35/40 ft-BEB with a 450 kWh nameplate capacity, representative of the average 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[11]. 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 routes and blocks that share characteristics similar to CCTS's routes.

CTE also collected average data on nominal and strenuous loading conditions from CCTS. 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

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

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 blocks in subsequent assessments.

Fixed Route Service

CTE obtained raw operational data for the Blue Line and the Red Line routes from CCTS, and performed comprehensive analysis on CCTS's blocking and operations. Both the Blue Line and the Red Line routes run less revenue service hours on Saturdays with similar weekday frequencies, and the Red Line extends service to the Dos Lagos shopping center. For the purpose of analysis, CTE considered 4 independent bus blocks (the Red Line, Blue Line, Red Line Saturday, and Blue Line Saturday), in order to accurately quantify the daily mileages and corresponding energy consumption metrics.

To calculate average block distances, CTE summed sequential daily mileages based on vehicle IDs, and calculated average and maximum daily block mileages. To plan for the longest block of operation, the maximum block mileage was input into the model. CCTS's routes and their corresponding characteristics are listed in **Table 9** below.

Table 9 – City of Corona's Transit Routes

Route Classification	Route	Maximum Block Mileage	Route Category
Local Fixed Route	Red Line	166	Hilly, Low Speed
	Blue Line	183	
	Red Line Saturday	116	
	Blue Line Saturday	101	

CTE collected CCTS's average weekday passenger loading data per fixed-route. Pre-COVID passenger loading was used to represent the strenuous case, while current (FY'22) passenger loading represents the nominal scenario. CTE then averaged the passenger loading data across the total number of trips per day, to determine the nominal and strenuous passenger loading conditions for weekday fixed-route service, which are listed in **Table 10**.

Table 10 – Nominal and Strenuous Passenger Loading by Fixed Route

Route	Average Passenger Loading (Number of People)	
	Nominal	Strenuous
Blue Line	16	20
Red Line	13	17

Energy efficiency and **operating range** are primarily driven by vehicle specifications. CTE's nominal and strenuous efficiency calculations for the bus fleet are based on 35-ft. BEB specifications, provided the lack of equivalent 32-ft. BEB models that suit the input requirements of the analysis. Additionally, modeled efficiency differences between vehicles with such similar lengths are negligible for the purposes of this study. 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 CCTS. This prevents an operator from assigning vehicles to a route or service day that requires more energy than the vehicle is capable of performing.

Calculated nominal and strenuous efficiencies per route have been listed in **Table 11.**

Table 11 – Modeling Results Summary

Blocks	Bus Length	Nominal Efficiency (kWh/mi)	Strenuous Efficiency (kWh/mi)
Red Line	32'	2.35	3.59
Blue Line			
Red Saturday			
Blue Saturday			

These efficiency calculations are used to determine the total energy required per route, and subsequently each block per day. Once daily energy demand is known, it can be compared to the energy capacity of zero-emission transit vehicles at the time of this report. CTE uses the strenuous efficiencies when determining feasibility to provide a conservative estimate that ensures technology solutions can meet the most challenging expected conditions. **Figure 6** below depicts how many of CCTS's blocks can be serviced by a standard battery electric transit bus on a single overnight depot charge before pullout. Since onboard energy capacity and equipment is improving, this figure also assumes standard battery technology improvements and a 5% capacity improvement each year.

None of CCTS's blocks are immediately feasible under current strenuous conditions with CTE's generic BEB vehicle as simulated with Autonomie. However, there currently exists a 40-ft. low-floor transit vehicle with a 738-kWh nameplate capacity and thus, more blocks could be feasible sooner with this vehicle. This has not been explored as part of the **route modeling**, as the Existing Conditions Report remains manufacturer agnostic. The Blue Line Saturday block becomes feasible in 2028, and the Red Line Saturday block becomes feasible in 2034. Neither the Red Line nor the Blue Line weekday service will be feasible by 2040 with solely overnight depot-charged battery-electric bus technology.

This means that weekend service can eventually be accomplished by a single overnight depot charged BEB, but other zero-emission technology solutions will be required to complete CCTS's remaining fixed-route blocks, which we will explore in subsequent reports. Block feasibility models are not generated for FCEBs because it is assumed that today's model of the low-floor transit FCEB can accomplish any block under 350 miles. Given that CCTS's blocks range between 101 and 183 miles, CCTS's fixed-route blocks would be feasible with a comparable FCEB.

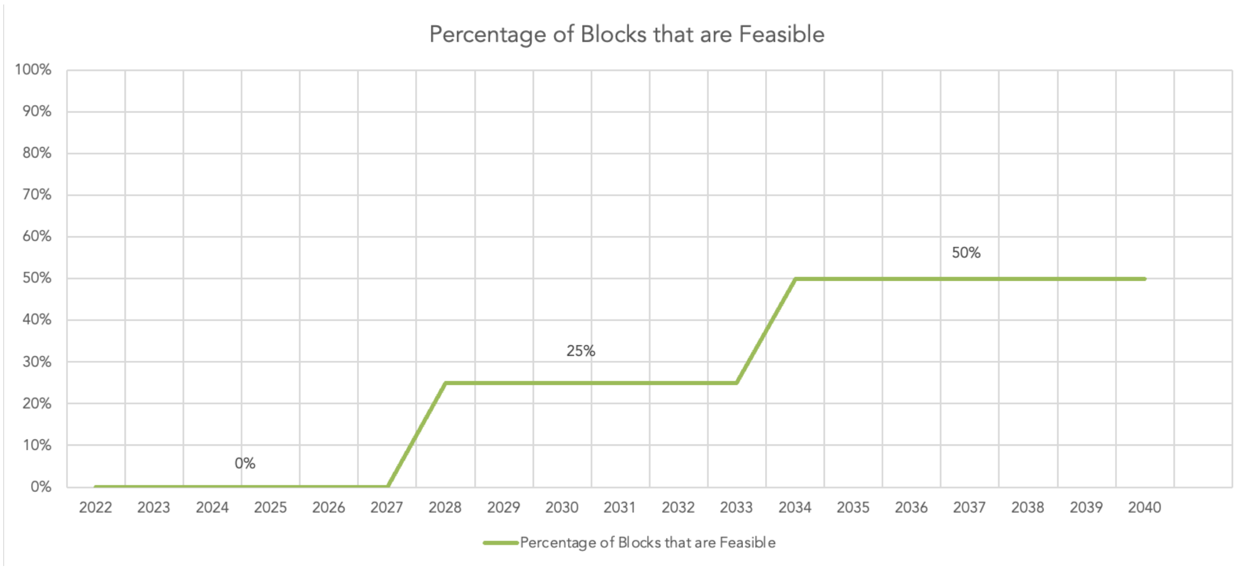

Figure 6 – Baseline Block Feasibility

Demand Response Service

CTE obtained service data for CCTS's DAR service from the month of May 2022. According to the operational data provided, CCTS operates DAR service six days a week, with daily mileages per vehicle ranging anywhere between 16 to 159 miles, and averaging about 78 miles. Unlike the fixed route service, the DAR service data could not be categorized into discrete blocks with known distances, due to the on-demand nature of the service. Instead of blocks, CTE used service days as a metric to represent the total distance and time that each cutaway traveled on each day during May 2022. This metric allows us to understand the energetic demand of DAR service, and set the precedent for performance expectations for zero-emission vehicles. CTE considered each service day to be individual and used averages across the dataset to describe trends in the route distances. The characteristics are described in **Table 12.**

Table 12 – Dial-A-Ride Service Characteristics

Service Characteristics	Miles Traveled in a Service Day
Minimum	16
Median	76.5
Max	159

Since each service day is unique, the energy usage was calculated based on both the mileage and the time that the cutaway was in service. The **tractive efficiency** is impacted by passenger loading, topography, and speed of the cutaway. The auxiliary load refers to the energy required to operate all other functions of the bus, including the HVAC, and can vary depending on operating temperatures, passenger loading, and duration of operation. 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 CCTS's vehicle efficiencies as performed by an equivalent battery-electric cutaway, specifically on hilly terrain and at low speeds. The calculated energy usage for CCTS's DAR service is listed in **Table 13** below.

Table 13 – Cutaway Energy Usage

Route	Bus Length	Tractive Efficiency (kWh/mi)	Auxiliary Load (kW)
Dial-A-Ride	26'	0.85	5

CTE determined the tractive and auxiliary efficiencies separately in order to calculate the total energy used for each service day. Once the energy demand for each 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 unfeasible 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 7** shows that 49% of the sample service days from May 2022 would be feasible given currently available vehicle nameplate capacities of 110 kWh. The most energy intensive service day from May 2022 that would be feasible under these conditions is 77 miles, and would require 98.25 kWh of energy.

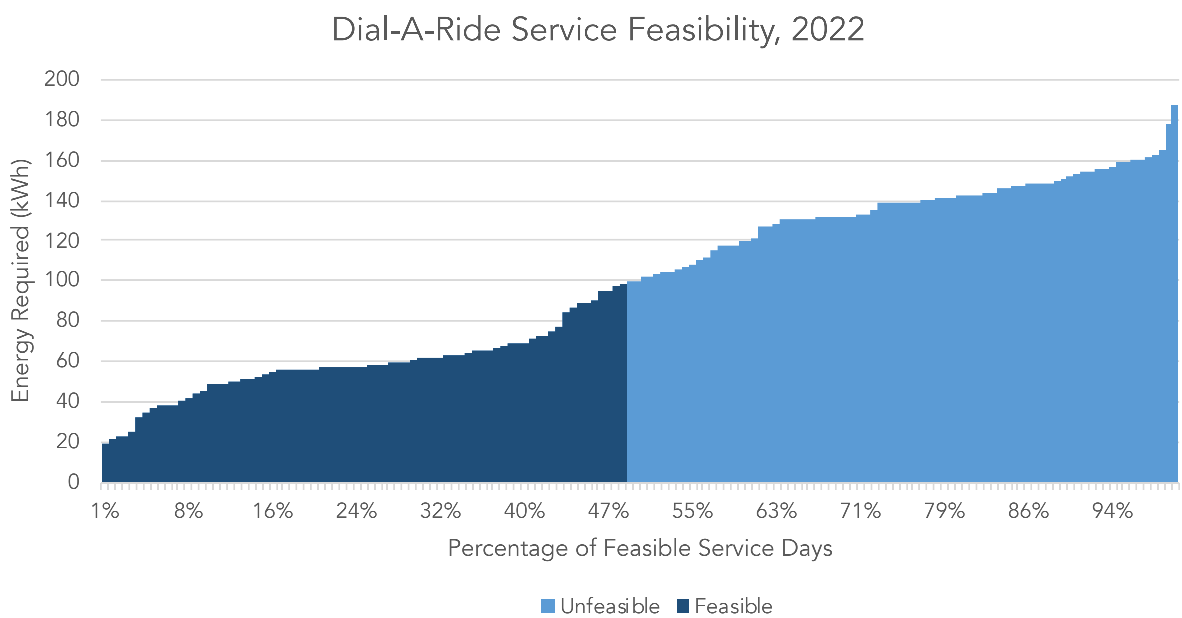

Figure 7 – Dial-A-Ride Service Feasibility, 2022

Figure 8 shows that by 2030 with technology improvements, 61% of the service days would feasible with a depot-charged battery-electric cutaway. This corresponds to a maximum energy usage of 119.71 kWh and distance of 89 miles.

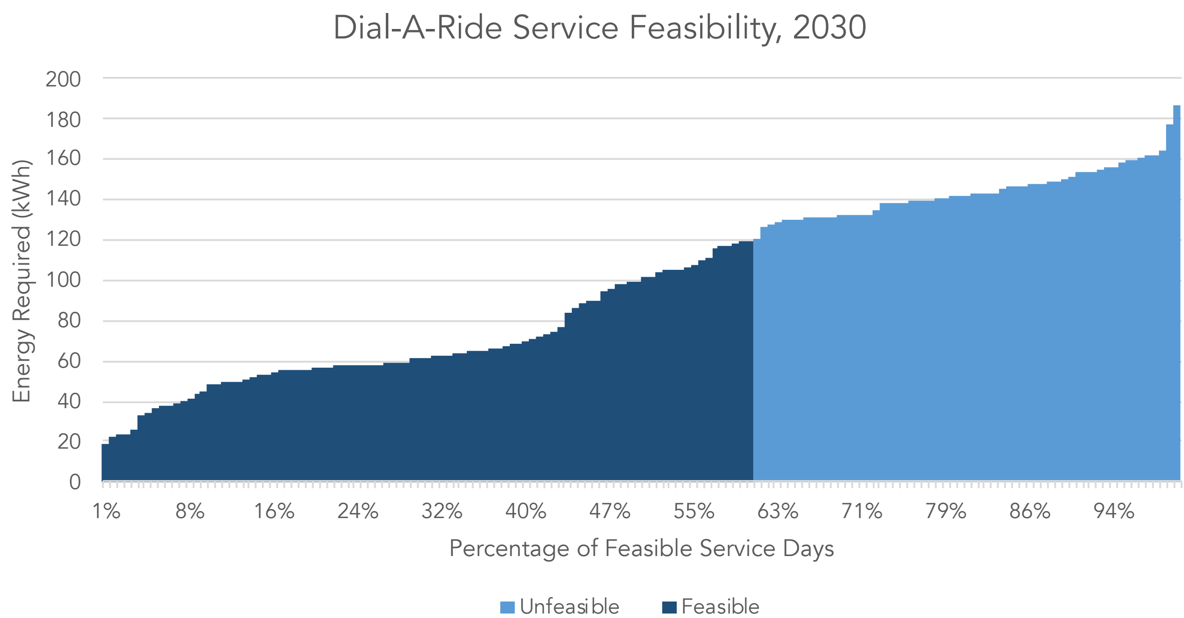

Figure 8 – Dial-A-Ride Service Feasibility, 2030

Figure 9 shows that by 2040, 91% of the current service days would be feasible with a depot-charged battery-electric cutaway. This represents distances of up to 126 miles, with an energy usage of 153.21 kWh.

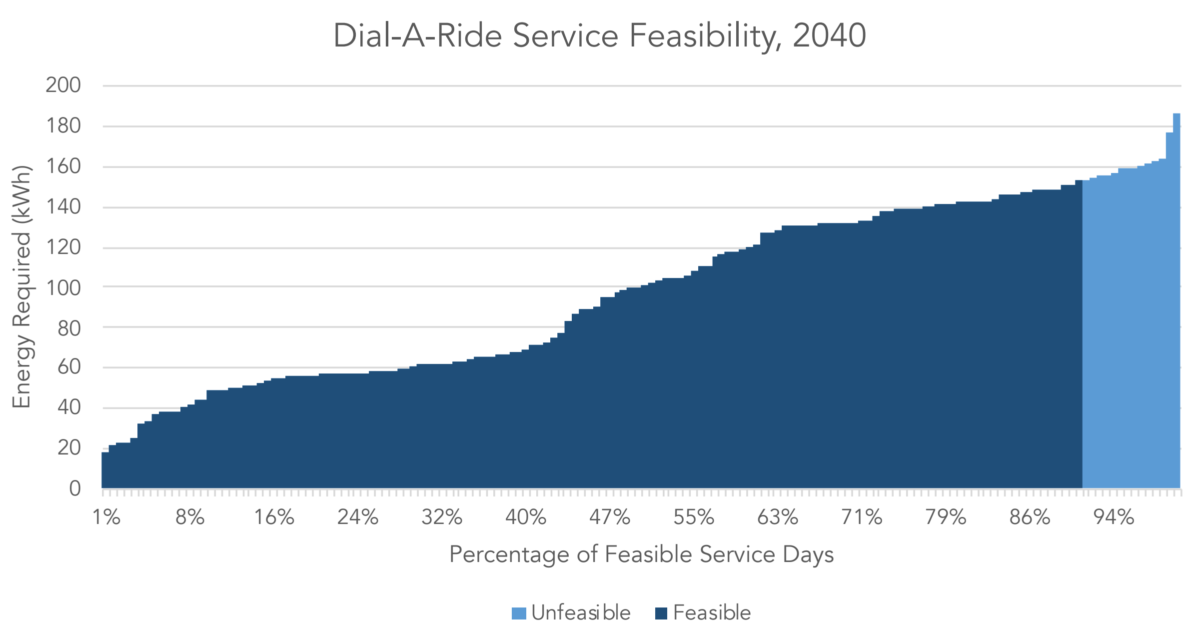

Figure 9 – Dial-A-Ride Service Feasibility, 2040

Conclusively, these findings demonstrate that CCTS will need to explore additional energy solutions such as midday opportunity charging at the depot or fuel cell cutaways to supply enough onboard energy to fulfill 100% of DAR service days. CCTS could also utilize 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. This option will not be explored in this project. CCTS can assume that early procurements of zero-emission cutaways should be assigned to lower-mileage DAR service assignments.

Baseline Vehicle Procurement Schedule

CCTS's fleet today is comprised of CNG cutaways and 32' low-floor buses. CTE projects that CCTS would continue to replace their 32' low-floor buses on a 12-year replacement cycle and cutaway vehicles on a 5-year replacement cycle, aligning with the FTA minimum service life categories for buses and vans[8]. For the purposes of establishing a baseline scenario, CTE projected vehicle procurements and costs over an 18-year period, assuming there will be no changes to CCTS's fleet 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. **Figure 10** 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, CCTS would spend approximately $22.7M in bus capital costs to replace their existing fleet with CNG buses and cutaways. **Table 14** outlines the annual procurement costs, through 2040.

Table 14 – Annual Procurements, Baseline Scenario

Purchase Year		2024	2028	2029	2034	2039	2040	Total
Vehicle Length	Cutaways	13	-	13	13	13	-	52
	32'	-	7	-	-	-	7	14
Price		$2.34M	$5.19M	$2.58M	$2.85M	$3.14M	$6.68M	$22.7

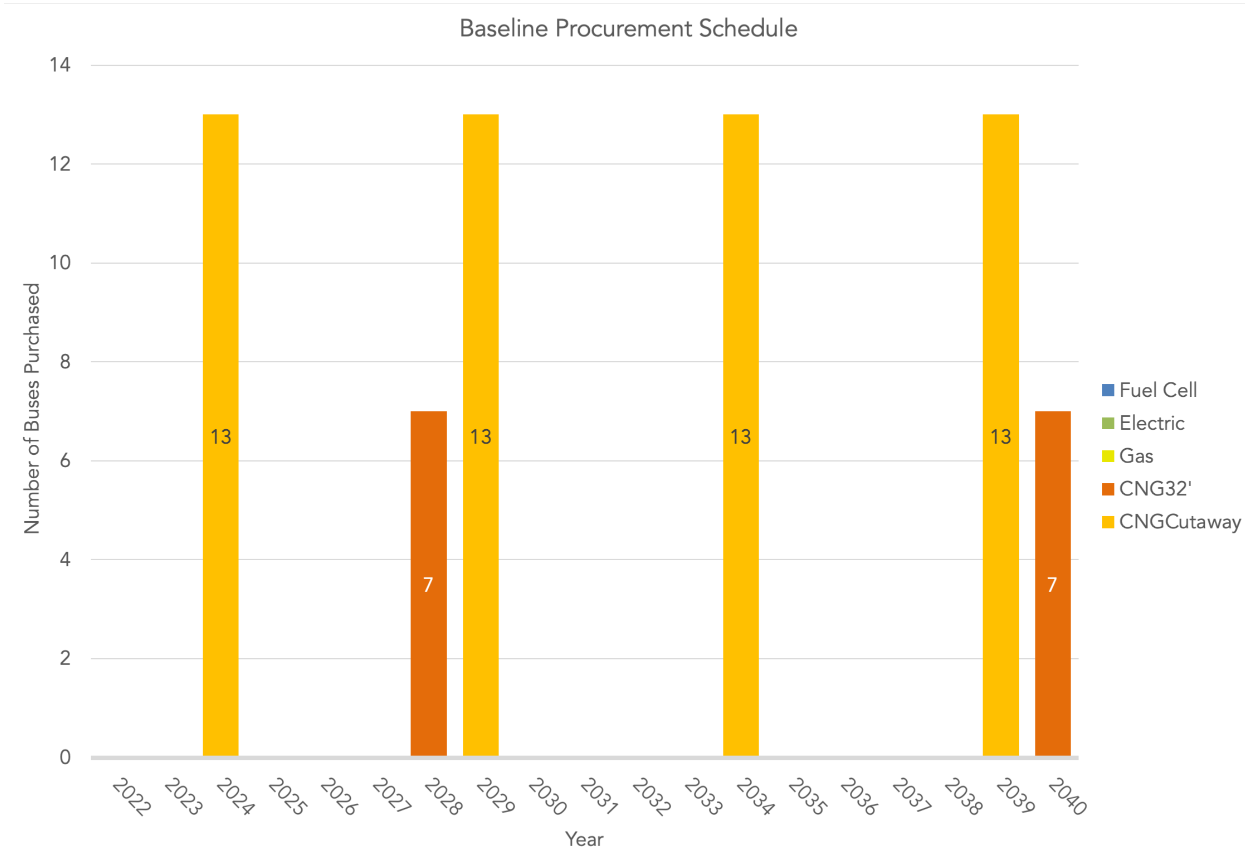

Figure 10 – Projected Bus Purchases, Baseline Scenario

Figure 11 depicts the annual fleet composition through 2040 for the *Baseline Scenario*; the fleet remains composed of low-floor 32′ CNG buses and CNG cutaway vehicles over the 18-year period.

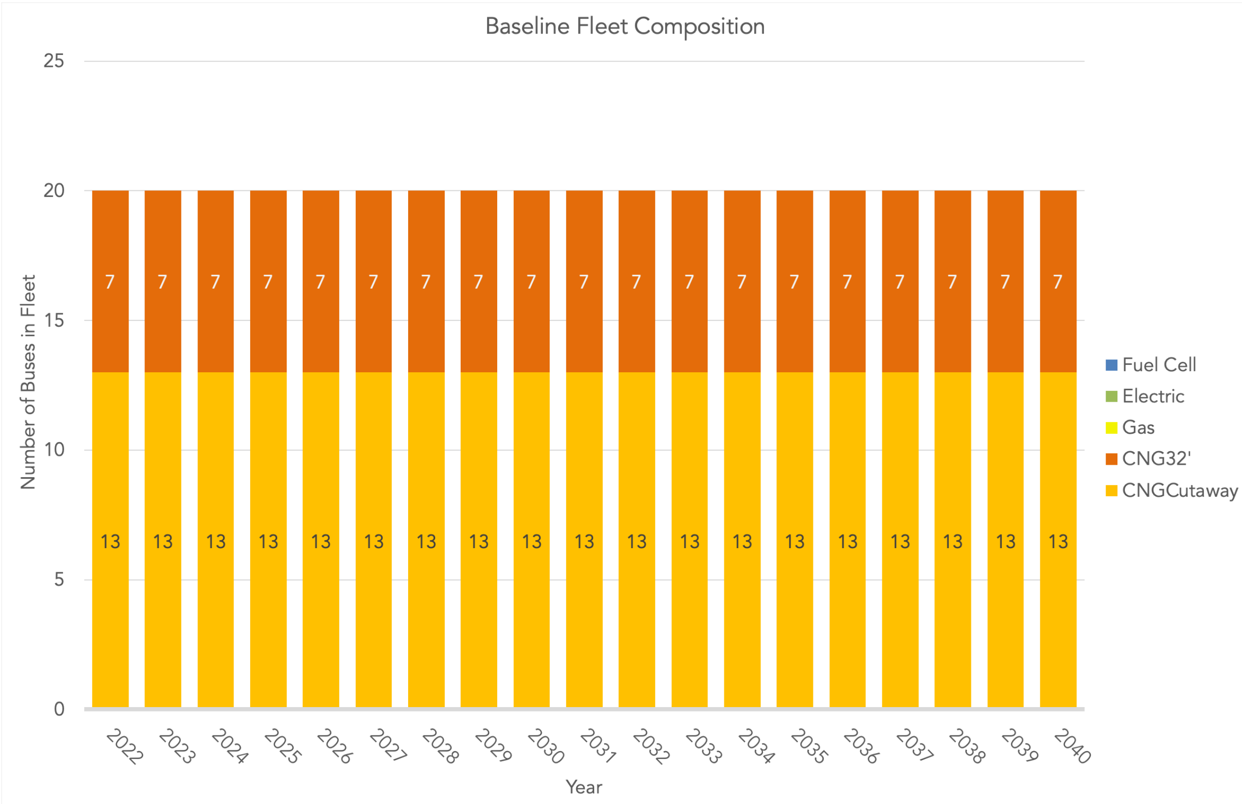

Figure 11 – Annual Fleet Composition, Baseline Scenario

Figure 12 shows the annual total bus capital costs for the CNG cutaways and low-floor buses purchased in each year in the *Baseline Scenario*.

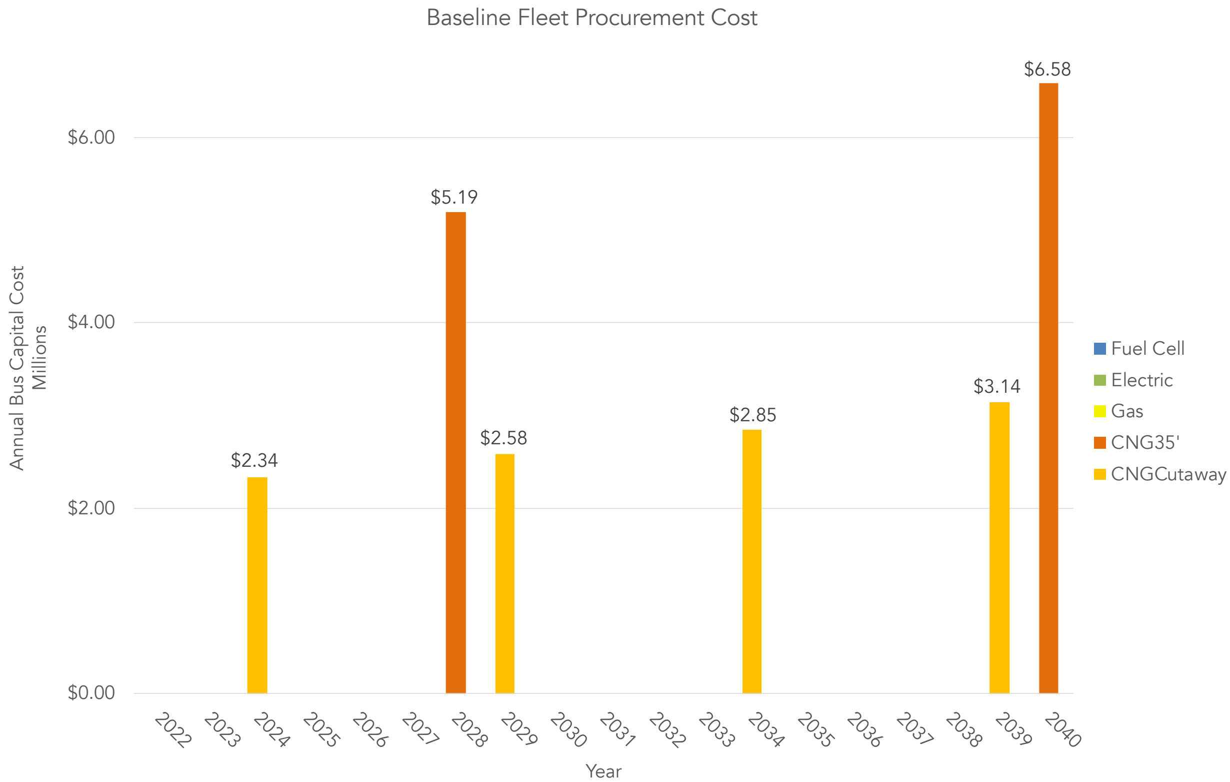

Figure 12 – Annual Capital Costs, Baseline Scenario

City of Corona Transit Service Sustainability Goals

CCTS is dedicated to sustainability and defines sustainability as the ability of the current generation to meet its needs without compromising the ability of future generations to meet their needs. 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, CCTS will be compliant at the conclusion of this project. To accomplish its sustainability goals, CCTS 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[12]. 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, within 40 miles of CCTS, two planned transit-operated hydrogen fueling station in Los Angeles County and Pomona, within 30 miles of CCTS. In addition, private hydrogen fueling stations by First Element Fuels and Stratosfuel within 80 miles of Corona, CA 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

[12] 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

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. Neighboring 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 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

Southern California Edison (SCE) is the electricity provider, or utility, for CCTS. SCE's Charge Ready Transport [13](CRT) program supports both California's greenhouse gas (GHG)-reduction goal and local air-quality requirements. The Program assists customers with transitioning to cleaner fuels by reducing their cost for the purchase and installation of required battery-electric vehicle (EV) charging infrastructure, as well as providing rebates to offset the cost of charging stations for certain eligible customers[14].

Primarily, the CRT program offers low- to no-cost electrical system upgrades to support the installation of EV charging equipment for qualifying vehicles – heavy-duty vehicles weighing 6000+ lbs. In addition, participants that will be acquiring school buses or transit buses within SCE territory are also eligible for a rebate against the purchase of charging equipment.

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

[13] https://crt.sce.com/program-details

[14] Charge Ready Transport, Quick Reference Guide

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, CCTS, 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 the City of Corona 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.

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, it 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 on to 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.