BUTTE COUNTY ASSOCIATION OF GOVERNMENTS

Zero-Emission Bus
Fleet Transition Study

Presented by Center for Transportation and the Environment

August 2022

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List of Acronyms

A&E	Architecture and Engineering
BCAG	Butte County Association of Governments
BEB	Battery Electric Bus
BROC	Butte Regional Operations Center
CARB	California Air Resources Board
CTE	Center for Transportation and the Environment
CI	Carbon Intensity
DOE	Department of Energy
DGE	Diesel Gallons Equivalent
dHEB	Diesel Hybrid
EPA	Environmental Protection Agency
EV	Electric Vehicle
ESS	Energy Storage System
FCEB	Fuel Cell Electric Bus
FCEV	Fuel Cell Electric Vehicles
FTA	Federal Transit Administration
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
LCFS	Low Carbon Fuel Standard
MPO	Metropolitan Planning Organization
MW	Megawatt
MWh	Megawatt-hours
NFPA	National Fire Protection Association
OCTA	Orange County Transit Authority
OEM	Original Equipment Manufacturer
ROW	Right-of-Way
TOU	Time-of-Use
ZEB	Zero-Emission Bus

Executive Summary

Butte County Association of Governments (BCAG) engaged the Center for Transportation and the Environment (CTE) to perform a zero-emission bus (ZEB) transition study with the aim to achieve a 100% zero-emission fleet by 2040 to comply with the Innovative Clean Transit (ICT) regulation, enacted by the California Air Resources Board (CARB). The results of the study will inform BCAG of the estimated costs, benefits, constraints, and risks of the transition to a zero-emission fleet and will guide future planning and decision-making.

On December 14, 2018, CARB enacted the ICT regulation, setting a goal for California public transit agencies to have 100% zero-emission fleets by 2040. The ruling specifies the percentage of new bus procurements that must be zero-emission buses for each year of the transition period (2021– 2040). Those annual percentages are outlined in **Table 1** below.

Table 1: ICT ZEB Percentage Requirements

Starting January 1	Percent of New Bus Purchases for Small Agencies
2026	25%
2027	25%
2028	25%
2029	100%

This schedule lays out a pathway to reaching 100% zero-emission fleets in 2040 based on a 12-year projected lifespan for a transit bus. BCAG has the opportunity to request waivers that allow purchase deferrals in the event of economic hardship or if zero-emission technology has not matured enough to meet the service requirements of a given route. These concessions recognize that zero-emission technologies may cost more than current internal combustion engine (ICE) technologies on a lifecycle basis and that zero-emission technology may not currently be able to meet all service requirements.

Zero-emission technologies considered in this study include battery-electric buses (BEB) and hydrogen fuel cell electric buses (FCEB). 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 electric drive components and energy source for a BEB and FCEB are illustrated in **Figure 1.**

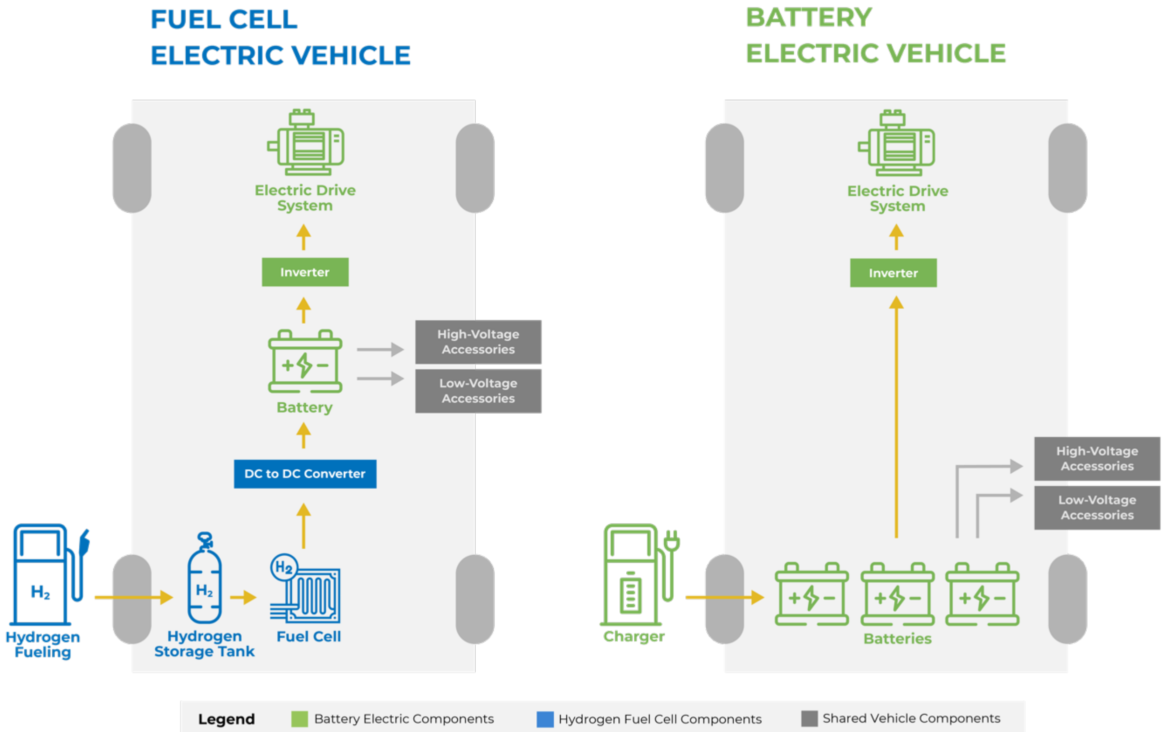

Figure 1 - Battery and Fuel Cell Electric Bus Schematic

CTE worked closely with BCAG staff throughout the project to develop an approach, define assumptions, and confirm the results. The approach for the study is based on analysis of four ZEB technology scenarios compared to a baseline scenario:

0. Baseline (current technology)
1. BEB Only

2a. Mixed Fleet - BEB Majority
2b. Mixed Fleet - FCEB Majority
3. FCEB Only

To accurately forecast service feasibility for each of these zero-emission technologies, CTE then assessed the block feasibility of BCAG's current service schedules. A block is the series of trips assigned to a single bus from the time of garage pull-out to its return pull-in, including deadhead, in-service hours, and layover. Block feasibility is determined by comparing the estimated energy required to operate a BEB on a given block to the usable onboard energy storage capacity of the bus. If the block energy requirement exceeds the usable onboard storage capacity, the block is considered unachievable. If the block energy requirement does not exceed the usable onboard storage capacity, the block is considered to be achievable. In order to calculate the block feasibility of BEBs, CTE modeled a market representative vehicle, which would have specifications that represent the average of the available vehicles in its class. Although not a zero-emission scenario, this study also includes a baseline scenario that is used to compare the cost of a ZEB transition to a "business-as-usual" case (i.e., without the need to meet ICT requirements).

The BEB-only scenario was developed to model an option with a fleet consisting entirely of battery electric buses that can meet existing service range requirements. Fleets consisting of BEBs that only charge at a depot may not be able to meet the range requirements of many routes and would require additional time to return to the depot to charge. According to CTE's modeling, BCAG's blocks are fully achievable with depot-charged BEBs by 2035. One drawback of a BEB-only fleet is that it may be less resilient than a mixed fuel fleet because interruptions to the power supply could jeopardize the operability of the fleet. This hurdle can be easily addressed by installing back-up power supplies and planning contingencies.

While the Feasibility Assessment determined that the range of market average BEBs would be sufficient to meet all of BCAG's service requirements, two mixed fleet scenarios were developed that allowed the agency to explore the cost and practicality of a BEB Majority fleet (75% BEB, 25% FCEB) and an FCEB Majority fleet (75% FCEB, 25% BEB). A mixed fleet is also more resilient to service interruptions if either fuel is temporarily unavailable. For agencies that operate only one depot, however, mixed fleets may present space constraints in order to host both infrastructure types in one depot. BCAG's facilities are not space constrained and are therefore able to accommodate the two technologies.

The FCEB-only scenario was developed to help identify benefits and mitigate challenges associated with switching the entire fleet to fuel cell technology. An FCEB fleet could replace diesel buses in a 1:1 ratio and avoids the need to install two types of fueling infrastructure. Additionally, hydrogen fueling infrastructure is less expensive at scale compared to a large-scale fleet transition to BEBs. And while hydrogen is a more expensive fuel than electricity at current market prices, applying a sensitivity analysis to hydrogen costs shows that it will likely become more competitive compared to the cost of electricity by 2040. A FCEB-only fleet, however, lacks the redundancy provided by having alternative technologies and fuel types in a mixed fleet, and current market prices for FCEBs are higher than BEBs.

The assessment follows CTE's ZEB Transition Planning Methodology, a complete set of analyses used to inform agencies planning the conversion of their fleets to zero-emission technologies. The methodology consists of data collection, analysis, and evaluation stages; these stages are sequential and build upon findings in previous steps. In the evaluation stage, CTE assesses energy efficiency and energy use by the buses to calculate the distance that a bus will be able to travel on a single charge or hydrogen fill. CTE collected sample data from multiple BCAG routes. Then, using market representative ZEB battery capacity specifications for given bus lengths, CTE estimated range and energy consumption on all BCAG routes and blocks under varying environmental and passenger load conditions. Once this information was established, CTE completed the following assessments to develop cost estimates for each of the scenarios.

The **Fleet Assessment** develops a projected timeline for replacement of current buses with ZEBs that is consistent with the agency's fleet replacement plan. This assessment also includes a projection of fleet capital cost over the transition lifetime and it can be optimized with regard to any state mandates, like CARB's ICT regulation, or to meet agency goals, such as minimizing cost or maximizing service levels. It should be noted that the assessment assumes buses are replaced with ZEBs of the same length as the ICE buses currently in operation.

The **Fuel Assessment** merges the results of the Service Assessment and Fleet Assessment to determine annual fuel requirements and associated costs. The Fuel Assessment calculates energy costs through the full life of the transition, including the agency's current ICE buses. As current technologies are phased out in later years of the transition, the Fuel Assessment calculates the increasing energy requirements for ZEBs. The Fuel Assessment also provides a total energy cost over the transition lifetime.

The **Facilities Assessment** determines the necessary infrastructure to support the projected zero-emission fleet based on results from the Fleet Assessment and Fuel Assessment. The Facilities Assessment is calculated to meet the fleet procurement schedules defined in the Fleet Assessment and the fueling capacity required based on the Fuel Assessment. The result shows quantities of hydrogen and battery electric infrastructure and calculates associated costs.

The **Redundancy, Resilience, and Emergency Response (3R) Assessment** investigates the new risks to an agency's ability to provide service during power outages or fuel disruptions and to support required emergency response activities, such as community evacuation with a full ZEB fleet. The outcomes of the 3R assessment are a summary of the risk reduction capabilities and cost effectiveness of the recommended alternatives to mitigate the impacts from identified risks specific to an agency's risk tolerances, facility constraints, and budget.

The **Maintenance Assessment** calculates all projected fleet maintenance costs over the life of the project. This includes costs related to existing ICE buses remaining in the fleet, as well as new ZEBs.

The **Total Cost of Ownership Assessment** compiles results from the previous assessment stages and provides a comprehensive view of all associated costs, over the transition lifetime. **Table 2** and **Figure 2** below provide a side-by-side comparison of the cumulative transition costs for each scenario. Since BCAG is already in the process of procuring 5 BEBs and will need to install chargers to support these vehicles, the Baseline scenario includes infrastructure costs although all ICE fueling infrastructure is assumed to already be installed.

Table 2 - Total Cost of Ownership, by Scenario

	0. Baseline (Current Technology)	1. BEB Only	2a. Mixed Fleet (BEB Majority)	2b. Mixed Fleet (FCEB Majority)	3. FCEB Only
Fleet	$35M	$45M	$50M	$55M	$57M
Fuel*	$24M	$21M	$24M	$26M	$27M
Maintenance	$15M	$13M	$15M	$17M	$18M
Infrastructure	$3M	$8M	$11M	$8M	$8M
TOTAL	**$ 76M**	**$ 88M**	**$ 101M**	**$106M**	**$ 110M**

*Excludes any potential LCFS credit revenue; near-term costs with sensitivity analysis applied.

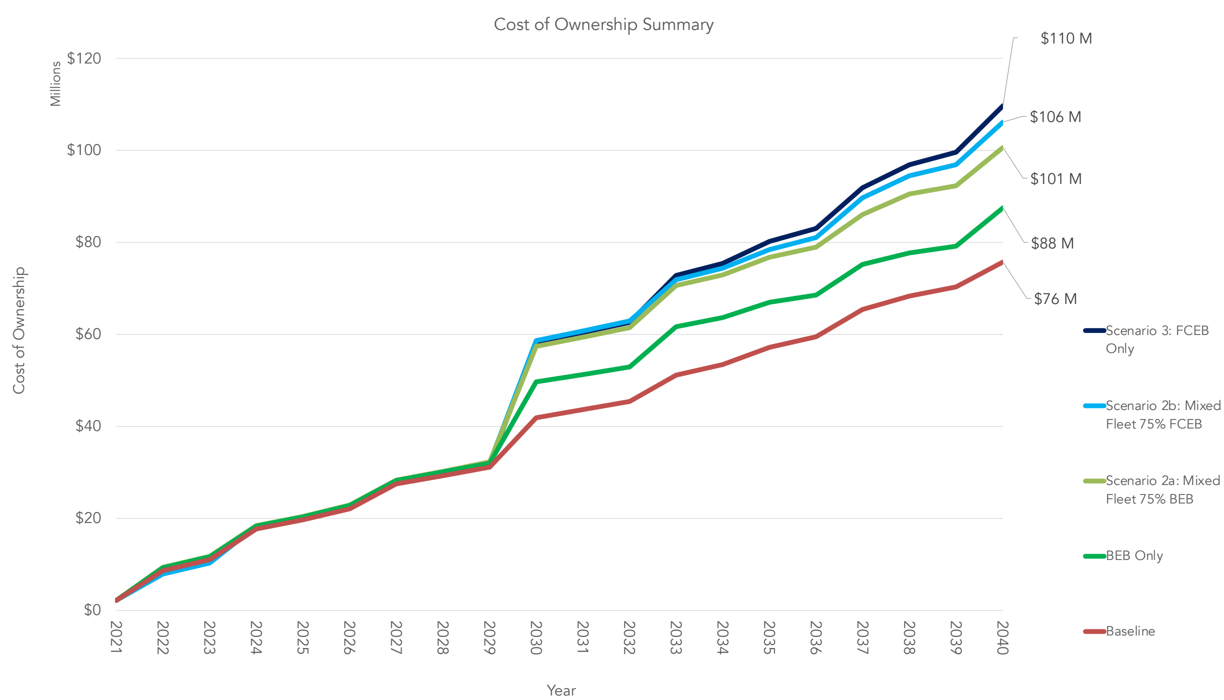

Figure 2 - Total Cost of Ownership, by Scenario

ZEB Transition Scenario Overview

1. Battery Electric Bus (BEB) Depot Only Scenario

For an all-BEB fleet that charges exclusively at the depot, ZEB transition costs are likely to be $88 million where 100% of BCAG's fleet is replaced with BEBs by 2040 without adding additional buses. The difference in cost between the Baseline and BEB Depot Only scenario is the result of higher capital costs for battery electric buses compared to diesel buses and from the significant infrastructure investment necessary for charging infrastructure.

2a. Mixed Fleet: BEB Majority

In the BEB Majority Mixed Fleet, 75% of BCAG's fleet is composed of battery electric buses, with the remaining 25% made up of hydrogen fuel cell buses. The total cost of this scenario is estimated at $101 million. Though all of BCAG's routes are feasible with BEBs, the addition of fuel cell buses adds redundancy and resilience in potential emergency situations.

2b. Mixed Fleet: FCEB Majority

The FCEB Majority Mixed Fleet Scenario resulted in a total cost of approximately $106 million to replace BCAG's entire fleet with ZEBs by 2040. Though the costs are less for a mixed fleet deployment than for the FCEB Only deployment, there is the added complexity of installing infrastructure for both fuel types. Since BCAG has only one depot, the space constraint of installing both infrastructure types may be a challenge.

3. Fuel Cell Electric Bus (FCEB) Only Scenario

In the FCEB Only scenario, ZEB transition costs are estimated at $110 million to replace 100% of BCAG's fleet with FCEBs by 2040. A primary assumption for the FCEB Only scenario is that 30-foot fuel cell electric buses and fuel cell cutaways will become available during the transition period. It is expected that, due to the limited deployment of FCEBs in service in the United States, capital costs for these buses and hydrogen fuel costs will remain high in the near-term due to low market competition. This is expected to change, although more data is needed to adequately forecast these cost decreases. As such, this study uses current FCEB and infrastructure pricing for the entirety of the ZEB transition period.

For estimates of FCEB maintenance costs, CTE used data reported from Orange County Transit Authority's (OCTA) FCEB fleet of 10 New Flyer Xcelsior buses in their first year of operation. Fuel cell technology was new to OCTA and, as a result, the maintenance costs were higher than expected. OCTA does expect reductions in the long run. Given the necessary reliance on this early-adoption maintenance data, FCEB maintenance cost data has a wider margin of error than BEB cost estimates. More concrete data will become available, and costs will likely fall as a larger number of fuel cell electric buses and hydrogen infrastructure are deployed, however, significant investments in hydrogen infrastructure may take years to materialize.

Project Risks

In addition to the uncertainty of technology improvements, there are other risks to consider in trying to estimate costs over the 20-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. In 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. The costs and benefits of various alternatives to mitigate the risks of power outages, hydrogen disruptions, and natural disaster impacts were evaluated in the Redundancy, Resilience, and Emergency Response (3R) Assessment.

Recommendations

Given these considerations, the recommendations for BCAG are as follows:

1. **Select a preferred scenario to refine in ICT Plan development and remain proactive with ZEB deployment grants:** This Master Plan was developed to present BCAG with options for transitioning to a zero-emission fleet. Following BCAG's selection of the BEB majority transition scenario, the ICT Rollout Plan has been developed for submittal to CARB in compliance with the ICT Regulation. This document will put forth BCAG's vision for a ZEB Transition and will act as a living document to help the agency plan grant funding requirements. As a greater proportion of BCAG's fleet converts to ZEB technology, auxiliary equipment, hardware, and software will be needed to ensure a successful fleet transition. BCAG should continue to remain proactive in the purchase and deployment of ZEBs and their associated systems by taking advantage of various grant and incentive programs.
2. **Apply learnings from emergency disaster response:** Evaluate the tradeoffs for various alternatives to reduce the risk from power outages and fuel disruptions, and allow BCAG to meet all first responder requirements from the 3R Assessment.

3. **Match the individual bus technology to the individual route and blocks:** BCAG should consider the strengths of given ZEB technologies and focus those technologies on routes and blocks that take advantage of their efficiencies and minimize the impact of the constraints related to the respective technologies. These technologies cannot follow a one-size-fits-all approach from either a performance or cost perspective. Matching the present technology to the present service levels will be a critical best practice.
4. **Monitor local and regional developments:** In the zero-emission technology sector, developments at the local level can have the ability to catapult the industry forward. When local bus OEMs or fuel providers enter the zero-emission market, it can spark technological innovation or cost reduction. Neighboring transit agencies can also work together through group purchasing agreements and lobbying efforts to bring about reduced purchase costs or more funding opportunities.

The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission transportation sector. Widespread adoption of zero-emission bus technology has the potential to significantly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. BCAG is committed to implementing environmentally-friendly policies and reducing its carbon footprint.

The analysis contained herein was completed based on the best available fleet data and procurement schedule available as of 2021. Between the completion of the analysis and the completion of this report, the agency's procurement schedule has changed slightly to include procuring at least 6 BEBs in the near future. Although this change will create a deviation from the results shown in this document, the impact on the relative cost differentials between scenarios would be fairly negligible as all scenarios would be equally impacted and it would not cause a significant change in the cost comparison of one scenario to the next.

Introduction

Butte County Association of Governments (BCAG), the owner and operator of Butte Regional Transit (B-Line), is in the process of converting its bus fleet to zero-emission buses (ZEB) by 2040. As a transit agency in California, BCAG is subject to the Innovative Clean Transit (ICT) regulation, requiring all California transit agencies to follow zero-emission procurement guidelines with the goal of achieving 100% zero-emission fleets by 2040. To explore BCAG's options for meeting this fleet electrification target, this transition study presents four zero-emission fleet transition scenarios and uses BCAG's current fleet operations as a baseline to measure the effects of each transition scenario. For each scenario, this study assesses bus and cutaway purchase costs, fuel costs, infrastructure investments, and maintenance costs. Additionally, this study also takes into account BCAG's local needs and conditions, namely considering resilience, redundancy, and emergency response adaptation options. By using real data provided by BCAG, its partners, and industry-reliable sources in the assessments, BCAG will be able to draw insights to choose the optimal zero-emission transition scenario.

BCAG Background Information

History

In June 2005, B-Line was formed in order to consolidate transit systems previously operated by the County of Butte (Butte County Transit), the City of Chico (Chico Area Transit), the City of Oroville (Oroville Area Transit) and the Town of Paradise. B-Line service is delivered by a contract transit operator, Transdev, Inc., which also performs dispatching and maintenance duties at the Butte Regional Operations Center (BROC) in the City of Chico.

BCAG is the Regional Transportation Planning Agency (RTPA) and Metropolitan Planning Organization (MPO) for Butte County, as designated by the Secretary of the Business Transportation & Housing Agency for the State of California. Through the BCAG Joint Powers Agreement, the BCAG Board also serves as the administrative and policymaking agency for B-Line allowing for better routes, a uniform fare structure, improved service with timed transfers, consistent headways for ease of use, and comprehensive customer service.[1]

1 BCAG Unmet Transit Needs Assessment – 2021/2022
http://www.blinetransit.com/documents/UTN/2122-Transit-Needs-Assessment-Final.pdf

Service Area and Bus Service

B-Line provides regional and local public transit services in Butte County and covers roughly 700 square miles. The current bus fleet consists of 32 fixed-route buses: 30 diesel buses (11 35-feet diesel and 19 40-feet diesel buses) and 2 CNG buses (40-feet).[2]

B-Line operates 21 fixed routes, which includes 5 regional routes, 15 local routes, and an express route to Chico Airport. Regional routes connect the towns and cities of Chico, Oroville, Paradise, Magalia, Gridley, and Biggs. Local routes serve the Chico urban area and the city of Oroville. The regional routes average speed is 28.9 mph. For local routes, the average speed is 15 mph. The average speed for the express route is 17.3 mph.

B-Line also operates 2 types of paratransit services—ADA Paratransit and Dial-A-Ride. Their paratransit fleet consists of 22 gasoline-powered cutaway vehicles (28-feet).

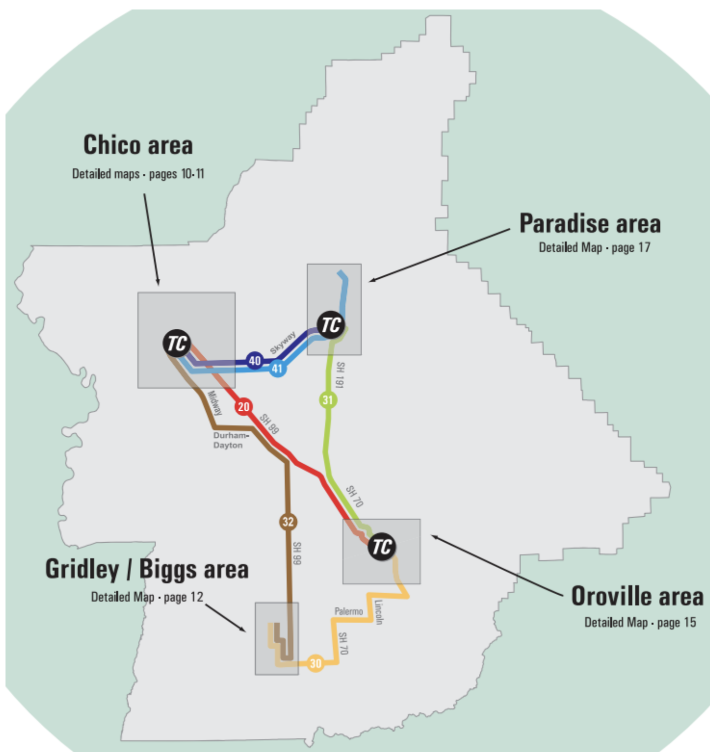

Figure 3 - BCAG Service Area

2 BCAG is expected to procure 2 New Flyer BEBs in 2022 and 3 more in 2024.

Ridership

B-Line serves a diverse community, with a large portion of its daily passengers being individuals without cars (by choice or because of financial limitation), university students, and paratransit riders. Although ridership on transit in general has been decreasing over the past few years due in part to lower gas prices and more affordable automobiles, which has allowed more people the opportunity to own personal cars, the ridership reductions seen by B-Line in recent years are more directly tied to reduced population in its service area following the Camp Fire. [3] In 2018, the Camp Fire burned through Butte County and destroyed homes and businesses in the town of Paradise, which is served by B-Line. In 2020, B-Line's service was further reduced by the Coronavirus Disease 2019 SARS-CoV-2 (COVID/COVID-19) pandemic.

B-Line's service experienced significant reduction after the 2018 Camp Fire and has not returned to its original service levels and is not expected to. Since the beginning of the COVID-19 pandemic, the services have stayed the same with the exception of Route 40 and 41, which runs through areas affected by the Camp Fire—demand for bus service in Paradise has remained low. Based on BCAG's data of available ridership and total fares received from July 2018 through the month of June 2019 (pre-COVID levels), there were 949,871 fixed-route passengers and 141,277 paratransit passengers.[4] BCAG anticipates annual ridership to be less than this over the next 5 years. In response to the changing ridership needs, due in part to the Camp Fire and COVID, BCAG is conducting a Route Optimization Study, which will be completed in the Summer of 2023 in order to re-assess how to most efficiently serve individual routes as well as the whole system.

Providing Zero-Emission Service to DACs

In California, CARB defines disadvantaged communities (DACs) as communities that are both socioeconomically disadvantaged and environmentally disadvantaged due to local air quality. Lower income neighborhoods are often exposed to greater vehicle pollution levels due to proximity to freeways and the ports, which puts these communities at greater risk of health issues associated with tailpipe emissions.[5] ZEBs will reduce energy consumption,

[3] Grengs, Joe, Jonathan Levine, and Qingyun Shen. (2013). Evaluating transportation equity: An inter-metropolitan comparison of regional accessibility and urban form. FTA Report No. 0066. For the Federal Transit Administration

[4] Page 21 of BCAG's Unmet Transit Needs Assessment – 2021/2022 http://www.blinetransit.com/documents/UTN/2122-Transit-Needs-Assessment-Final.pdf

[5] Reichmuth, David. 2019. Inequitable Exposure to Air Pollution from Vehicles in California. Cambridge, MA: Union of Concerned Scientists. https://www.ucsusa.org/resources/inequitable-exposure-air-pollution-vehicles-california-2019

harmful emissions, and direct carbon emissions in six opportunity zones and disadvantaged communities in rural Northern California as shown in in the service map below. B-Line serves the following census communities identified as DACs: 6007003700 and 6007001300, which have a pollution burden of 85-90% according to CalEnviroScreen. They are shown in **Figure 4** below.

Environmental impacts, both from climate change and from local pollutants, disproportionately affect transit riders. For instance, poor air quality from tailpipe emissions and extreme heat harm riders waiting for buses at roadside stops. The transition to zero-emission technology will benefit the region by reducing fine particulate pollution and improving overall air quality. In turn, the fleet transition will support better public health outcomes for residents in DACs served by the selected routes.

Public transit has the potential to improve social equity by providing mobility options to low-income residents lacking access to a personal vehicle and helping to meet their daily needs. In California, transit use is closely correlated with car-less households as they are five times more likely to use public transit than households with at least one vehicle.[6] Although 21% of Californians in a zero-vehicle household are vehicle free by choice, 79% do not have a vehicle due to financial limitations. Many low-income people therefore rely solely on public transportation for their mobility needs.[7] B-Line's current fleet of fixed route diesel buses consumes an annual average of 247 thousand gallons of diesel. The combustion of this fuel exposes those who are reliant on public transportation to diesel exhaust, which has been classified as a probable human carcinogen with links to asthma and other lung related health issues.[8] Portions of B-Line's service area are in the 90th-100th percentile for diesel particulate matter (PM) according to CalEnviroScreen 4.0. Moving B-Line's fleet to zero-emission technology will help alleviate this pollution, which will improve the health of communities impacted by high diesel PM and all Sacramento Valley communities.

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6 Grengs, Joe, Jonathan Levine, and Qingyun Shen. (2013). Evaluating transportation equity: An inter-metropolitan comparison of regional accessibility and urban form. FTA Report No. 0066. For the Federal Transit Administration

7 Paul, J & Taylor, BD. 2021. Who Lives in Transit Friendly Neighborhoods? An Analysis of California Neighborhoods Over Time. Transportation Research Interdisciplinary Perspectives. 10 (2001) 100341. https://reader.elsevier.com/reader/sd/pii/S2590198221000488?token=CABB49E7FF438A88A19D1137A2B1851806514EF576E9A2D9462D3FAF1F6283574907562519709F8AD53DEC3CF95ACF27&originRegion=us-east-1&originCreation=20220216190930

8 National Resources Defense Council Coalition for Clean Air. No breathing in the aisles — diesel exhaust inside school buses. New York: The Council; January 2001.
Available: www.nrdc.org/air/transportation/schoolbus/sbusinx.asp

Access to quality transit services provides residents with a means of transportation to go to work, to attend school, to access health care services, and run errands. By purchasing new vehicles and decreasing the overall age of its fleet, B-Line is also able to improve service reliability and therefore maintain capacity to serve low-income and disadvantaged populations. Replacing diesel vehicles with zero-emission vehicles, will also benefit these populations by improving local air quality and reducing exposure to harmful emissions from diesel exhaust.

Emissions Reductions for DACs

Greenhouse gases (GHG) are the compounds primarily responsible for atmospheric warming and include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The effects of greenhouse gases are not localized to the immediate area where the emissions are produced. Regardless of their point of origin, greenhouse gases contribute to overall global warming and climate change.

Criteria pollutants include carbon monoxide (CO), nitrogen oxides (NOx), particulate matter under 10 and 2.5 microns (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOC), and sulfur oxides (SO_X). These pollutants are considered harmful to human health because they are linked to cardiovascular issues, respiratory complications, or other adverse health effects.[9] These compounds are also commonly responsible for acid rain and smog. Criteria pollutants cause economic, environmental, and health effects locally where they are emitted. CARB defines DACs in part as disadvantaged by poor air quality because polluting industries or freight routes have often been cited in these communities. The resulting decrease in air quality has led to poorer health and quality of life outcomes for residents.

By transitioning to ZEBs from diesel buses, B-Line's zero-emission fleet will produce fewer carbon emissions and fewer harmful pollutants from the vehicle tailpipes. Communities disadvantaged by pollution served by B-Line's fleet will therefore directly benefit from the reduced tailpipe emissions of ZEBs compared to ICE buses.

9 Institute of Medicine. Toward Environmental Justice: Research, Education, and Health Policy Needs. Washington, DC: National Academy Press, 1999; O'Neill MS, et al. Health, wealth, and air pollution: Advancing theory and methods. Environ Health Perspect. 2003; 111: 1861-1870; Finkelstein et al. Relation between income, air pollution and mortality: A cohort study. CMAJ. 2003; 169: 397-402; Zeka A, Zanobetti A, Schwartz J. Short term effects of particulate matter on cause specific mortality: effects of lags and modification by city characteristics. Occup Environ Med. 2006; 62: 718-725.

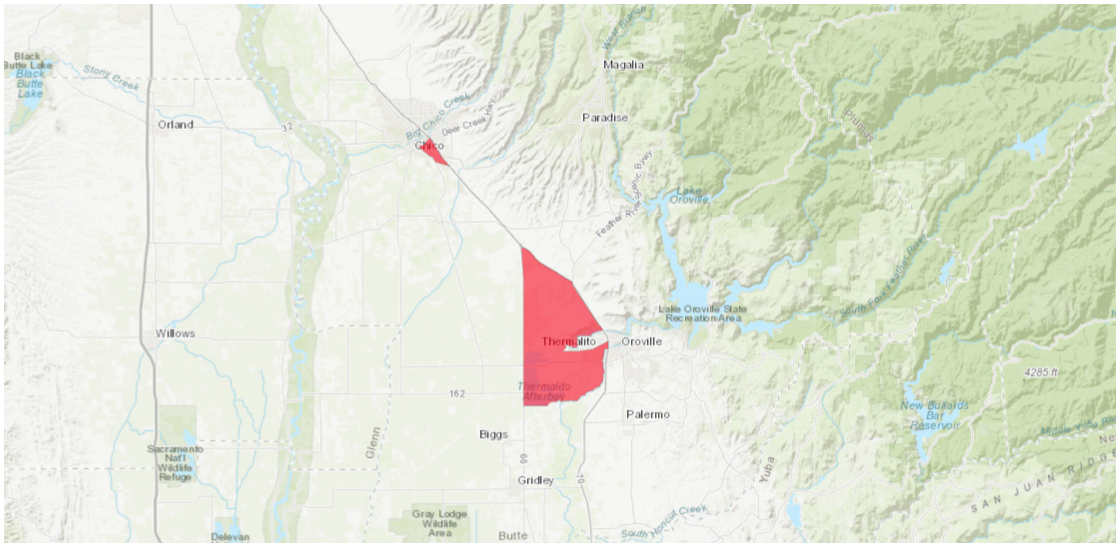

Figure 4 - B-Line Disadvantaged Communities Service Map

About BCAG

Transit Agency's Name: Butte Regional Transit

Mailing Address: 326 Huss Dr. Suite 150, Chico, CA 95928

Transit Agency's Air Districts: California's 35 local Air Districts are responsible for regional air quality planning, monitoring, and stationary source and facility permitting. The districts administer air quality improvement grant programs and are CARB's primary partners in efforts to ensure that all Californians breathe clean air.[10] BCAG is part of the Butte County Air Quality Management District.

Transit Agency's Air Basin: Butte County Air Quality Management District is part of Sacramento Valley Air Basin District.[11]

Total number of buses in Annual Maximum Service: The maximum number of active buses operating fixed-route service out of the Butte Regional Operations Center is 32. B-Line also operates 22 gas cutaway vehicles in support of dial-a ride and paratransit service.

Urbanized Area: Chico, CA. Chico is 28 square miles of land area with 2,161 people per square mile living within that area. Chico is the metropolitan center of the county. The current population of the Chico Urbanized Area is approximately 101,475 and the population of Butte County is approximately 211,632. Before the Camp Fire, the Chico Urbanized Area had a population of approximately 104,538 residents and the total population of Butte County was approximately 223,877.

Population of Urbanized Area: 101,475

Approximately 211,632 people live in Butte County, California. Butte's southern border is located about 50 miles north of Sacramento. The total area of the county is 1,665 square miles. Most of this land area is sparsely populated, at an average of 124 people per square mile. There are four main population centers located around the county. These are the cities of Oroville and Gridley/ Biggs in the south and Chico and Paradise in the north. The city of Chico is home to 101,475 residents. This number represents nearly half of the county's entire population. The greater Oroville area is home to about 20,042 people and the town of Paradise is home to about 27,000 people. There are approximately 7,421 persons living in Gridley and 1,799 living in neighboring Biggs. The remainder of Butte's population is spread out around other rural areas. Chico is the only population cluster in Butte County that falls under the U.S. Census classification of urban. Oroville, Paradise,

[10] https://ww2.arb.ca.gov/california-air-districts

[11] https://www.airquality.org/Meetings/Sacramento-Valley-Basinwide-Air-Pollution-Control-Council

Gridley, Biggs, and other unincorporated county areas are all classified as rural (April 1, 2020 U.S. Census Bureau).

Contact information Deputy Director:

Andy Newsum, Deputy Director, Butte County Association of Governments
326 Huss Drive, Suite 150
Chico, CA 95928
Tel: (530) 809-4616
ANewsum@bcag.org

Is your transit agency part of a Joint Group? No

Fleet Facility

BCAG/B-Line currently has one maintenance facility, located at 326 Huss Ln, Chico, CA 95928 as shown in **Figure 5.**

Figure 5 - Butte Regional Operations Center

California Air Resources Board Innovative Clean Transit Regulation

On December 14, 2018, California Air Resources Board (CARB) enacted the Innovative Clean Transit (ICT) regulation, requiring all California public transit agencies to create a plan to achieve a 100% zero-emission fleet by 2040. In April 2021, BCAG entered into contract with the Center for Transportation and the Environment (CTE) to conduct a full fleet ZEB Transition Plan in accordance with the California Air Resources Board's (CARB) Innovative Clean Transit (ICT) program. The project includes operational and technical analysis to support BCAG through the creation of a zero-emission transition plan.

The zero-emission technologies considered in this study 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 gaseous hydrogen, stored in tanks, is converted to electricity within a fuel cell. The electricity from the fuel cell is used to recharge the batteries.

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 agencies to a 100% ZEB fleet by 2040.

CARB designates B-Line's fleet 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 3.**

Table 3 - CARB ICT ZEB Transition Timeline for Small Agencies

Starting January 1	Percent 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 has passed Altoona testing (GreenPower's EV Star) but CARB has not revised its regulation regarding cutaway buses, noting that the vehicle that has passed is too small to meet the requirements of many cutaway vehicles.

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 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.

BCAG's ZEB Credits

ZEBs that are purchased ahead of mandated deadlines can be submitted to CARB when the deadlines come into effect. The agency is able to submit any combination of new ZEBs and ZEBs already in the fleet in order to meet the required purchase percentage. All buses already in the fleet can only be used once to offset one single bus purchase. BCAG plans to procure up to eight BEBs that will enter into service beginning in 2023. BCAG plans to submit two of these buses that will already be in the fleet prior to 2026 to offset the 25% ZEB purchase requirement in 2027.

ZEB Rollout Plan

BCAG is required to submit a ZEB Rollout Plan to CARB that has been approved by their governing body by July 1, 2023. Per CARB regulations, Rollout Plans must include all of the following components:

- A goal of full transition to ZEBs by 2040 with careful planning that avoids early retirement of conventional internal combustion engine (ICE) buses;
- Identification of the types of ZEB technologies a transit agency is planning to deploy, such as battery-electric or fuel cell electric buses;
- A schedule for construction of facilities, infrastructure modifications, or upgrades including charging, fueling, and maintenance facilities to deploy and maintain ZEBs. This schedule must specify the general location of each facility, type of infrastructure, service capacity of an infrastructure, and a timeline for construction;
- A schedule for zero-emission and conventional ICE bus purchases and lease options. This schedule for bus purchase replacements must identify the bus types, fuel types, and number of buses;
- A schedule for conversion of conventional ICE buses to ZEBs, if any. This schedule for bus conversion must identify number of buses, bus types, the propulsion systems being removed and converted to;
- A description on how a transit agency plans to deploy ZEBs in disadvantaged communities as listed in the latest version of CalEnviroScreen at the time the Rollout Plan is submitted;
- A training plan and schedule for ZEB operators and maintenance and repair staff;
- The identification of potential funding sources.

Findings outlined in this Master Plan are intended to inform BCAG in selecting a scenario to put forward in the ICT Rollout Plan that will be submitted to CARB.

Reporting Requirements

Starting March 31, 2021, and continuing every year thereafter through March 31, 2050, each transit agency must submit an annual ICT ZEB compliance report by March 31 for the prior calendar year. The initial report was to have been submitted by March 31, 2021 and must have included the number and information of active buses in the transit agency's fleet as of December 31, 2018.

Assessment Scenarios

For this study, CTE developed 4 scenarios to compare to a baseline scenario and analyze the feasibility and cost effectiveness of implementing each bus technology as well as co-implementation of both technologies. The scenarios are referred to by the following titles and described, in detail, below. A baseline scenario was developed to represent the typical "business-as-usual" case with retention of ICE buses for cost comparison purposes.

0. Baseline (current technology)
1. BEB Only

2a. Mixed Fleet - BEB Majority
2b. Mixed Fleet - FCEB Majority
3. FCEB Only

In the **BEB with Depot-Only Charging** scenario, BEBs are purchased and deployed only on blocks that are within a BEB's achievable range as determined by CTE's modeling. If depot-charged BEBs are not capable of meeting a transit agency's daily service requirements, there is an exception in the ICT regulation that will allow the agency to request an exemption to retain ICE buses in their fleet. Based on CTE's modeling, all of B-Line's blocks are fully achievable using BEB technology by 2035.

In the **Mixed Fleet – BEB Majority – (75% BEB) scenario**, FCEBs supplement a primarily BEB fleet to make up a fully ZEB fleet. The costs for infrastructure and installation of two different charging and fueling infrastructures are taken into account. FCEBs and hydrogen fuel, however, are more expensive than BEBs and electricity, so this scenario allows BCAG to assign the less expensive BEB technology where possible and supplement service with FCEBs as needed in support of resilience and redundancy adaption measures.

A **Mixed Fleet – FCEB Majority (75% FCEB) scenario** BEBs supplement a primarily FCEB fleet to make up a fully ZEB fleet. The costs for infrastructure and installation of two different charging and fueling infrastructures are taken into account. Based on CTE's modeling, all of B-Line's blocks are fully achievable using BEB technology by 2035, however, the range of FCEBs already currently exceed that of BEBs. This assessment therefore considers FCEBs capable of replacing diesel buses at a 1:1 ratio and allows B-Line the flexibility to operate the FCEBs in any of its blocks. In turn, blocking assignments are a key consideration for BEBs, particularly for those that are purchased prior to 2035. Overall, a mixed fleet is more resilient as it would allow service to continue if either fuel became temporarily unavailable for any reason.

Finally, the **FCEB Only scenario** was developed to examine the costs for hydrogen fueling and transitioning to a 100% FCEB fleet. A fully FCEB fleet avoids the need to install two types of fueling infrastructure by eliminating the need for depot charging equipment. Fleets comprised entirely of fuel cell electric buses also offer the benefit of scalability compared to battery electric technologies. Adding FCEBs to a fleet does not necessitate large complementary infrastructure upgrades. Despite this benefit, the cost of FCEBs and hydrogen fuel are still more expensive than BEBs and electricity at current market prices.

When considering the various scenarios, this study can be used to develop an understanding of the range of costs that may be expected for BCAG's ZEB transition, but ultimately, can only provide an estimate. Furthermore, this study aims to provide an overview of the myriad considerations the agency must take into account in selecting a transition scenario that go beyond cost, such as space requirements, safety implications, and operational changes that may differ between scenarios.

Terms and Definitions

- "Fuel" and "energy" are used interchangeably in this report, as ZEB technologies do not always require traditional liquid fuel. In the case of BEBs, "fuel" is electricity and costs include energy, demand, and other utility charges.
- The transition period is defined as achieving 100% ZEB fleet purchasing by 2040 to comply with the CARB ICT regulation.

Assessment Assumptions

This transition study uses multiple assumptions to model B-Line's long-term fleet transition. The overarching assumptions are:

- Heavy-duty large buses have a normal service life of 12 years.[12]
    - This assumption follows the Federal Transit Administration's (FTA's) definition of vehicle useful life of 12 years as its retirement policy for their standard bus sizes.
- BEBs are modeled to have a battery capacity of 440 kWh (35' & 40'). FCEBs have fuel tank capacity of 40kg (35' & 40').
    - These figures are based on the average of the bus manufacturers' specifications for the model compared with the Altoona Bus Testing and Research Center's bus report at the time of analysis.[13]
- Electric cutaways are modeled to have a battery capacity of 110 kWh. Since a commercially available fuel cell electric cutaway is not yet available, it was assumed that the capacity would be specified in BCAG's RFP to be 13kg.
- A 5% improvement in battery capacity occurs every two years, with a cap at 733 kWh.
    - For this study, considering the extended period of a complete fleet transition through 2040, CTE assumes a conservative 5% improvement of battery capacity every two years[14]. If the trend continues, buses will continue to

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[12] Federal Transit Administration, "Useful Life of Transit Buses and Vans". U.S. Department of Transportation. Retrieved on May 5, 2021, from https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/Useful_Life_of_Buses_Final_Report_4-26-07_rv1.pdf

[13] Altoona Bus Research and Testing Center, Bus Tests. Penn State College of Engineering. Retrieved on May 5, 2021, from https://www.altoonabustest.psu.edu/bus-tests/index.aspx

[14] BloombergNEF, "Hitting the EV Inflection Point". Bloomberg Finance L.P.2021. Retrieved on December 5, 2021, from https://www.transportenvironment.org/wp-content/uploads/2021/08/2021_05_05_Electric_vehicle_price_parity_and_adoption_in_Europe_Final.pdf

increase the amount of energy they carry on-board without added onboard battery storage or reduction in passenger capacity.

- CTE calculated a reasonable cap on the maximum battery capacity range based on the current (2021) top of the market nameplate capacity of 686 kWh, current battery capacity improvement rates, and physical limitations of bus designs. This cap was calculated at 733 kWh and is expected to be reached by 2032.

- A 5% improvement in hydrogen tank size occurs every two years.
  - This serves as a proxy for other component improvements such as battery capacity, motor efficiency, and fuel cell efficiency.
- FCEBs can more readily replace ICE buses one-for-one.
  - Alameda-Contra Costa Transit District (AC Transit) and OCTA have reported operational ranges for FCEBs up to 350 miles.

ZEB Transition Planning Methodology

This study uses CTE's ZEB Transition Planning Methodology. The methodology encompasses nine key phases; these stages are sequential and build upon findings in previous steps. The phases specific to this study are outlined below:

0. Planning & Initiation
1. Requirements & Data Collection
2. Service Assessment
3. Fleet Assessment
4. Fuel Assessment
5. Facilities Assessment
6. Maintenance Assessment
7. Total Cost of Ownership Assessment
8. ZEB Transition Plan – Document Creation

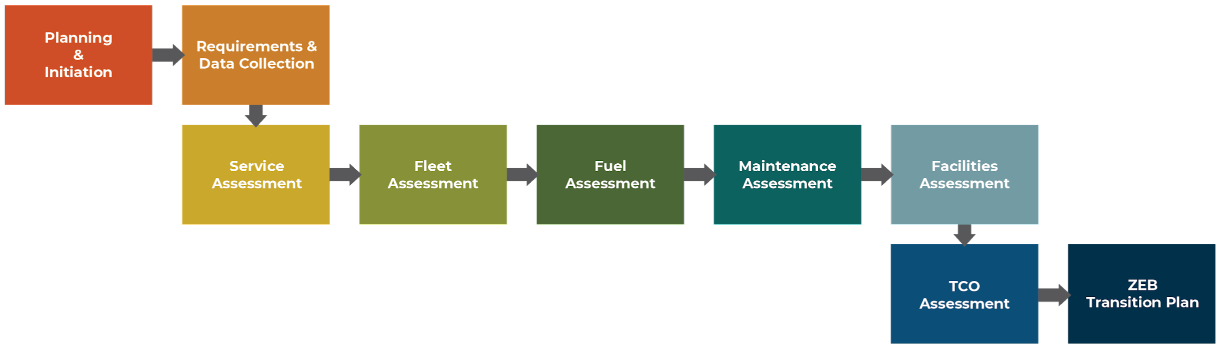


Figure 6: CTE's ZEB Transition Study Methodology

The **PLANNING & INITIATION** phase builds the administrative framework for the transition study. During this phase, the project team drafts the scope, approach, tasks, assignments and timeline for the project. CTE worked with BCAG staff to plan the overall project scope and all deliverables throughout the full life of the study.

For the **REQUIREMENTS & DATA COLLECTION**, CTE collects GPS data on selected routes and utilizes software models to estimate ZEB performance. The results from this modeling are used to estimate feasibility of every block in B-Line's network using BEBs and FCEBs.

The **SERVICE ASSESSMENT** phase initiates the technical analysis of the study. The results from the Service Assessment are used to guide ZEB procurements in the Fleet Assessment and to determine energy requirements (depot charging and/or hydrogen) in the Fuel Assessment. CTE met with BCAG to define assumptions and requirements used throughout the study and to collect operational data. This process was conducted for both the fixed service blocks and the paratransit cutaway fleet. Since the paratransit fleet was also expending a significant amount of energy idling, CTE also conducted an Endurance Analysis, which brought the energy requirements of the HVAC while idling into consideration for determining the range of these vehicles. The results found that idling would have a significant detrimental impact on cutaway range. BCAG elected not to pursue electric cutaways further in the analysis, but were interested in seeing fuel cell cutaways being introduced to makeup 20% of the cutaway fleet in 2030 in the Fleet Assessment.

The **FLEET ASSESSMENT** develops a projected timeline for replacement of ICE buses with ZEBs that is consistent with the agency's fleet replacement plan based on results from the Service Assessment. Since B-Line's blocking was determined to be achievable with BEBs, the mixed fleet scenarios were defined based on composition percentages that would allow for BCAG to explore the impacts of a majority FCEB, majority BEB fleet, and an all FCEB fleet on bus capital, fuel and infrastructure costs. This analysis included an outline of the expected fleet structure and capital costs expected over the transition period for all scenarios explored and how they can be best optimized with regard to any state mandates, such as CARB's ICT regulation, or to meet agency goals, such as minimizing cost or maximizing service levels.

The **FUEL ASSESSMENT** merges the results of the Service Assessment and Fleet Assessment to determine annual fuel requirements and associated costs. The Fuel Assessment calculates energy costs throughout the entire transition timeline for each scenario, including the agency's current ICE buses. As current technologies are phased out in later years of the transition, the Fuel Assessment calculates the increasing energy requirements for ZEBs. The Fuel Assessment also provides a total energy cost over the transition lifetime.

The **FACILITIES ASSESSMENT** determines the necessary infrastructure to support the projected zero-emission fleet based on results from the Fleet Assessment and Fuel Assessment. The Facilities Assessment is calculated for each scenario used in the Fleet and Fuel Assessments. The assessment determines the required hydrogen and battery-electric infrastructure and calculates associated costs.

The **REDUNDANCY, RESILIENCE, AND EMERGENCY RESPONSE (3R) ASSESSMENT** investigates the new risks to an agency's ability to provide service during power outages or fuel disruptions, and to support required emergency response activities, such as community evacuation with a full ZEB fleet. The outcomes of the 3R assessment are a summary of the risk reduction capabilities and cost effectiveness of recommendation of alternatives to mitigate the impacts from identified risks specific to an agency's risk tolerances, facility constraints, and budget.

The **MAINTENANCE ASSESSMENT** calculates all projected fleet maintenance costs over the life of the project. These costs include those related to existing ICE buses remaining in the fleet, as well as new cutaways, BEBs and FCEBs, calculated for each scenario.

The **TOTAL COST OF OWNERSHIP ASSESSMENT** compiles results from the previous assessments and provides a comprehensive view of all associated costs, organized by scenario, over the transition lifetime.

Requirements Analysis

Baseline Data Collection

Understanding the key elements of B-Line's service is essential to evaluating the costs of a complete transition to a zero-emission fleet. BCAG staff provided key data on current B-Line service including:

- Current fleet composition including vehicle propulsion types and lengths
- Route and block information including distances and trip frequency
- Mileage and fuel consumption
- Maintenance costs

CTE prepared the templates for BCAG's ZEB Transition data collection and the BCAG Agency Data Collection Template was prepared and distributed to the agency to begin the **Requirements Analysis & Data Collection** stage of the project. As part of this effort, CTE travelled to Chico to ride identified sample routes and collect GPS data. CTE and BCAG also decided that because paratransit service makes up a large percentage of BCAG's service, CTE should include these cutaways as part of the modeling for the ZEB Transition Plan assessment, although it was not required by the ICT regulation since there is not currently an Altoona tested zero-emission paratransit vehicle that can operate this service. For this purpose, GPS data was also collected for a full day of paratransit service. CTE also met internally to discuss the best approach for conducting the analysis of these service vehicles for the purposes of ZEV transition planning.

Fleet Composition

In May 2021, the B-Line bus fleet included 2 CNG buses and 30 diesel buses used for fixed route service, and 22 gasoline powered cutaways used for paratransit service. A summary of the 2022 fleet by vehicle size, fuel type, and bus length is shown in **Table 4**. Bus services operate out of one depot in Chico, CA. Operations, maintenance, and fueling functions are performed at the depot. B-Line's current service consists of 21 fixed routes run on 57 blocks.

Table 4 - Fleet Summary by Depot, Length, and Fuel Type

Depot	Bus Length	Fuel Type			
		CNG	Diesel	Gasoline	Total
	Cutaway (28')			22	22
Huss Drive	35'		11		11
	40'	2	19		21
	Total	2	30	22	54

Planned Procurement

In planning B-Line's replacement schedule, CTE documented and integrated BCAG's in-progress procurements. BCAG has already been awarded and allotted funding for up to 8 BEBs that will be in service by the end of 2024. However, at the time of this report, only five BEBs were expected. These five, as well as the additional procurement are outlined in **Table 5** below.

Table 5 - Known Procurements

Purchase Year	First Service Year	Fuel Type	Number of Buses	Series Being Replaced
2022	2023	BEB	6	081,082, 1101, 1103-1106

Miles and Fuel Consumption

Data on B-Line's current fuel use is used to estimate energy costs throughout the transition period. This study assumes no cost escalation for fuel throughout the transition period. Average annual fleet mileage and fuel use are shown in **Table 6** and **Table 7.**

Table 6 - Average Annual Service Miles by Bus Length

Average Annual Miles per Bus				
Fuel Type / Length	**CNG**	**Diesel**	**Gasoline**	**Total Average**
Cutaway 28'			20,368	20,368
35'		39,617		39,617
40'	40,509	49,316		48,477

Table 7 - Total Average Annual Diesel Consumption by Bus Length

Bus Length	Total Average of Annual Fuel Use (Diesel Gallon Equivalent DGE)
Cutaway 28'	80,190
Diesel 35'	92,979
Diesel 40'	154,137
CNG 40'	9,826
Total Average	67,427

Service Assessment

The **SERVICE ASSESSMENT** analyzes the feasibility of maintaining B-Line's current level of service with BEB and FCEB buses. The key component of the Service Assessment is the Block Analysis, which analyzes bus range limitations to determine if ZEBs can meet the service requirements of the blocks within the transition period. The energy needed to complete a block is compared to the available energy for the prospective bus type that is planned for the block. If the prospective bus's available energy exceeds the block's required energy, then that block is considered feasible for that ZEB type. The Service Assessment also yields a timeline for when blocks become achievable for zero-emission buses as technology improves. This information is used to then inform ZEB procurements in the Fleet Assessment.

Bus efficiency and range are primarily driven by bus specifications; however, both 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 (i.e., passenger loads and auxiliary loads). As such, the efficiency and range of a given ZEB model can vary dramatically from one agency to another. Therefore, it is critical to determine efficiency and range estimates that are based on an accurate representation of B-Line's operating conditions.

The first task in the Service Assessment is to develop route and bus models to run operating simulations for typical B-Line routes. In order to accomplish this, the efficiency values that were obtained through modeling based on the collected GPS data of B-Line's routes were used to determine the amount of energy required for each of B-Line's blocks. The Service Assessment determines the percentage of the agency's blocks that will be achievable in a given year considering the energy demand of the blocks and the battery capacity of the buses (for 35' and 40') with an assumed battery capacity improvement factor of 5% every year. This improvement in battery capacity increases the estimated range of the buses over time, which gradually increases the percentage of blocks that are achievable by 2040. This process was conducted for both the fixed service blocks and the paratransit cutaway fleet.

CTE obtained this data for routes 3, 5, 16, 20, 30, and 41. A full day of B-Line's paratransit service was also sampled. CTE uses a sampling approach for gathering data on an agency's service in which representative sample routes are identified based on topography and average speed characteristics. CTE collected GPS data—which includes time, distance, bus speed, bus acceleration, GPS coordinates, and roadway grade—from 6 B-Line routes that were identified with the sampling approach, which are included in **Table 8** below.

CTE modeled B-Line's route and the vehicle energy demand to predict to predict which of B-Line's blocks can feasibly be transitioned to ZEB technology and when. By 2035, CTE's modeling predicts that a market representative BEB will be able to complete 100% of the B-Line blocks under strenuous driving conditions.

Table 8 - Selected Routes for Modeling

Route ID	Route Description	Route Mileage (Round Trip - miles)	Route Category (Speed, Topography)
3	Nord/East	10.88	Flat, Low Speed
5	East 8th	14.1	Flat, Low Speed
16	Esplanade/SR99	13.54	Flat, Low Speed
20	Chico - Oroville	52.26	Flat, High Speed
30	Oroville – Biggs	51.41	Flat, High Speed
41	Magalia - Chico	51.25	Hills, Low Speed

CTE used component-level specifications for a generic electric bus and B-Line sample route data to develop a baseline performance model by simulating the operation of an electric bus on each route in Autonomie. Autonomie is a powertrain simulation software program developed by Argonne National Labs for the heavy-duty trucking and automotive industry. CTE has modified software parameters in Autonomie to assess energy efficiencies, energy consumption, and range projections for ZEBs. The energy requirements of the sample routes were then applied to all routes and blocks that share the same characteristics as the sampled routes.

The **ROUTE MODELING** analyzes varying passenger loads, accessory loads, and battery degradation to estimate real-world bus performance, fuel efficiency, and range. The GPS data from routes and the specifications for each of the bus models are used to simulate operation on each type of route. The models were run under nominal and strenuous load conditions.

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. **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. 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) shown in **Table 9** below. The projected nominal and strenuous efficiencies were then used to predict if the ZEB technology will be able to complete all blocks under various battery capacity assumptions and in subsequent assessments.

Table 9 - Modeling Results Summary

Route/Bus Length	Nominal Efficiency (kwh/mi)	Strenuous Efficiency (kWh/mi)
2	1.9	2.5
3	1.9	2.5
4	1.9	2.5
5	1.7	2.2
7	1.9	2.5
8	1.9	2.5
9	1.9	2.5
14	1.9	2.5
15	1.9	2.5
16	2.0	2.8
17	1.9	2.5
20	2.4	2.7
24	1.9	2.5
25	1.9	2.5
26	1.9	2.5
27	1.9	2.5
30	1.7	2.0
32	2.0	2.4
40	1.8	2.2
41	1.8	2.2
52	1.9	2.5

Cutaway Modeling

CTE's modeling also included an analysis for battery electric cutaway vehicles using B-Line's paratransit drive cycles. CTE found that the power limitations of the battery electric cutaway motor may only be able to meet 8 to 9% of B-Line's paratransit annual service. By 2025, 16.4% of B-Line's paratransit annual service would be considered feasible and by

2030, an electric cutaway vehicle is projected to be able to complete about half of their annual service.

Since the paratransit fleet also expends significant amount of energy idling, CTE conducted an Endurance Analysis, which brought the energy requirements of the HVAC while idling into consideration for determining the range of these vehicles. Endurance may be more representative of the paratransit duty cycle as it accounts for idling energy during breaks, loading, or pauses in service along with miles traveled. Taking into account endurance, by 2025, only 4.4% of B-Line's paratransit annual service would be considered feasible. The results found that idling would have a significant detrimental impact on cutaway range.

Based on these results, BCAG opted to refrain from applying a full zero-emission transition plan to their paratransit cutaway fleet in this current scope. BCAG, however, requested CTE to introduce fuel cell electric cutaways in future procurement cycles with the goal of transitioning up to 20% of their paratransit fleet composition from gasoline to fuel cell starting in 2030. BCAG may need to submit a request for exemption from the zero-emission bus purchase requirements in section 2023.1(c).

The **BLOCK ANALYSIS**, using the assumed 5% improvement in battery capacity or hydrogen storage capacity every two years, determines the timeline for when routes and blocks become achievable for BEBs and FCEBs. This information is used to inform ZEB procurement projections in the Fleet Assessment. Overall, the block analysis helps to determine when, or if, a full transition to ZEBs may be feasible and when there are requirements for supplemental energy solutions. Results from this analysis are also used to determine the specific energy requirements and develop the estimated costs to operate the ZEBs in the Fuel Assessment. Results from the block analysis for BEBs are included **Figure 7** below.

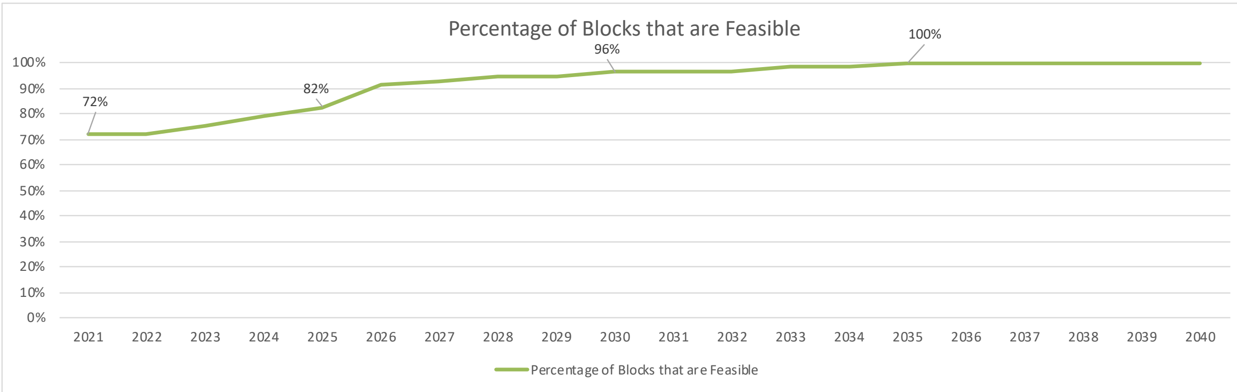


Figure 7: BEB Block Feasibility Percentage by Year

The BEB feasibility shows that, by 2035, 100% of B-Line's blocks can be completed under normal driving conditions when operating with a 450-kWh usable battery capacity with 5% improvement every two years capped at 733 kWh for 35-foot and 40-foot BEBs. As covered in the **Introduction** of this report, this analysis assumes the following:

- FCEBs can complete any block under 350 total miles and therefore all blocks are achievable with FCEBs throughout the transition period.
- B-Line will maintain service to similar destinations within the region and therefore the blocks maintain a similar distribution of distance, relative speeds, and elevation changes throughout the transition period. This core assumption affects energy use estimates and block feasibility in each year.

Another factor affecting block feasibility is battery degradation. BEB range is negatively impacted by battery degradation over time. A BEB placed in service on a given block with beginning-of-life batteries may not be able to complete the entire block at some point during its life before the batteries reach end-of-life. End-of-life is typically defined as when batteries reach 80% of available service energy. Conceptually, older buses can be moved to shorter, less demanding blocks and newer buses can be assigned to longer, more demanding blocks. B-Line can rotate the fleet to meet service energy demand, assuming there is a steady procurement of BEBs to match service requirements.

Considerations for Block Analysis

With a 660kWh battery (the largest on the market), only three blocks are not feasible (95% feasibility). A zero-emission fleet could be achieved sooner with other ZEB technology solutions. However, the assumption of 5% battery capacity improvement per year may not prove out in market as forecasted. Additionally, hydrogen fuel may become more accessible in cost and distribution.

Fleet Assessment

The goal of the FLEET ASSESSMENT is to determine what type of ZEB technology solutions are required to transition an entire fleet to zero-emission vehicles. Results from the Service Assessment are integrated with B-Line's current fleet replacement plan and purchase schedule to produce two main outputs: 1) a projected bus replacement timeline through the end of the transition period and 2) the total capital costs of those replacements. Throughout the assessment, the projected bus procurement plan is referred to. It is important to note that this is referencing the projected bus procurement at the time that CTE's assessment began in May of 2021, which only included two BEBs that would be in service by 2023, rather than the updated procurement plan that includes 6 to 8.

For this effort, the Service Assessment was used to inform the percentage of buses that could be transitioned to BEBs in a given year during the transition. Since B-Line's blocking was determined to be achievable with BEBs, the mixed fleet scenarios were defined based on composition percentages that would allow for BCAG to explore the impacts of a majority FCEB and a majority BEB fleet on bus capital, fuel and infrastructure costs. An all FCEB fleet will also be explored. This analysis included an outline of the expected fleet structure and capital costs expected over the transition period for all of the scenarios explored.

Cost Assumptions

CTE and BCAG developed cost assumptions for each bus length and technology type (e.g., CNG, gasoline, BEB, FCEB). Key assumptions for bus costs for the BCAG ZEB Transition Plan Study are as follows:

- The base price for the gasoline-powered cutaway, CNG bus, and diesel bus are based on BCAG's reported purchase price of existing fleet inclusive of options and taxes.
- The base price for the Battery Electric 35'/40' and Fuel Cell Electric 35'/40' are from the 2019 CA State Contract Bus Pricing Report adjusted annually at the PPI rate and inclusive of tax.
    - The Battery Electric 35'/40' prices include $50K for extended battery warranty & $120K for configurable options
    - The Fuel Cell Electric 35'/40' prices include $11k for extended fuel cell battery warranty & for $120K configurable options
- The Electric Cutaway price is based on the CA State Contract and also includes $50K for extended battery warranty & $75K for configurable options.
- The Fuel Cell Cutaway price is based on the battery-electric cutaway price + $100,000 for fuel cell components (based on comparable costs for fuel cell trucks)

and also includes $11k for extended fuel cell battery warranty & $75K for configurable options.

- The local sales tax (7.25%) is applied to the base price.
- The nominal cost of the bus capital remains level over the ZEB transition period.

For bus lengths that are not currently available in the market for a specific technology the costs in **Table 10** were used. The price for a 40’ bus was used as an estimate for a 35’ FCEB.

Table 10 - Fleet Assessment Cost Assumption

Fuel Type					
Length	CNG	Gas	Diesel	Electric	Fuel Cell
Cutaway	NA	$70,000	NA	$381,000	$446,000*
35'	NA	NA	$575,000	$967,000	$1,262,000*
40'	$399,000	NA	$600,000	$978,000	$1,262,000

*Bus size not currently available for this technology

Baseline Scenario

In the Baseline scenario, BCAG continues to replace retired buses at the end of their useful life, with vehicles of the same fuel type and length as currently operates in its 2021 fleet. The exceptions to this replacement strategy are the BEBs that BCAG is already in the process of procuring. As previously noted, six BEBs are expected to be purchased in 2022 and put into service in 2023 although only two are currently shown in the graphs below since the purchasing plan changed after CTE conducted the transition plan analysis. These vehicles were included in the Baseline since they are agnostic to the full fleet transition and will not influence scenario selection. This scenario illustrates the costs that BCAG would expect over the 20-year period if it maintained its current fleet composition including the BEBs that are part of the agency’s near-term procurement plans.

Figure 8 shows the number of diesel buses and BEBs that would be purchased each year through 2040 in this scenario. As of May 2021, the bus fleet consists of 32 fixed route buses: 30 diesel buses and 2 CNG buses. Their paratransit fleet consists of 22 gasoline-powered cutaway vehicles (28-feet). The baseline also includes BCAG’s previous known procurements of 2 BEBs in 2022 and 3 more in 2024, which will phase out the last of their

CNG buses. The analysis and figures were based on the procurement plans that were available at the time, and have not been updated to take into account the revised bus procurement schedule, which will have six BEBs in service by 2023.

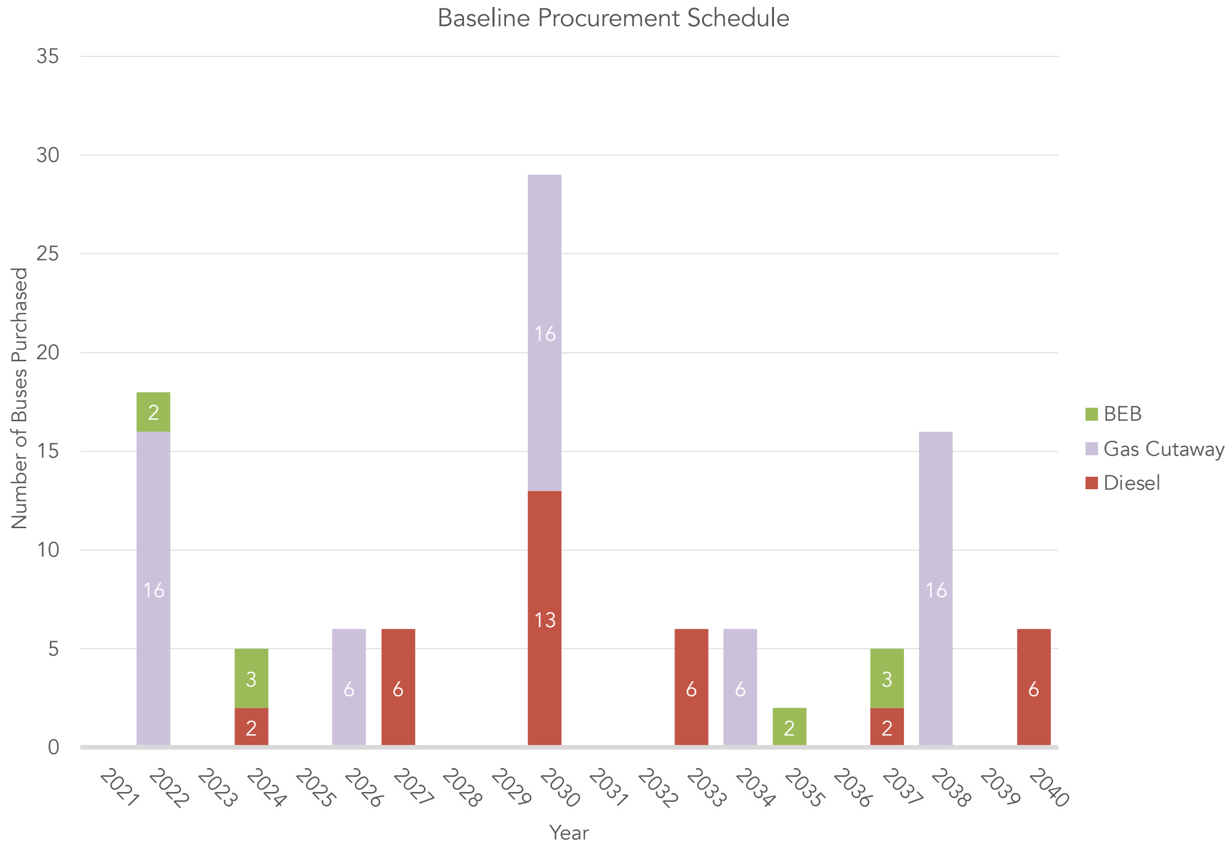


Figure 8 - Projected Bus Purchases, Baseline Scenario

Figure 9 depicts the annual fleet composition through 2040 for the Baseline scenario; the fleet remains composed of primarily diesel over the 20-year period. Note that the CNG buses are scheduled to be replaced with BEB buses in 2022, which is why they are represented in the annual fleet composition for 2021 only. As noted previously, this and the following charts have not been updated with the revised BEB procurement schedule.

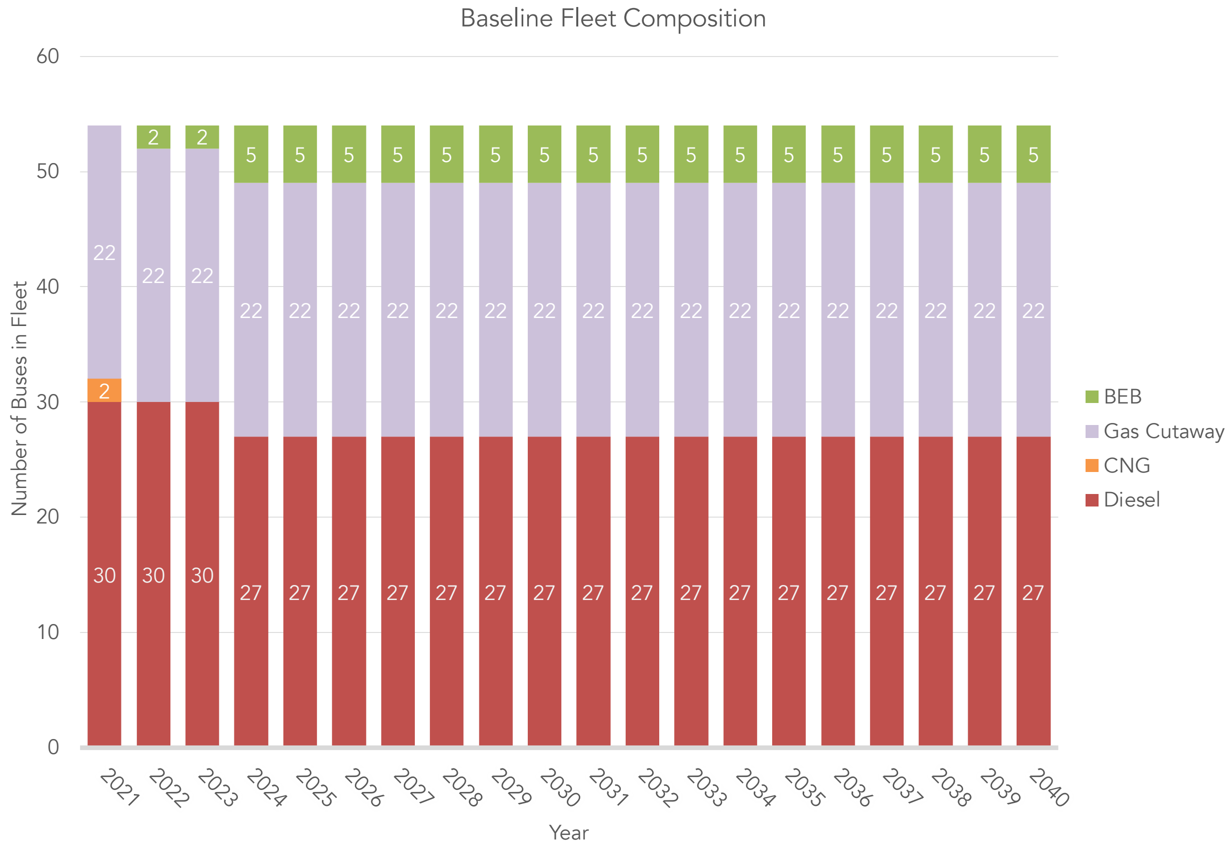


Figure 9 - Annual Fleet Composition, Baseline Scenario

Figure 10 shows the annual total bus capital costs for the diesel and battery electric buses purchased in each year in the Baseline scenario that corresponds with the procurement schedule outlined in **Figure 8** that reflects the planned purchases as of 2021.

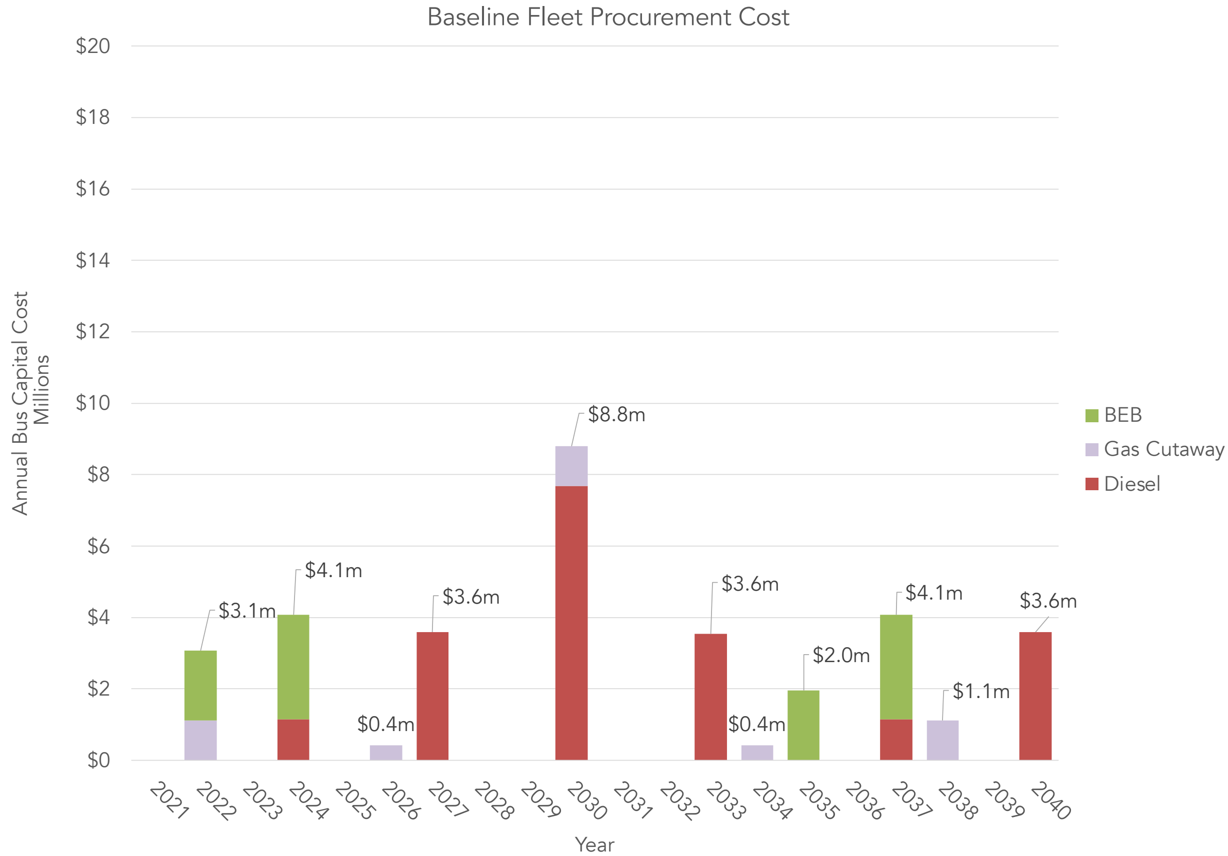


Figure 10 - Annual Capital Costs, Baseline Scenario

BEB Only Scenario

In the BEB Only scenario, BEBs are purchased and deployed only on blocks that are within a BEB's achievable range as determined by CTE's modeling. As discussed, according to CTE's modeling, all of B-Line's fixed route service is feasible with depot-only charged BEBs by 2035 therefore an on-route charging scenario was not explored in this study. Based on CTE's modeling, battery-electric cutaways were determined to lack the range required to support B-Line's paratransit and dial-a-ride service requirements, so cutaways were assumed to remain gas for the time being, but BCAG will continue to monitor improvements in this technology and will re-assess this decision when an Altoona tested cutaway's battery capacity approaches BCAG's requirements. This scenario assumes that BCAG will be in compliance with the 25% ZEB purchase requirement starting on January 1st, 2026 after purchasing six BEBs that are included in their procurement schedule from 2021 to 2025, which will be eligible for submittal in 2027 to meet the purchasing requirement and allow BCAG to offset the purchase requirement in that year.

Figure 11 depicts the number of buses by type that are scheduled to be purchased per year (as of the 2021 procurement schedule) in the BEB Only scenario. In this scenario, 2 BEBs are introduced in 2022, 3 BEBs in 2024, 13 BEBs in 2030, 6 BEBs in 2033, 2 BEBs in 2037, and 6 BEBs in 2040.

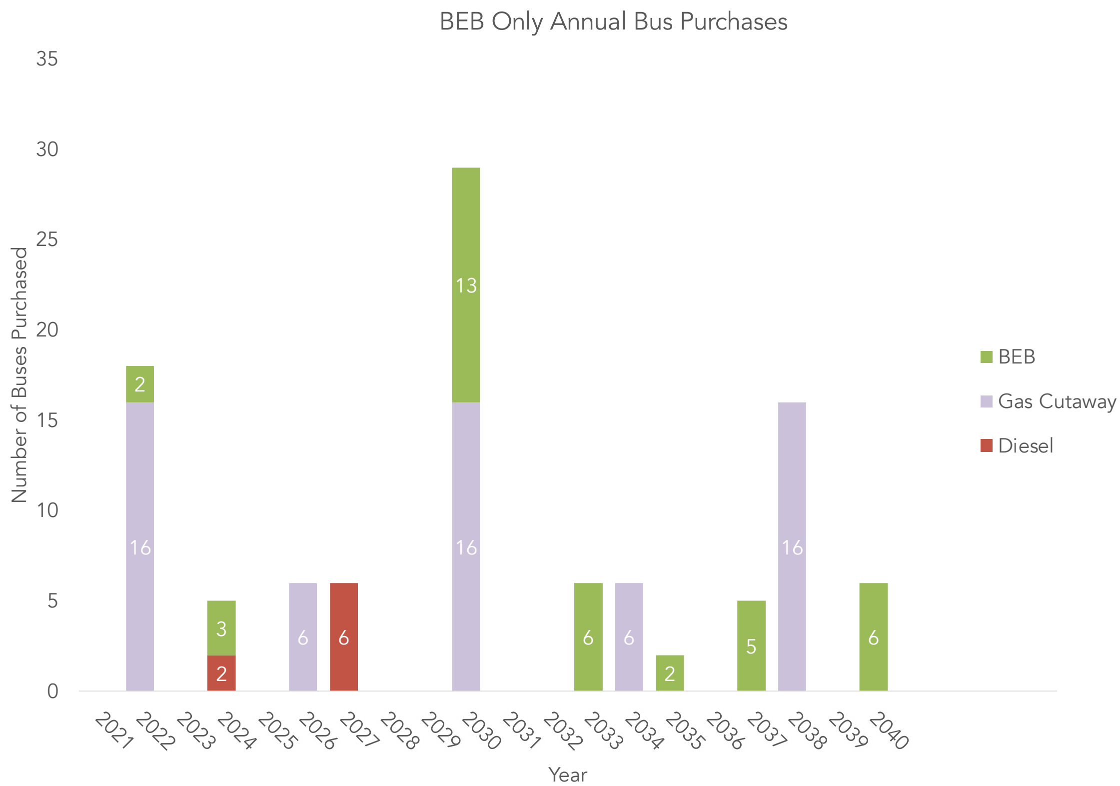


Figure 11 - Projected Bus Purchases, BEB Only Scenario

Figure 12 shows the fleet composition year-by-year that results from the procurement schedule shown above. Diesel buses will remain in B-Line's fleet until 2039 since BCAG will purchase diesel buses until 2030 in favor of reserving ZEB purchases later in the timeline for improved technology. As previously discussed, BCAG has the opportunity to request waivers if zero-emission technology has not matured enough to meet all service requirements. Since battery-electric cutaways were assessed to have insufficient range to meet B-Line's non-fixed-route service, B-Line does not plan to convert their cutaway fleet to this zero-emission technology at this time.

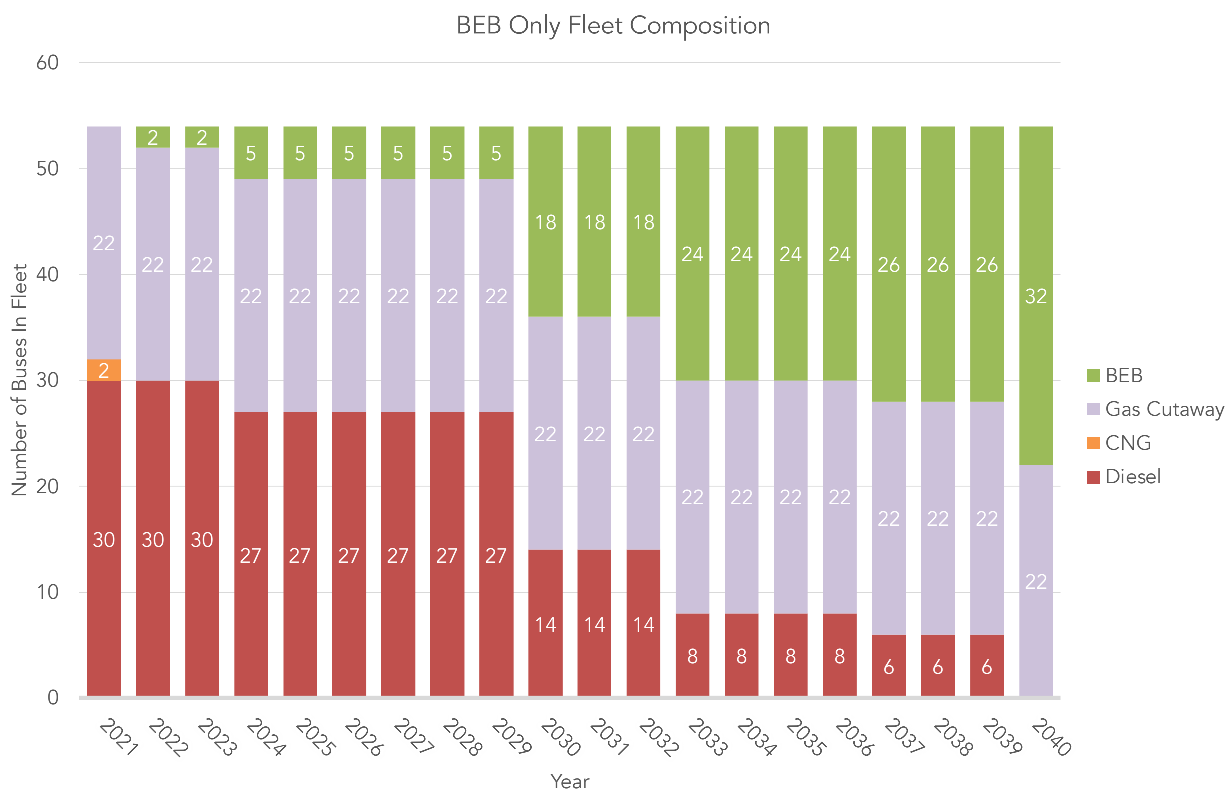


Figure 12 - Annual Fleet Composition, BEB Only Scenario

Figure 13 shows the annual total bus capital costs for the diesel and battery electric buses purchased in each year in the BEB Depot-Only scenario. 2030 is a major purchase year, with 13 BEBs expected for purchase for an estimated $13.8 million.

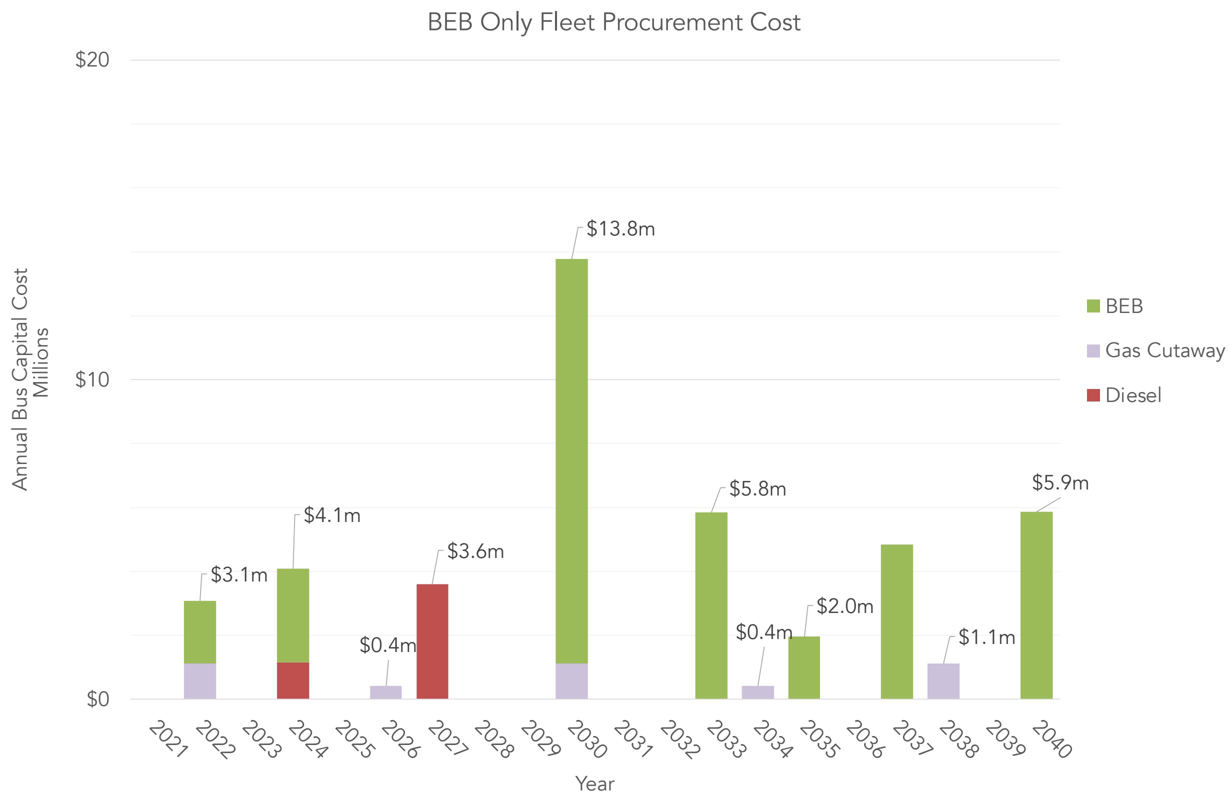


Figure 13 - Annual Capital Costs, BEB Only Scenario

Mixed Fleet – BEB Majority Scenario

Two Mixed Fleet (BEB and FCEB) scenarios were developed to review the costs and benefits associated with a mixed fleet. While BEB technology can complete all of B-Line's existing routes, BCAG prioritizes redundancy and resilience given their service plan covers areas that have recently been affected by fires and flooding. A mixed fleet that includes different technology and fuel is more resilient as it would allow service to continue if either fuel became temporarily unavailable for any reason. A BEB Majority Mixed Fleet Scenario was developed to explore the pros and cons of a mixed fleet that is 75% BEB, 25% FCEB. In this scenario, BCAG also elected to transition 20% of their cutaway fleet to zero-emission fuel-cell vehicles for all scenarios containing FCEBs. As in the BEB Only Scenario, this scenario assumes that BCAG will offset the 2027 purchasing requirement that would require 25% of that year's purchases to be zero-emission by submitting two BEBs that will already be in the fleet prior to the purchasing requirement.

Figure 14 shows the number of ZEBs that would be purchased each year from 2021 through 2040 in this scenario based on the purchasing schedule that was expected in 2021 although that has since changed to include more BEBs by 2024. In the Mixed Fleet – BEB Majority scenario, 8 FCEBs and 4 fuel cell electric cutaways will be purchased in 2030 along with 5 BEBs. Proceeding bus procurements will prioritize BEBs while roughly 20% of cutaway purchases will be reserved for fuel cell electric cutaways.

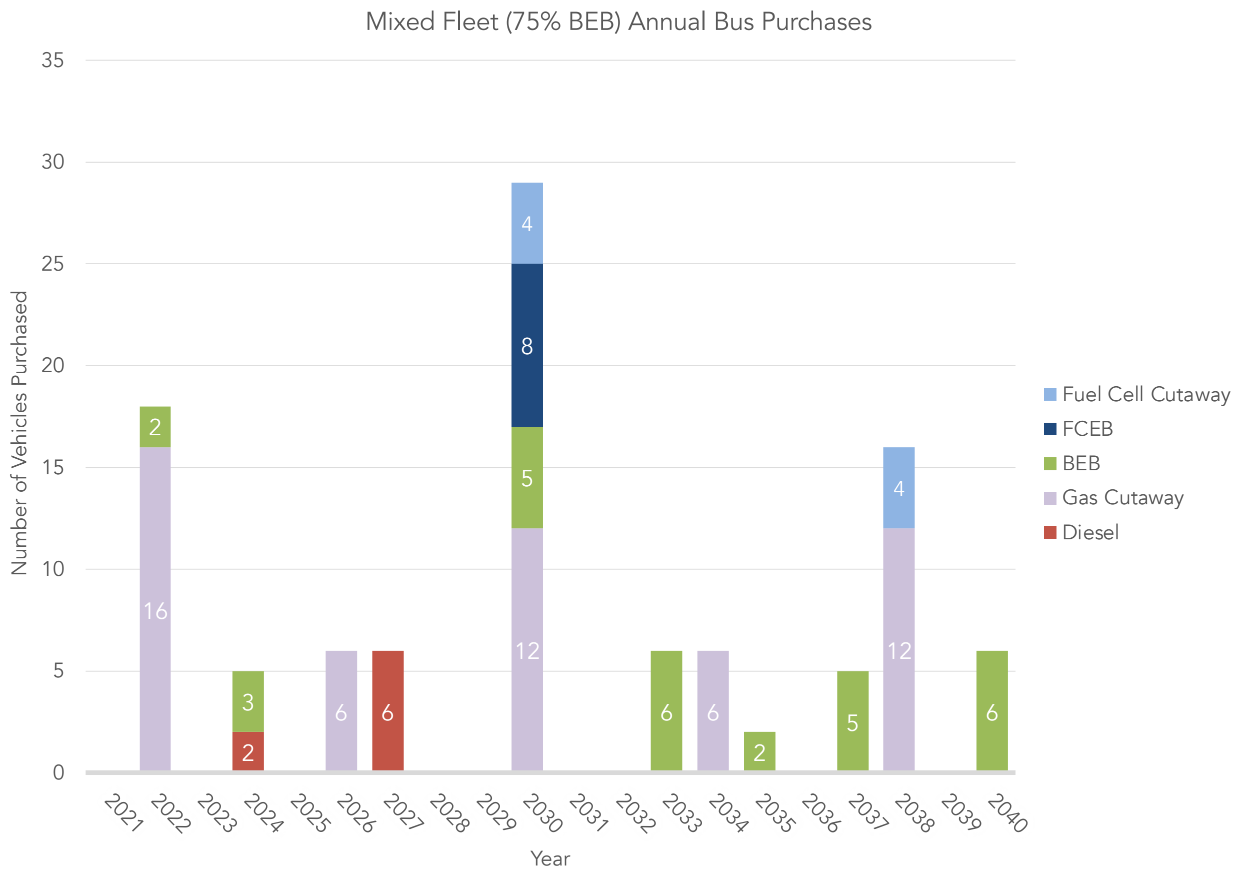


Figure 14 - Projected Bus Purchases, Mixed Fleet - BEB Majority

Figure 15 depicts the annual fleet composition through 2040 for the Mixed Fleet - BEB Majority scenario. As in all the scenarios, BCAG will procure 5 BEBs between 2022 and 2024. In this scenario, 5 more BEBs are added in the fleet composition in 2030, 6 more BEBs in 2033, 2 in 2037, and finally 6 in 2040. Additionally, 8 FCEBs and 4 fuel cell electric cutaways are procured in 2030. Note that the fleet will have small portion of diesel buses until they are fully phased out in 2039. Gasoline-powered cutaways will remain the majority of B-Line's paratransit fleet due in part to is resilience and redundancy strategies.

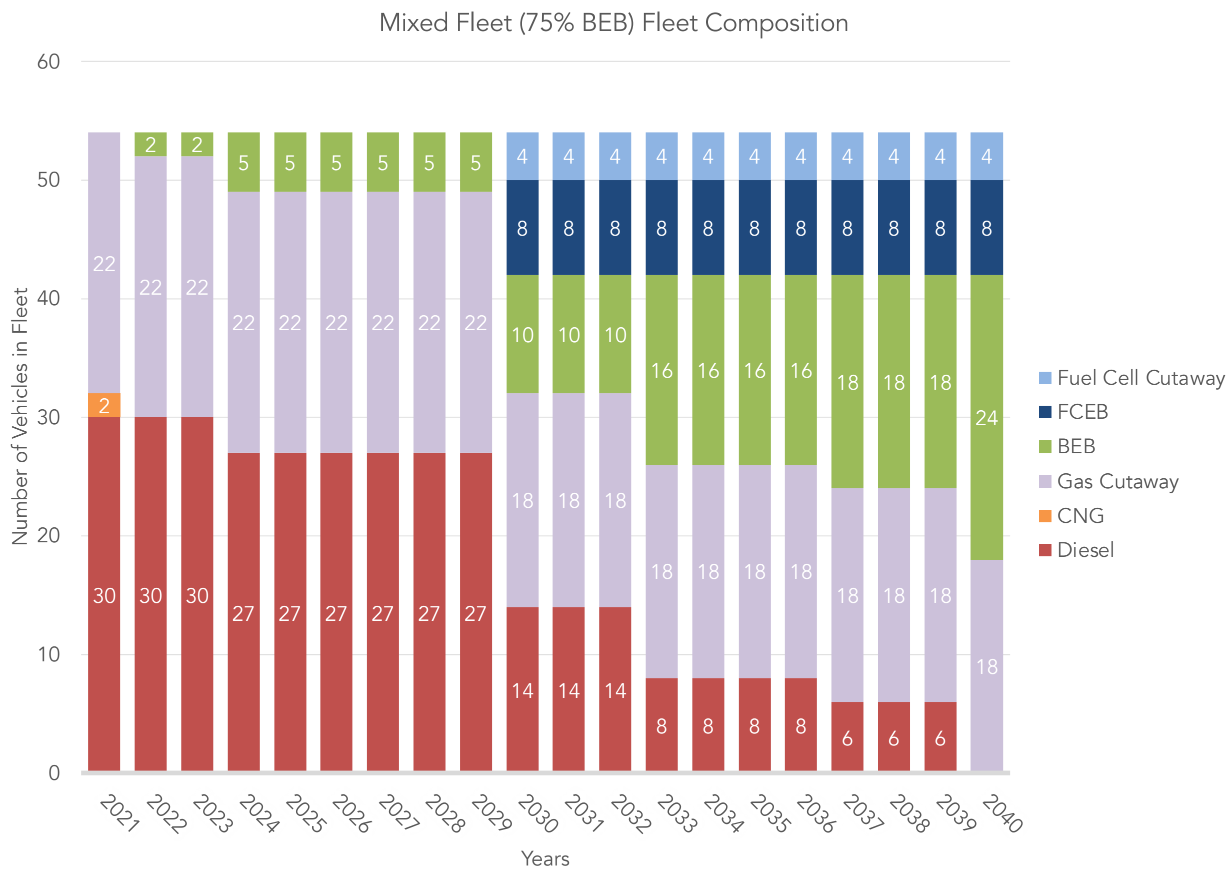


Figure 15 - Annual Fleet Composition, Mixed Fleet - BEB Majority

Figure 16 shows the annual total bus capital costs in the Mixed Fleet - BEB Majority Scenario. 2030 is a major purchase year when 13 diesel buses will reach the end of their 12-year useful service life and 16 gasoline powered cutaways will reach the end of their 7-year useful life.

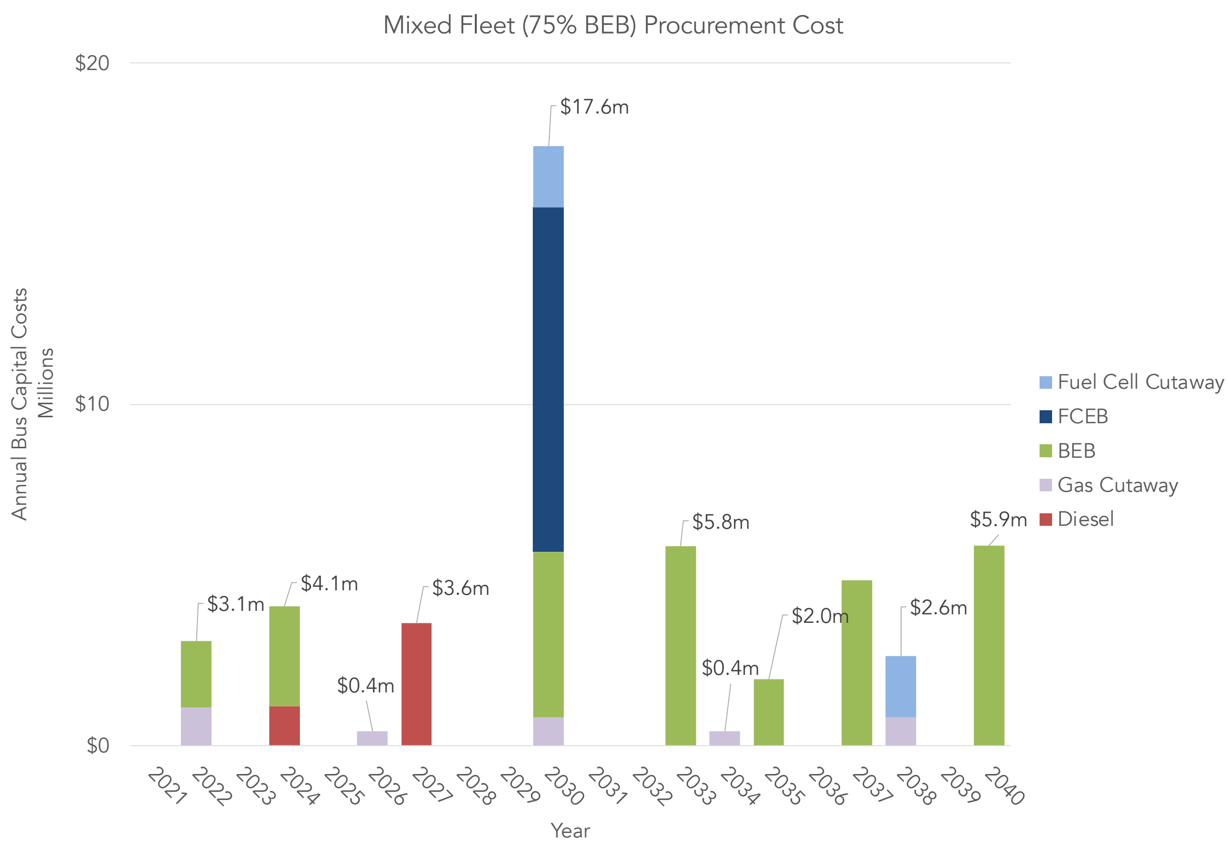


Figure 16 - Annual Capital Cost, Mixed Fleet - BEB Majority

Mixed Fleet - FCEB Majority Scenario

The second Mixed Fleet (BEB and FCEB) scenarios was developed to review the costs and benefits associated with a FCEB fleet majority. This scenario also assumes that BCAG will be in compliance with the 25% ZEB purchase requirement starting on January 1st, 2026 by submitting two of the six BEBs that are included in their procurement schedule from 2022 to 2025.

Figure 17 shows projected purchases, annual fleet composition, and annual total capital costs for the Mixed Fleet - FCEB Majority scenario based on the purchasing schedule anticipated as of spring 2021. In this scenario, 13 FCEBs and 4 fuel cell cutaways are scheduled for purchase in 2030. Two additional FCEBs are introduced into B-Line's fleet composition in 2033, five FCEBs in 2037, and finally four FCEBs in 2040. Keeping in line with BCAG's request for a 20% fuel cell electric paratransit fleet, the cutaway fleet composition consistently maintains four fuel cell cutaways.

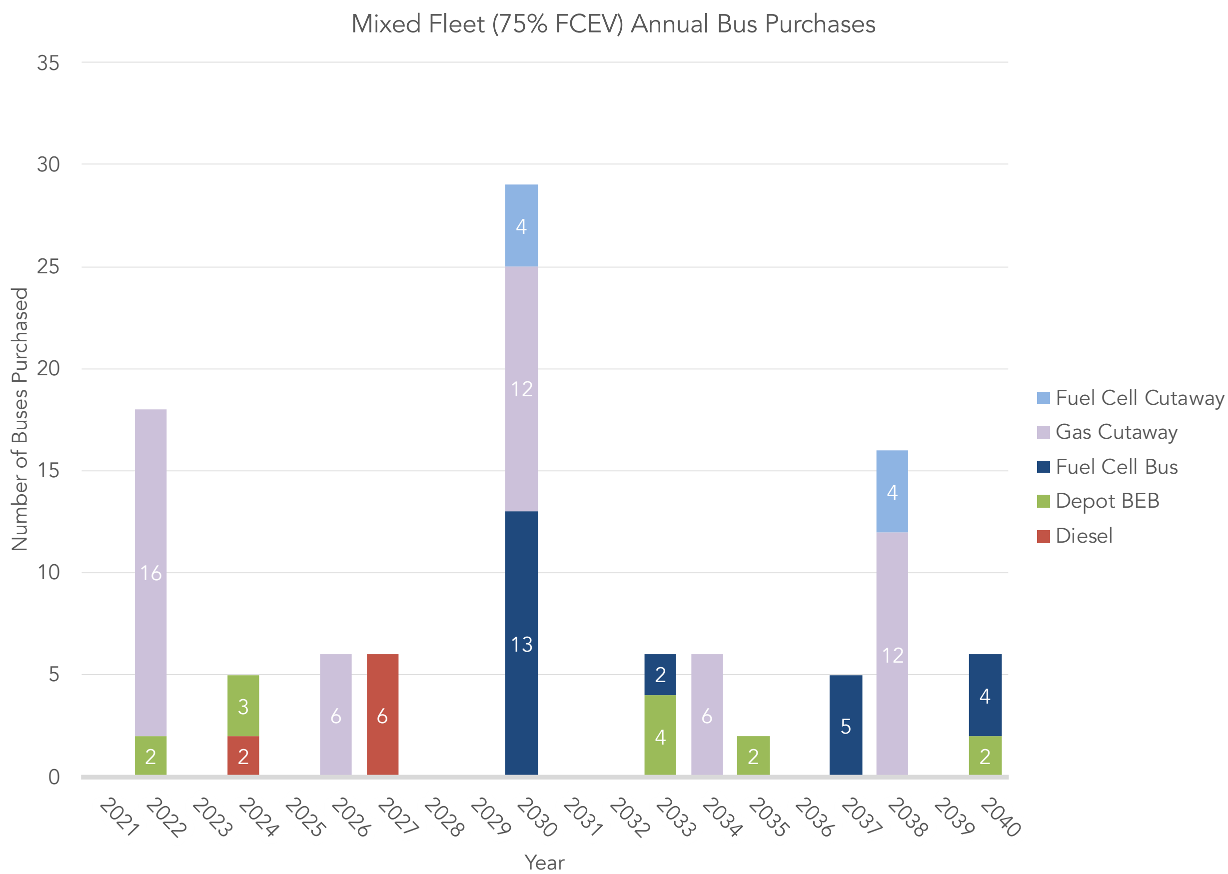


Figure 17 - Projected Bus Purchases, Mixed Fleet (75% FCEB)

Figure 18 depicts the annual fleet composition through 2040 for the Mixed Fleet - FCEB Majority scenario. In contrast to the Mixed Fleet - BEB Majority scenario, FCEBs make up the majority of the bus purchases starting in 2030.

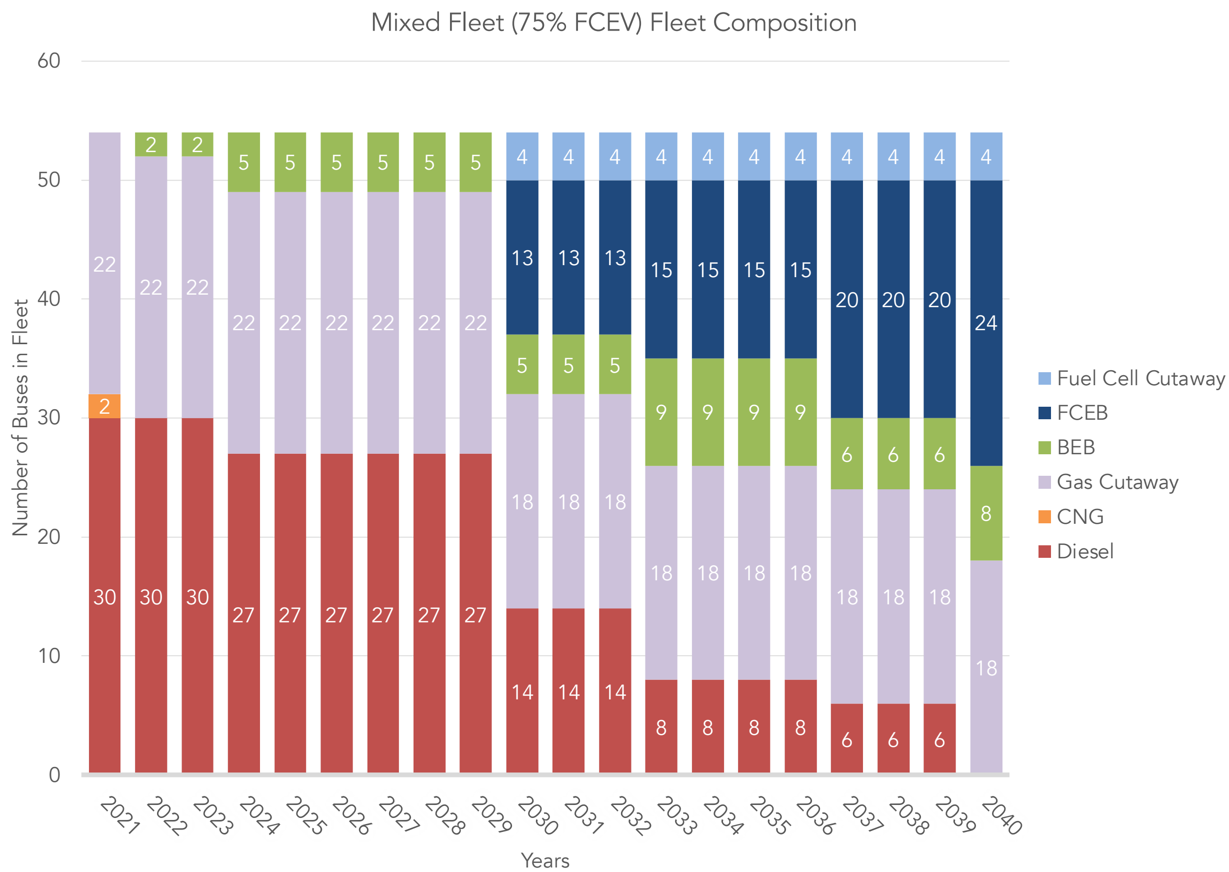


Figure 18 - Annual Fleet Composition, Mixed Fleet - FCEB Majority

Figure 19 shows the annual bus capital cost for the Mixed Fleet - FCEB Majority scenario. While the same number of diesel buses are being replaced in this scenario as in the Mixed Fleet - BEB Majority scenario, the bus capital cost is increased due to higher prices for FCEB technology. As seen in the previously discussed scenarios, 2030 is a major purchase year with estimated annual expenditures of $19 million.

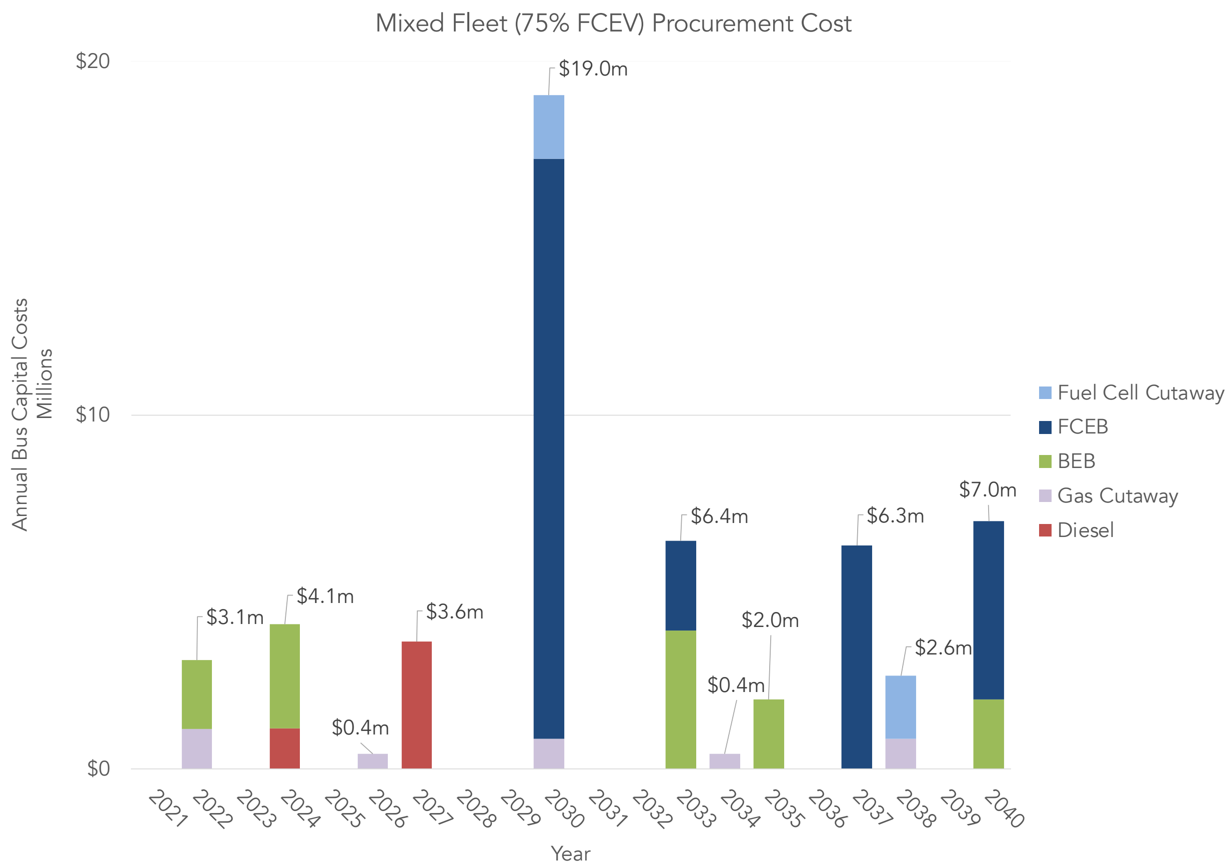


Figure 19 - Annual Capital Cost, Mixed Fleet (75% FCEB)

FCEB Only Scenario

The FCEB Only scenario was developed to examine the costs for hydrogen fueling and transitioning to a 100% FCEB fleet. This scenario includes BCAG's known BEB procurements (as of 2021), but anticipates replacing those five BEBs with FCEBs in the second purchasing round. This scenario also assumes that BCAG will be in compliance with the 25% ZEB purchase requirement starting on January 1st, 2026 after purchasing 2 of the 6 BEBs that are included in their procurement schedule from 2021 to 2025. Maintenance costs are highly dependent on the size and complexity of the vehicle fleet being supported. There are efficiencies gained in maintaining a single technology versus in a mixed fleet scenario where maintenance of both hydrogen equipment and charging infrastructure will need to be considered. The figures below show projected purchases, annual fleet composition, and annual total capital costs for the FCEB Only scenario.

By 2040, B-Line is able to replace 100% of its fixed route fleet with FCEBs, as well as 20% of their cutaway fleet.

Figure 20 shows the number of buses scheduled for purchase per year in the FCEB Only scenario. In this scenario, beyond the 5 known BEB procurements, diesel and gasoline powered vehicles are replaced with fuel cell technology starting with 4 fuel cell cutaways and 16 FCEBs in 2030. 8 additional FCEBs are procured in 2033; 8 FCEBs in 2035; 9 FCEBs in 2037, and finally 2 FCEBs in 2040.

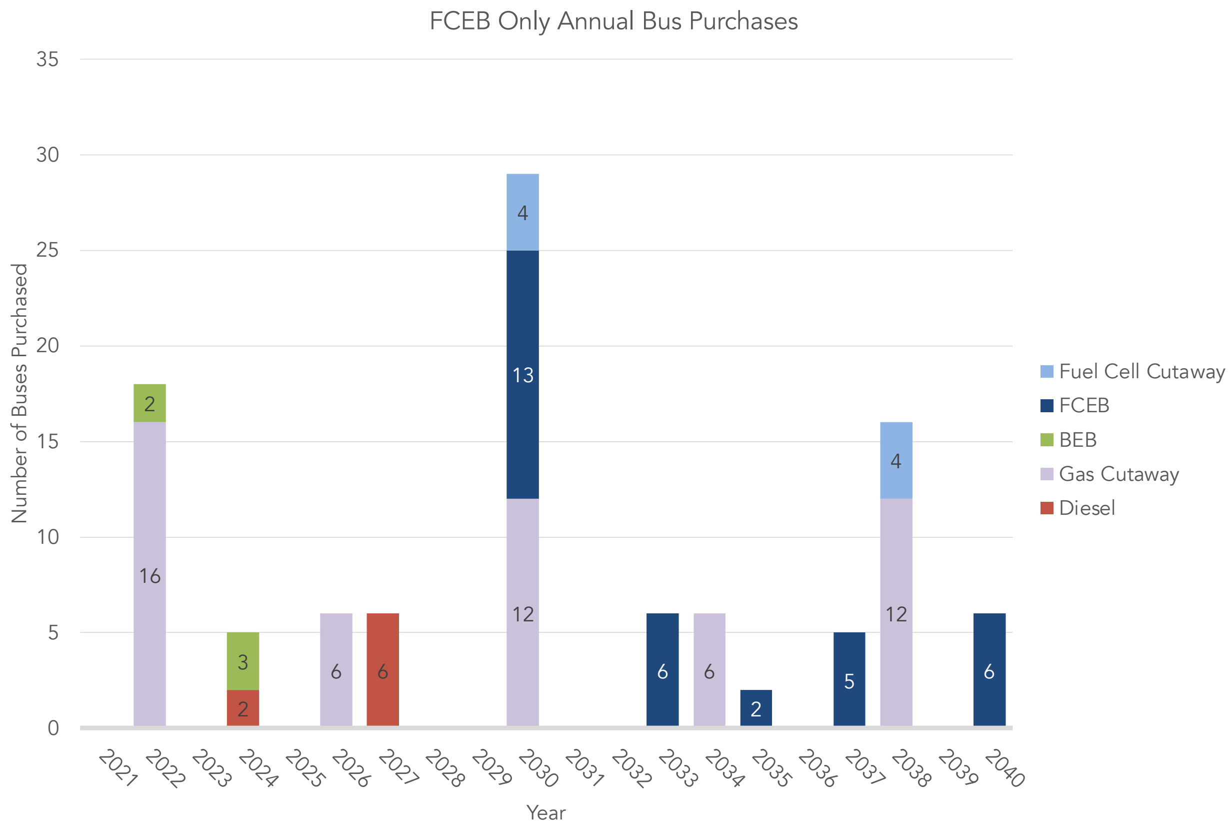


Figure 20 - Projected Bus Purchases, FCEB Only Scenario

Figure 21 shows the annual fleet composition for the FCEB Only Scenario. Diesel buses are replaced with FCEBs at a 1:1 ratio starting in 2029. BEBs are fully phased out by 2036 and diesel buses are fully phased out by 2040.

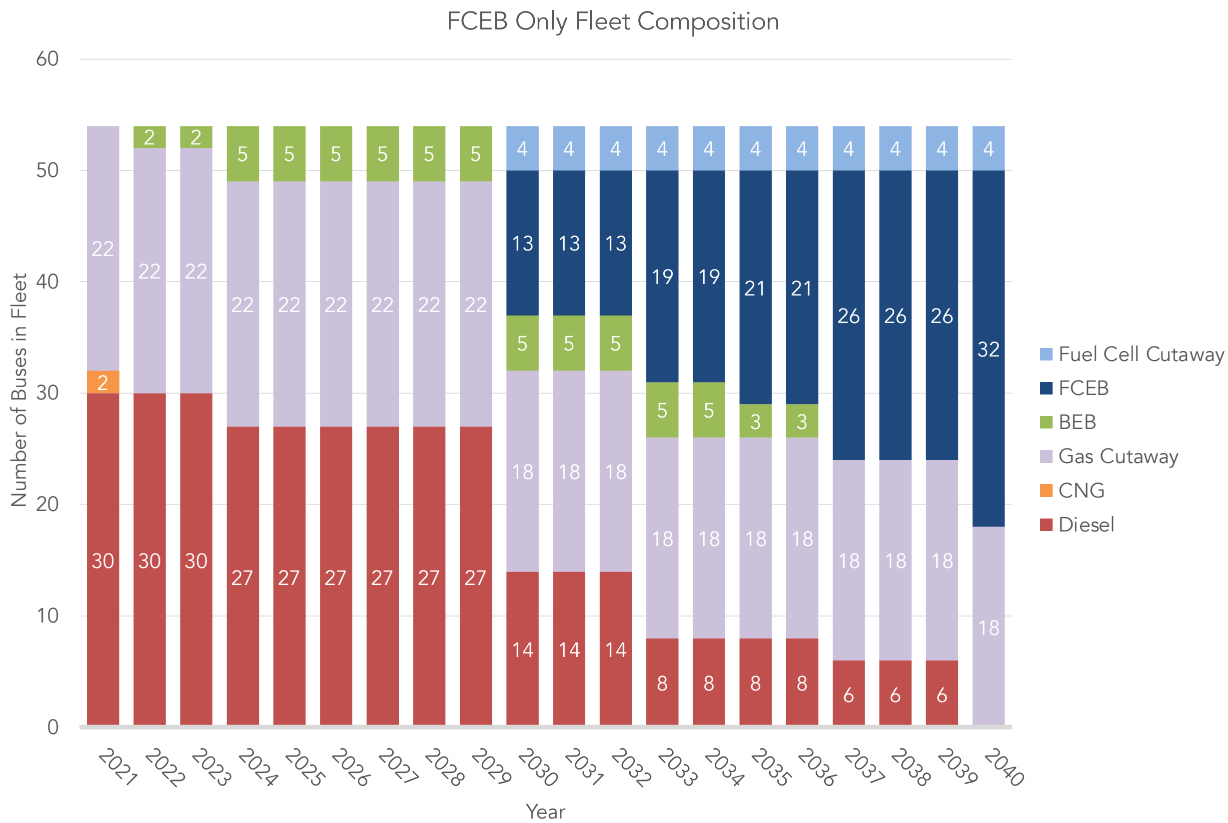


Figure 21 - Annual Fleet Composition, FCEB Only Scenario

Figure 22 shows the annual bus capital cost for the FCEB Only scenario. 2030 is a major purchase year with estimated annual expenditures of $19 million.

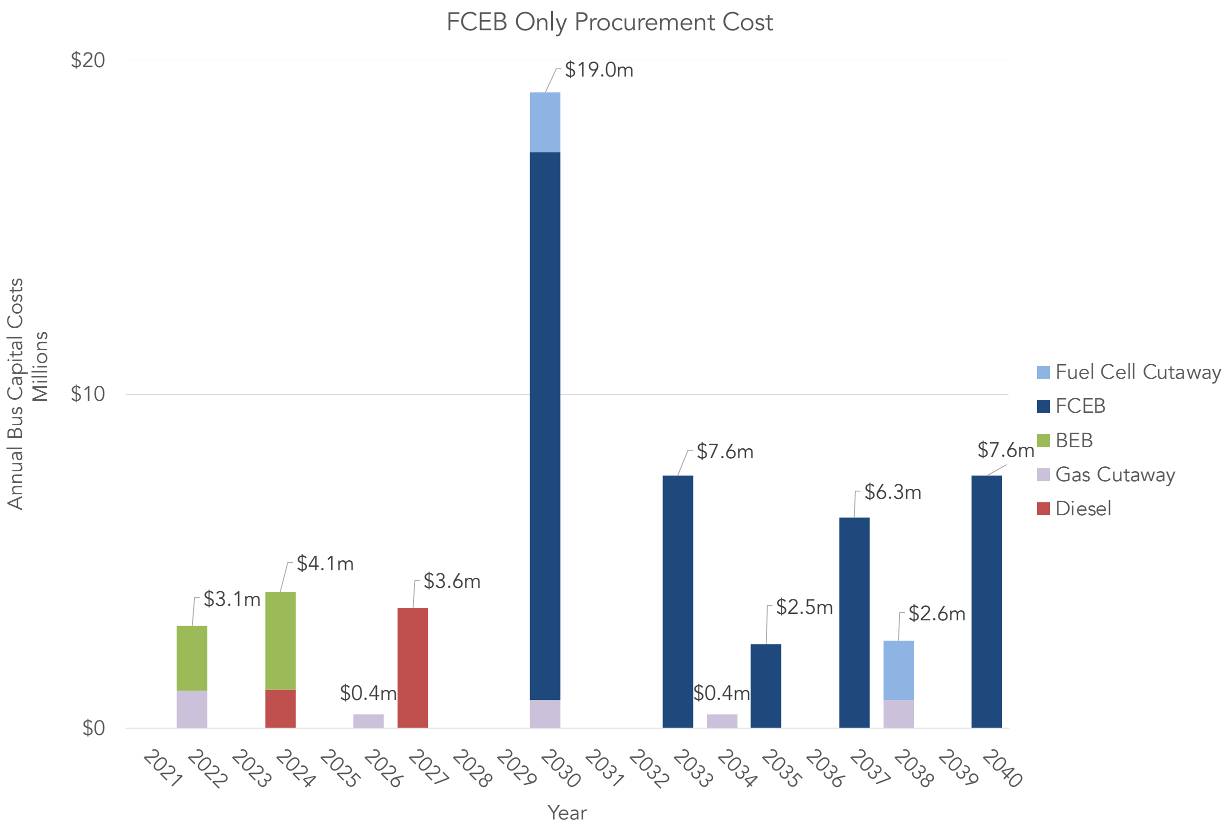


Figure 22 - Annual Capital Costs, FCEB Only Scenario

Fleet Assessment Cost Comparison

The transition and fleet composition schedules were used to develop the total capital cost for bus purchases through the transition period.

Figure 23 shows the cumulative bus purchase capital costs for each scenario.

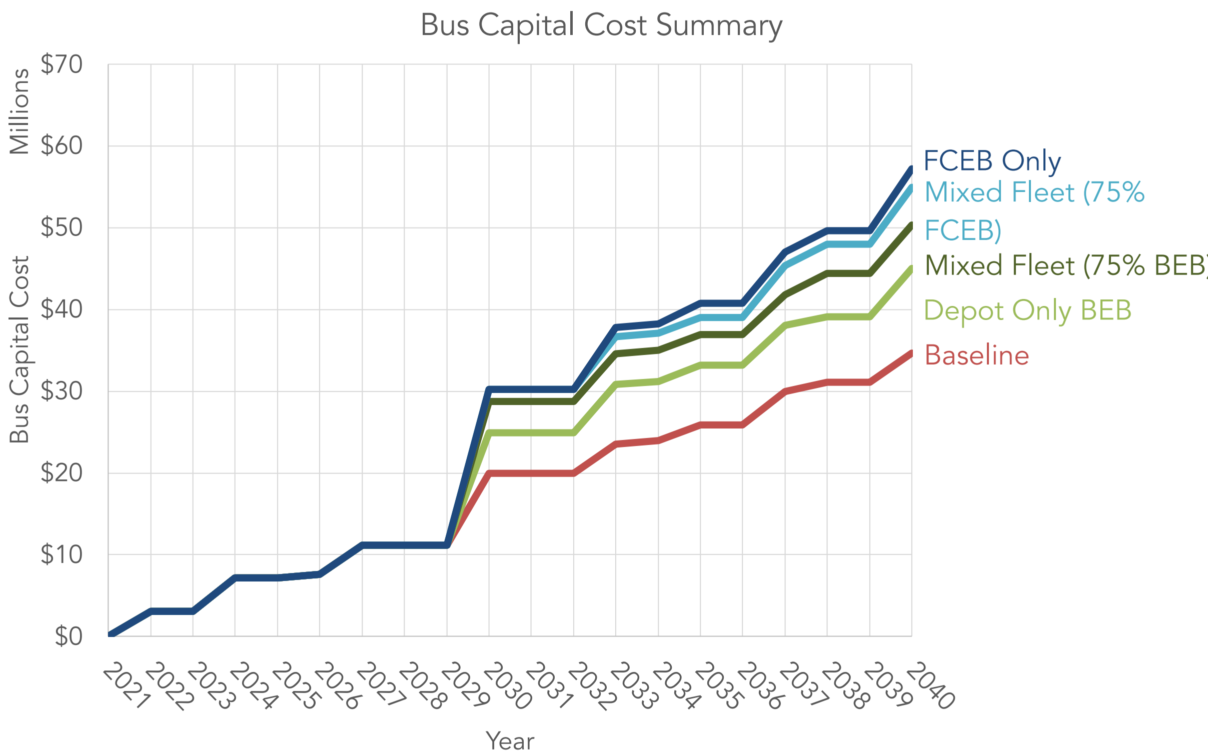


Figure 23 - Cumulative Bus Capital Costs, Fleet Assessment

By the end of the transition period, the cumulative bus capital costs vary substantially according to the technology selected with all transition scenarios. **Table 11** summarizes the combined total costs for each transit scenario and the percentage of ZEBs present in the fleet in 2040 for the scenario. Although all of the transition scenarios achieve a fully zero-emission fleet for the agency's fixed route service, there is a $12M difference between the least expensive (BEB Only) and most expensive (FCEB Only) transition scenario.

Table 11 - Total Bus Capital Costs, Fleet Assessment

Scenario	Cost	% ZEB in 2040 For Fixed -Route Fleet	% ZEB in 2040 For Total Fleet
Baseline (current technology)	$35M	15.6%	9.3%
BEB Only	$45M	100.0%	59.3%
Mixed Fleet - BEB Majority	$50M	100.0%	66.7%
Mixed Fleet - FCEB Majority	$55M	100.0%	66.7%
FCEB Only	$57M	100.0%	66.7%

Fuel Assessment

The Fuel Assessment estimates fuel consumption and costs for each of the technologies—diesel, electric, and hydrogen—studied in the relevant scenario.

Using ZEB performance data from the route simulation, CTE analyzed expected bus performance on each block in BCAG's service catalog to calculate the daily fuel required for that block's completion. CTE completed this analysis for each of the four zero-emission fleet transition scenarios and the baseline scenario. The analysis produced estimates of the fuel costs for each projected fleet composition through the transition period. Operation and maintenance costs for BEB and FCEB fueling infrastructure are also included. Fuel cost estimates are based on the assumptions shown in **Table 12** below.

Table 12 - Fuel Cost Assumptions

Fuel	Cost	Source
Diesel	$3.80/DGE	Based on the average of BCAG's reported price in calendar year 2019 to 2020.
CNG	$1.79/ Therm	Based on the average of BCAG's reported price in calendar year 2019 to 2020.
Gasoline	$3.60/GGE	Based on the average of BCAG's reported price in calendar year 2019 to 2020.
Hydrogen (liquid)	$7.95/kg	Based on OCTA's 2017 contractual price of liquid hydrogen (trucked in). Cost is inclusive of hydrogen fueling station maintenance by provider.
Electricity	$0.13/kWh (Off-Peak)	PG&E Commercial EV Tariff Schedule

The primary source of energy for a BEB is often the local electrical grid. Pacific Gas & Electric (PG&E) is the electricity provider, or utility, for BCAG. PG&E charges customers for energy consumption, measured in kWh, using a time-of-use (TOU) rate. Under a TOU rate, the cost per kWh of electricity varies by time of day.

Demand charges are the costs incurred by an agency's peak power demand. Peak demand is defined as the maximum amount of energy that a customer pulls from the grid for any 15-minute window within a month. Demand charges are then applied on a per-kW basis to that maximum demand. Demand charge is considered for depot and on-route charging. These separate charges are then totaled to produce an agency's electricity bill for the month.

As a transit agency adds more buses and chargers, the agency's energy consumption and the peak power demand both increases. Electricity rates also vary throughout the year and throughout the day, making costs highly variable if charging is not managed. Charge management strategies aim to minimize charging costs by taking advantage of this variability. Charge management strategies include charging buses during times of day at which rates are lower and avoiding demand charges by spreading out the number of buses charging at once to minimize increases in peak power demand. In the scenarios presented in this transition plan, the buses would all depot charge in the off-peak times to help reduce overall fuel cost, which the buses at B-Line can achieve by charging at night.

Table 13 shows a summary of the PG&E's Electric Schedule BEV-2-S Commercial Electric Vehicles (EV) for Secondary Voltage, which was used in the Fuel Assessment to estimate electricity costs for BEBs. These rates are averaged from monthly rates and are a summarized version of PG&E's full rate schedule. Because this is a TOU rate, the rate per kWh changes based on the time of day and year that the kWh is consumed. Depot-charged buses are assumed to charge entirely during the off-peak hours between 9:00pm and 9:00am. The depot charge rate is therefore the same as the off-peak rate ($0.13 per kWh).

PG&E's Commercial EV Rate allows agencies to subscribe to a set fee of $95.56 per 50 kW of power demand in lieu of traditional demand charges in addition to consumption charges. This standard fee rate applies to the demand at the depot. BCAG will be moved to the new Commercial EV rate structure when their demand exceeds their current rate. The Depot Charge Rate included in the table below represents the average cost per kilowatt-hour expected for BCAG. While some locations have rates that vary by season, BCAG's rates will remain constant year-round.

Table 13 - PG&E's Electric Schedule BEV-2-S Commercial Electric Vehicles for Secondary Voltage

	Per meter charge	Average rates
Electric Utility Rates	On Peak (per kWh)	$0.34
	Off-Peak (per kWh)	$0.13
	Super Off (per kWh)	$0.11
	Depot Charge Rate	$0.13
	Depot Demand Charge (per 50kW/month)	$95.56

Charging Analysis

To accurately estimate energy consumption, peak power demand, and resultant costs, CTE conducted simulations of charging at the depot for each year of the transition. Electrical energy consumption and peak power demand were estimated based on current block schedules and projections of BEB purchases. CTE then used PG&E tariff schedules to calculate the annual cost of charging. This annual cost is evaluated for each year of the study (2021–2040) to obtain a total charging cost of BEBs with depot charging for the transition period. This estimate of total charging cost is used as the total fuel cost for the BEB-Only scenarios and is used in the other fleet scenarios, where relevant, in addition to hydrogen fuel costs, or fossil-fuel costs.

Hydrogen Pricing, Electricity Pricing, and Sensitivity Analyses

A sensitivity analysis was conducted for BCAG regarding hydrogen pricing because it is widely believed that these prices will fall over time. The high end of the expected price is the current price paid by AC Transit ($8.50/kg), a transit agency in California, and the bottom rate was estimated based on NREL and Department of Energy (DOE) projections at $5.50.[15,16] This pricing sensitivity is shown in the summary and total estimates for the fuel cell scenarios. In contrast, electricity prices are likely to rise in the future, in part due to PG&E's necessary fire safety upgrades to older electrical infrastructure. The electricity

[15] Melaina, M. and Penev, M. 2013. Hydrogen Station Cost Estimates Comparing Hydrogen Station Cost Calculator Results with Recent Estimates. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5400-56412 https://www.nrel.gov/docs/fy13osti/56412.pdf

[16] Hydrogen Production Tech Team Roadmap. 2017. U.S. DRIVE (Driving Research and Innovation for Vehicle efficiency and Energy sustainability). Washington, DC: Department of Energy. https://www.energy.gov/sites/prod/files/2017/11/f46/HPTT%20Roadmap%20FY17%20Final_Nov%202017.pdf

price increases are expected to translate into an increase in cost of 3.2% per year.[17] This price was included as part of a sensitivity analysis for electricity pricing. Because hydrogen and electricity pricing are expected to move in opposite directions, the near-term electricity price is the least expensive whereas the near-term hydrogen price is the most expensive.

Baseline

The Baseline scenario assumes the same service and ICE technology, apart from the five BEBs that are part of the agency's near-term procurements. **Figure 24** depicts energy consumption by fuel type over the transition period for the Baseline scenario. CTE used B-Line's reported annual fuel consumption in 2019-2020 to calculate the average mile per gallon fuel efficiency per vehicle series in its current fleet. Fleet energy use remains constant over the entire period at around 0.33 million diesel-gallon-equivalent (DGE).

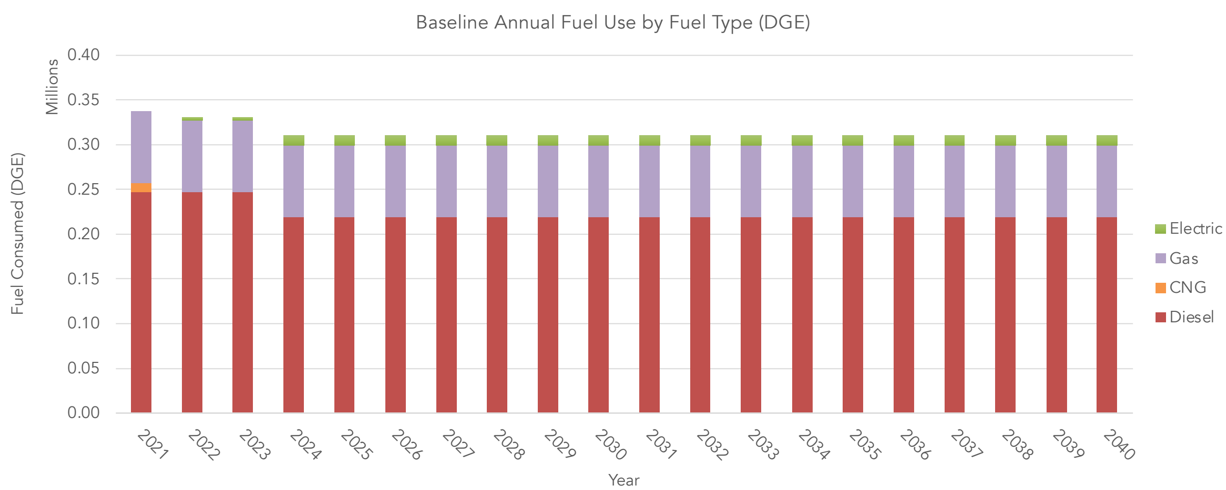


Figure 24 - Annual Fuel Consumption, Baseline Scenario

[17] Utility Costs and Affordability of the Grid of the Future. 2021. California: California Public Utilities Commission. https://www.cpuc.ca.gov/uploadedFiles/CPUC_Website/Content/Utilities_and_Industries/Energy/Reports_and_White_Papers/Feb%202021%20Utility%20Costs%20and%20Affordability%20of%20the%20Grid%20of%20the%20Future.pdf

Figure 25 shows the annual fuel costs for each fuel type in the Baseline scenario, based on the consumption quantities (in DGE) shown in **Figure 24**. In the Baseline scenario, the fleet is primarily composed of diesel buses. The fleet size, frequency of trips per route, and associated annual mileage are sustained throughout the analysis period and have not been adjusted for inflation. The total estimated fuel costs in 2040, approximately $1.2 million, are slightly less than in 2021 due to efficiencies gained with the 5 BEBs.

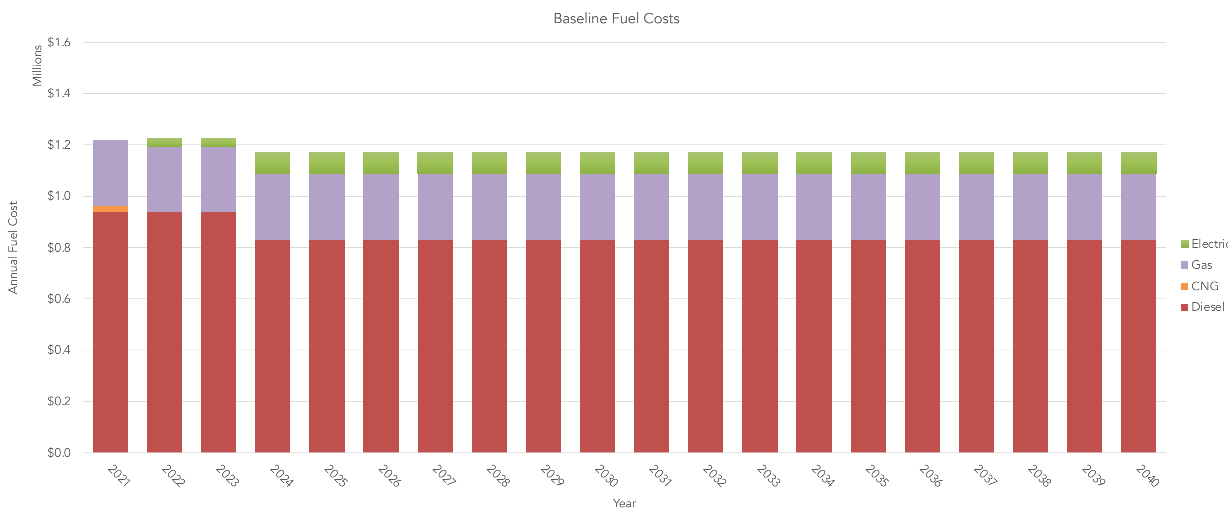


Figure 25 - Annual Fuel Costs, Baseline Scenario

BEB Only

In the BEB Only scenario, BEBs are purchased and deployed only on blocks that are within a BEB's achievable range as determined by CTE's modeling. According to CTE's modeling, all of B-Line's routes are feasible in a BEB with depot-only charging scenario by 2035. **Figure 26** depicts energy consumption for each fuel type over the transition period. Legacy fuels are phased out as electricity consumption increases, reflecting an increasing number of BEBs in the fleet. Fleet energy use is thus reduced from about 0.34 million DGE in 2020 to about 0.16 million DGE in 2040. Fleet energy use is shown to reduce by half in 2040 compared to 2021 fuel consumption levels due to the efficiencies of BEB technology. Since the gasoline cutaways are not assumed to transition to zero-emission technology in this scenario, there is no reduction to the DGE consumption for those vehicles.

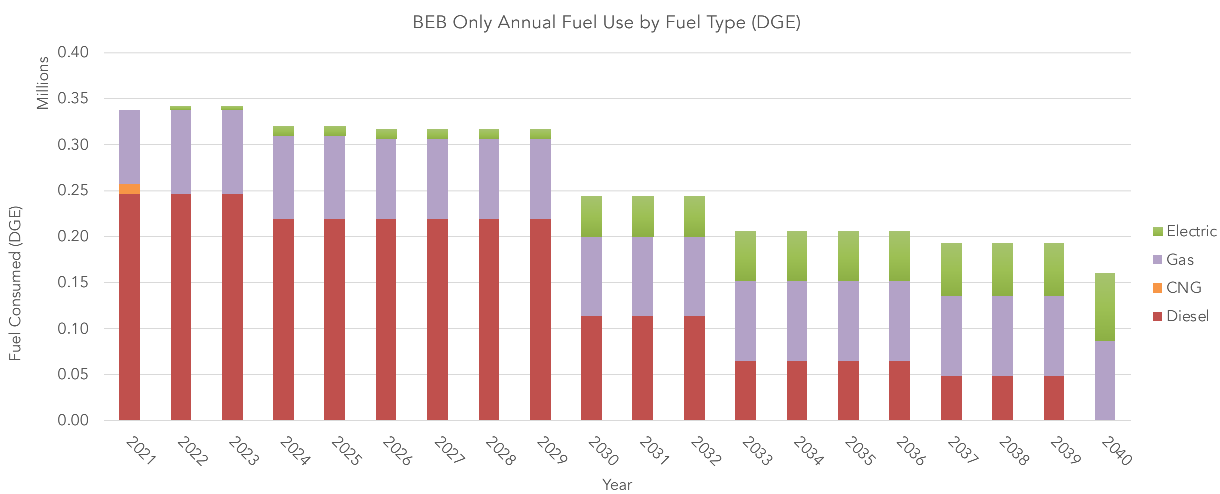


Figure 26 - Annual Fuel Consumption, BEB Depot-Only

Figure 27 shows the annual costs for each fuel type based on the quantities in **Figure 26**. Electricity consumption increases as diesel fuel consumption decreases. The total estimated fuel costs in 2040, approximately $0.8 million, is less than that of the Baseline scenario.

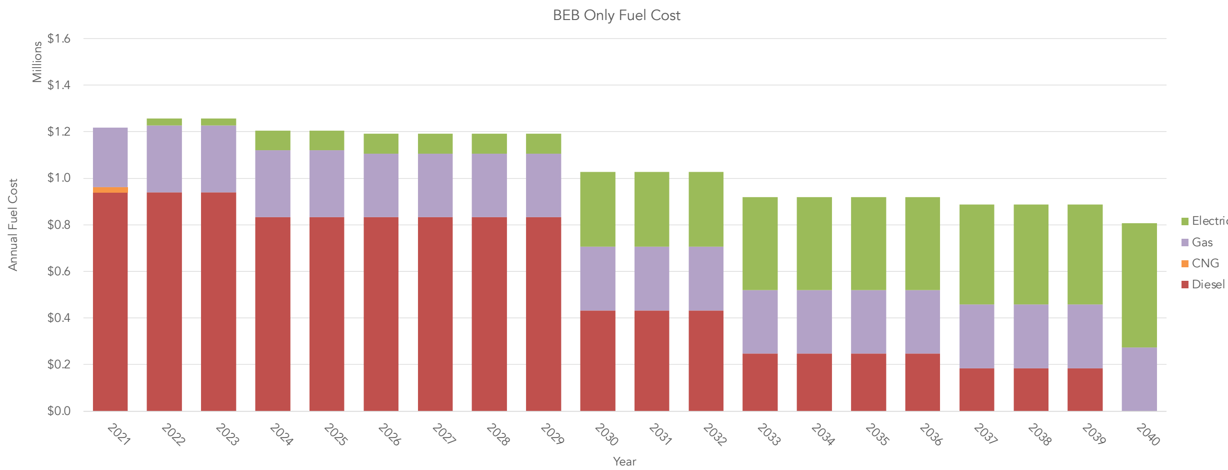


Figure 27 - Annual Fuel Costs, BEB Depot-Only

Mixed Fleet - BEB Majority Scenario

Two Mixed Fleet (BEB and FCEB) scenarios were developed to review the costs and benefits associated with a mixed fleet. While BEB technology can complete all of B-Line's existing routes, BCAG prioritizes redundancy and resilience given that their service plan covers areas that have recently been affected by fires. A mixed fleet that includes different technology and fuel is more resilient as it would allow service to continue if either fuel became temporarily unavailable for any reason.

The Mixed Fleet - BEB Majority scenario compares the advantages and disadvantages of a primarily BEB fleet with that of a primarily FCEB fleet to help with BCAG's scenario selection for their ICT Rollout Plan. The figures below show energy consumption for each fuel type over the transition period and the annual costs for each fuel type within the Mixed Fleet - BEB Majority scenario.

In **Figure 28,** fleet energy use is shown to reduce from about .34 million DGE to under .20 million DGE in 2040 due to the efficiencies of BEB technology. As a reminder, four of B-Line's paratransit vehicles were assumed to transition to FCEBs in all scenarios that explored the technology, so this scenario, as well as all of the following, sees a reduction in the DGE consumed by the paratransit vehicles as a result of their partial transition to ZEVs.

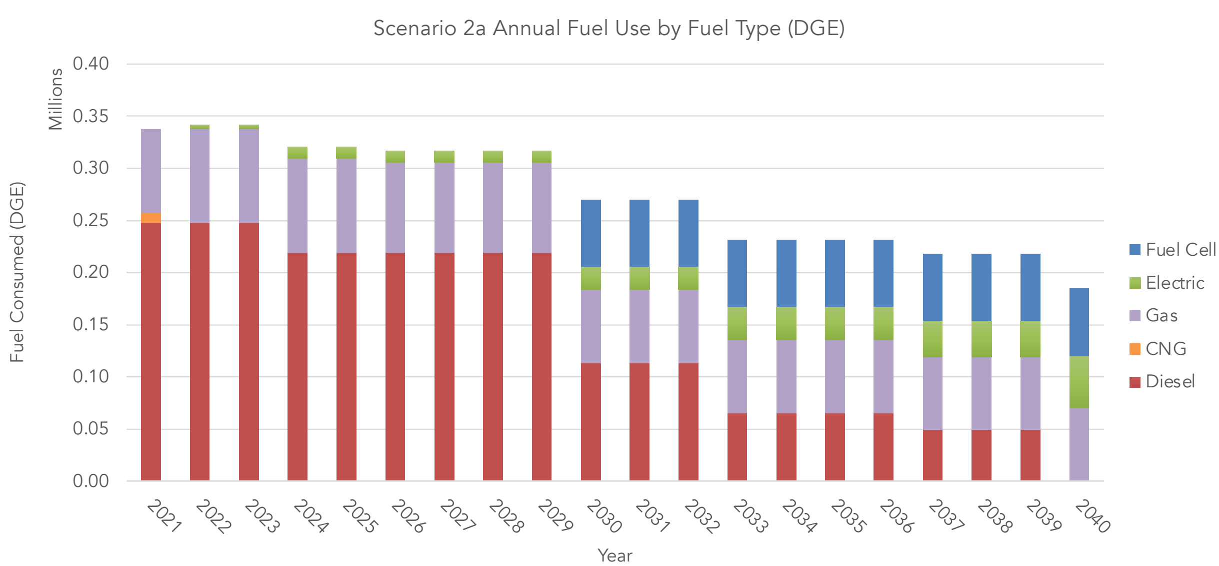


Figure 28 - Annual Fuel Consumption, Mixed Fleet - BEB Majority

The total amount of energy consumed by the fleet decreases over the fleet transition period, however, a spike in fuel cost can be seen with the introduction of hydrogen, as shown in **Figure 29**. The prices stabilize and begin to decrease as more diesel buses are retired from the fleet in favor of ZEBs.

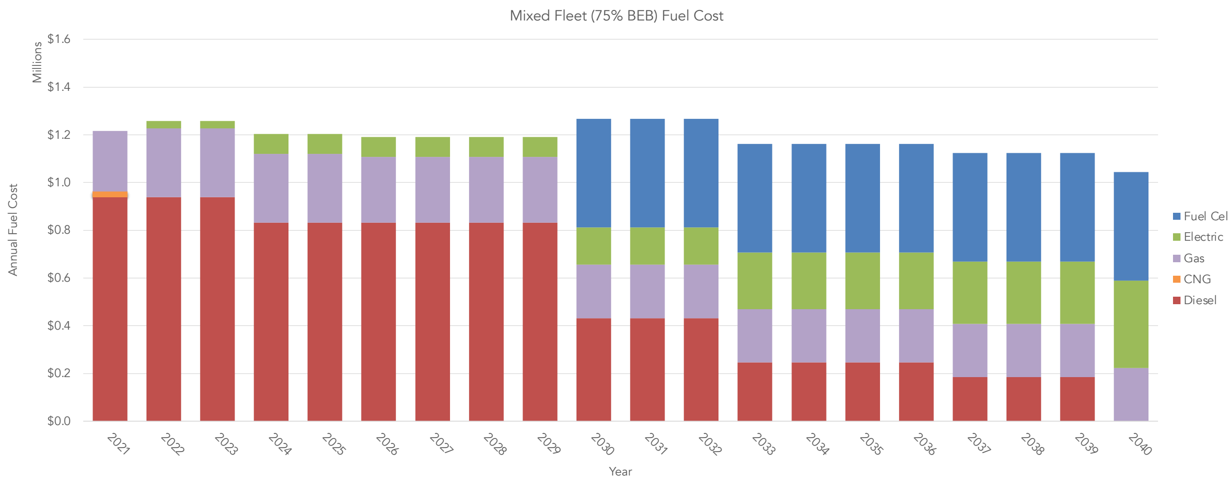


Figure 29 - Annual Fuel Costs, Mixed Fleet - BEB Majority

Mixed Fleet - FCEB Majority Scenario

In this Mixed Fleet Scenario, the majority of the fleet is transitioned to FCEBs, rather than BEBs. **Figure 30** depicts energy consumption for each fuel type over the transition period for the Mixed Fleet - FCEB Majority scenario. Legacy fuels are phased out as electricity and hydrogen consumption increases, reflecting an increasing number of BEBs and FCEBs in the fleet. Fleet energy use is reduced from about 0.34 million DGE in 2021 to under 0.25 million DGE in 2040 as a result of converting to ZEB technology.

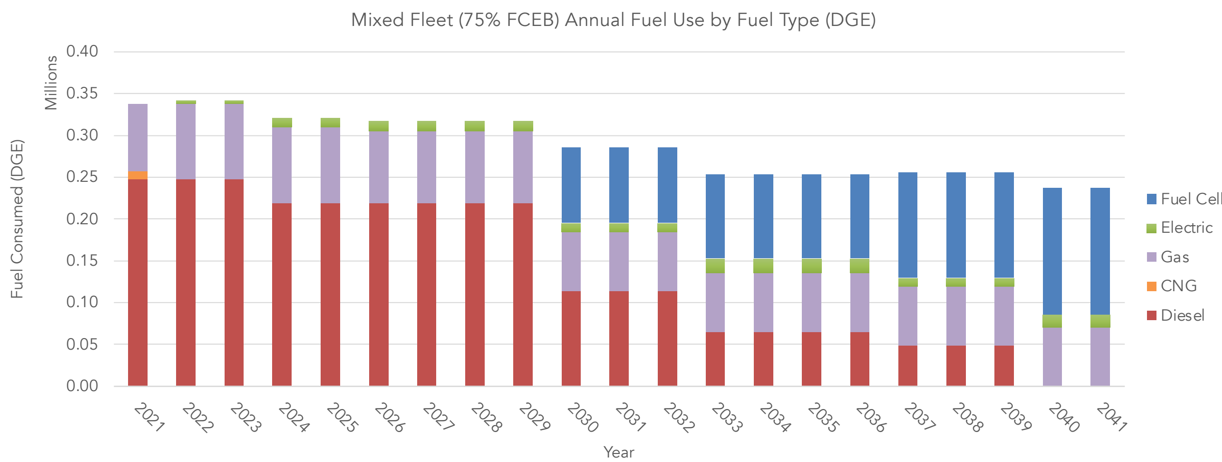


Figure 30 - Annual Fuel Consumption, Mixed Fleet - FCEB Majority

Figure 31 shows the estimated annual costs for each fuel type based on the quantities consumed, as shown in **Figure 30**. Total estimated fuel costs in 2040 are approximately $1.4 million, which are incurred from electricity use for BEBs and hydrogen fuel for FCEBs. Although the total amount of energy consumed decreases over the fleet transition period (**Figure 30)** the total fuel costs increase over that timeframe. These trends reflect hydrogen and electricity's greater efficiency but also hydrogen's higher costs compared to diesel fuel.

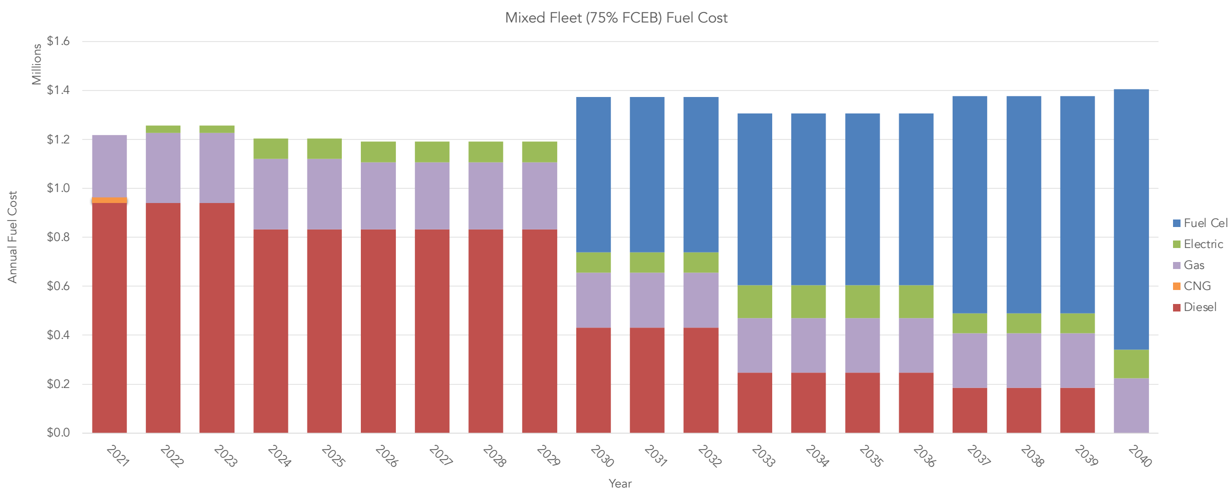


Figure 31 - Annual Fuel Costs, Mixed Fleet - FCEB Majority

FCEB Only

Finally, the FCEB Only scenario was developed to examine the costs for hydrogen fueling and transitioning to a 100% FCEB fleet. A fully FCEB fleet enables all ICE buses to be replaced at a 1:1 ratio. It also avoids the need to install two types of fueling infrastructure by eliminating the need for depot charging equipment. Fleets comprised entirely of fuel cell electric buses also offer the benefit of scalability compared to battery electric technologies. Despite this benefit, the cost of FCEBs and hydrogen fuel renders this scenario the most expensive scenario at current market prices.

Figure 32 depicts fuel consumption for each fuel type over the transition period for the FCEB Only scenario. Legacy fuels are phased out as hydrogen consumption increases, reflecting an increasing number of FCEBs in the fleet. Fleet energy use is reduced by one-third, from about 0.34 million DGE in 2021 to just under 0.26 million DGE in 2040.

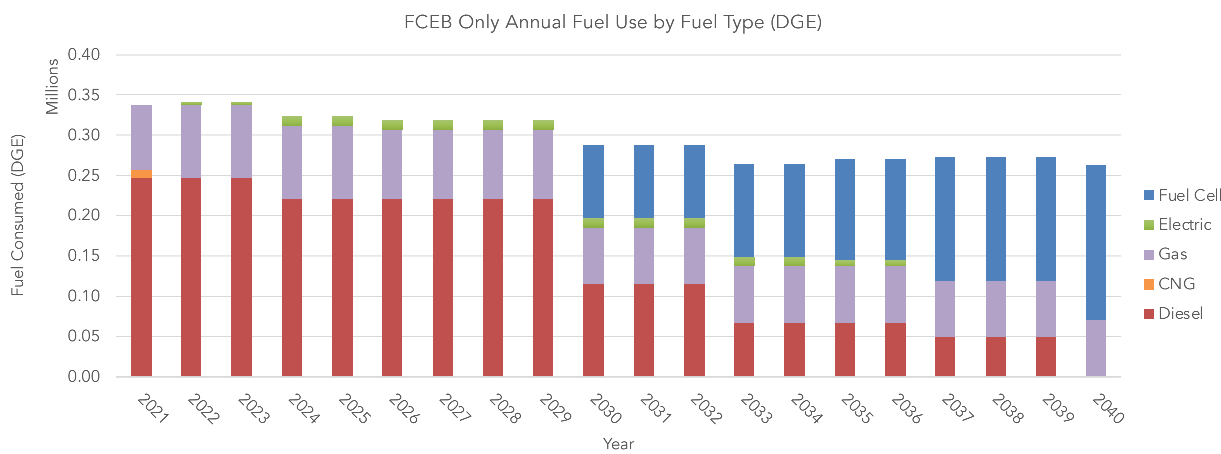


Figure 32 - Annual Fuel Consumption, FCEB Only

Figure 33 shows estimated annual costs for each fuel type based on the quantities consumed, as shown in **Figure 32**. Total estimated fuel costs in 2040, from hydrogen fuel and the gasoline for the remaining ICE cutaways, are approximately $1.6 million, which is double the price of electricity in 2040 in the BEB Only Scenario. This scenario is the most expensive scenario at current market prices, however, when applying sensitivity analysis to hydrogen costs, it does become cost competitive when compared with the cost of electricity in 2040.

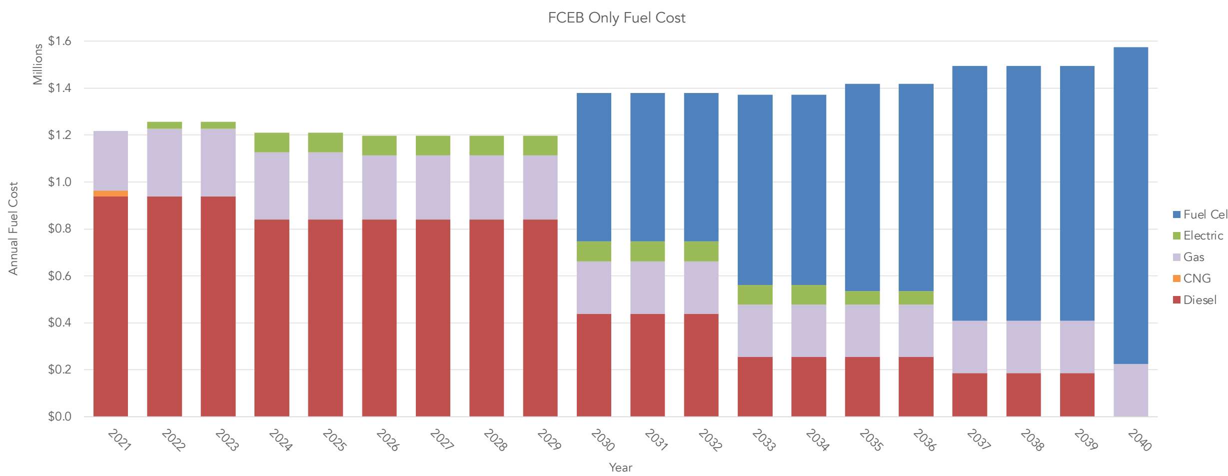


Figure 33 - Annual Fuel Costs, FCEB Only

Fuel Assessment Cost Comparison

The Fuel Assessment includes all fuel costs over the transition for each scenario. **Table 14** shows the combined total costs based on a sensitivity analysis. Note that the sensitivity analysis includes rate increases due to proposed infrastructure upgrades of 3.2% annually.

For electricity and hydrogen, the projected costs per mile are more variable. Hydrogen is the most expensive fuel in the near-term because of its high cost of production. Future technology and policy advancements may reduce the production cost for hydrogen and the resulting price of the fuel. Therefore, the estimate is shown to reflect the potential decrease in hydrogen prices in the future in the FCEB Only scenario. In reverse, electricity prices are likely to rise in the future in California, which is predominantly served by PG&E. BCAG receives electricity from PG&E and will be affected by increases in electricity costs should PG&E decide to bundle costs to upgrade their infrastructure with end user pricing as they have indicated is their intention. The table and graphs below only show the impact of the sensitivity analysis on the BEB Only and FCEB Only scenarios to avoid confounding the impacts of the sensitivity analysis on possible future pricing by mixing the fuels.

Table 14 – 2040 Fuel Sensitivity Cost, Fuel Assessment

Scenario	2040 Fuel Cost (2021 $)	2040 Fuel Cost with Sensitivity Analysis Applied	Difference ($)	Difference (%)
1: BEB Only	$ .808M	$ 1.245M	$ .437M	54%
3. FCEB Only	$ 1.575M	$ 1.098M	$ .477M	-30%

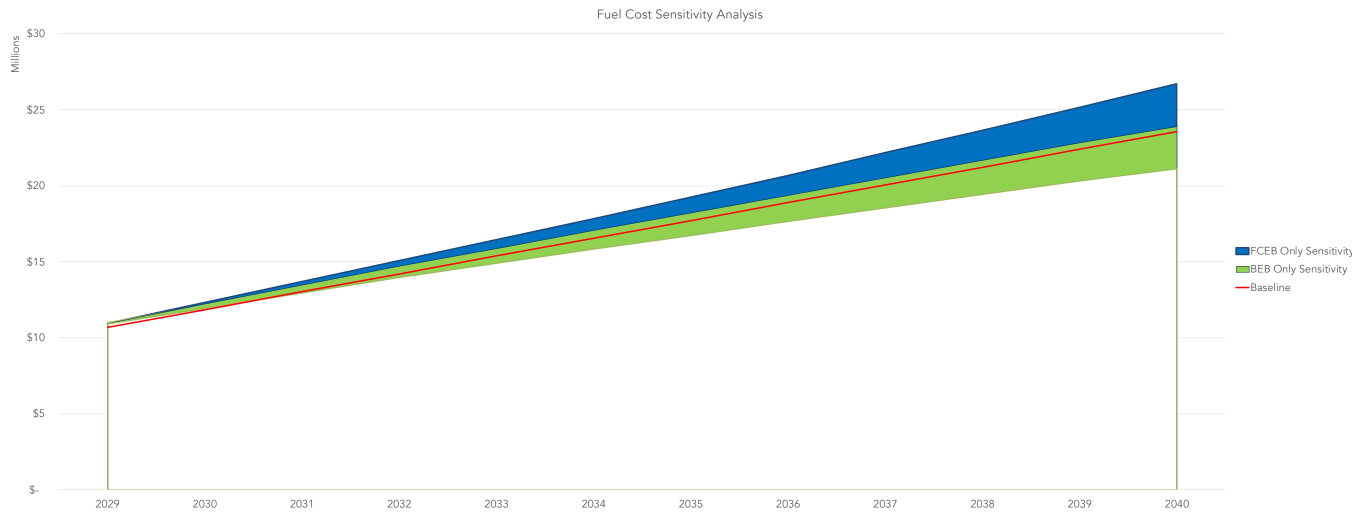


Figure 34 – Cumulative Fuel Costing Sensitivity Analysis, Hydrogen and Electricity

Maintenance Assessment

The Maintenance Assessment examines the changes to fleet maintenance costs for each fleet composition scenario over the transition period. Since ICE and zero-emission vehicles have different maintenance requirements, they generally have different maintenance costs associated with them. For both BEB and FCEB maintenance cost estimates, CTE developed assumptions using real-world data from early adopters of ZEBs and applied them to BCAG's Maintenance Assessment. Taking on a conservative outlook of vehicle performance, CTE also included the cost impact of midlife overhauls (where technicians look for signs of corrosion and install more durable parts) for major components of B-Line's current fleet and FCEBs in the Maintenance Assessment. CTE used BCAG's reported costs for maintenance and average engine and transmission overhaul for the newest models of their existing fleet (consisting of CNG and diesel-powered buses and gasoline-powered cutaways). CTE also included the price of a midlife overhaul for FCEBs that covers the cost of a complete overhaul of the fuel cell system, which, if required, can be significant and may offset savings from traditional maintenance costs. It is worth noting that the cost of a battery replacement for a BEB, and the battery portion of FCEB's midlife maintenance costs, is covered under the battery warranty. This is purchased in the procurement year and is therefore considered a capital cost versus an operational/maintenance cost.

Cost Assumptions

CTE's maintenance cost assessment includes labor, materials, and midlife overhaul costs. This assessment applied unit maintenance cost per mile by vehicle type with total costs based on average annual vehicle mileage as reported by BCAG. Total costs are based on the following assumptions:

- Maintenance costs for diesel buses and gasoline-powered cutaways are based on data from B-Line's current fleet.
- Maintenance costs for BEBs are based on a 30% reduction of diesel equivalent bus maintenance costs.
    - It is important to keep in mind that maintenance costs are hard to predict. Compared to conventional diesel and gasoline fueled vehicles, BEBs incur different maintenance needs that vary based on manufacturer and operating environment. In addition, a lot of the equipment for BEBs is covered by warranty, so costs in the first few years for maintenance are significantly lower than in the latter half of their service lives.
- Hydrogen maintenance costs were based on OCTA's reported labor and maintenance costs.

- This FCEB maintenance per mile value is based on the costs for the first year of service at OCTA. Therefore, this cost is likely high and will eventually trend downward since this is a first-generation vehicle. Long-term FCEB maintenance costs for US manufactured buses are still to be determined and should be carefully considered as BCAG implements their transition plan.

Table 15 is a summary of the estimated combined costs for scheduled and unscheduled labor and maintenance for each type of bus explored in this study.

Table 15 - Labor and Materials Cost Assumptions

Vehicle Type	Estimate (Per Mile)	Source
40' CNG Bus	$ 0.49	BCAG maintenance cost for a 2008 model
30'/35' Diesel Bus	$ 0.32	BCAG maintenance cost for a 2017 model
40' Diesel Bus	$ 0.35	BCAG maintenance cost for a 2017 model
Gas Cutaway	$ 0.33	BCAG maintenance cost for a 2018 model
30'/35' Electric Bus	$ 0.22	30% reduction of maintenance cost for a 30'/35'/40' Diesel Bus
40' Electric Bus	$ 0.24	30% reduction of maintenance cost for a 30'/35'/40' Diesel Bus
30'/35'/40' Fuel Cell Bus	$ 0.56	OCTA reported labor and maintenance costs for the first year of service of a first-generation vehicle
Fuel Cell Cutaway	$ 0.56	OCTA reported labor and maintenance costs for the first year of service of a first-generation vehicle

This assessment also estimates the cost impact of midlife overhauls for major components in each type of bus, as summarized in **Table 16.** In a midlife overhaul, technicians look for signs of corrosion and install more durable parts. The costs in **Table 16** are the starting values for midlife overhaul costs. As a reminder, BEB maintenance cost does not include the battery warranty price of $50,000, which is purchased in the year of procurement and covers a single mid-life battery replacement.

Table 16 - Midlife Overhaul Cost Assumptions

Type	Overhaul Scope	Estimate	Source
Diesel	Engine/Transmission Overhaul	$56k per bus	BCAG
Cutaway	Engine/Transmission Overhaul	$10k per cutaway	BCAG
FCEB	Fuel Cell Overhaul	$40k per bus	Average cost by OEM and fuel cell manufacturer

Baseline

The 12-year replacement cycle creates a cyclical pattern in maintenance costs every six years due to midlife overhauls. As a result, expected maintenance costs spike every six years after a large number of buses are purchased, such as in 2036. Since this scenario represents a fleet that stays almost entirely composed of diesel buses and gas cutaways, the peaks consistently repeat every 12 years at the midlife of large purchases. In non-midlife and replacement years, the average annual maintenance cost is approximately $640,000.

Figure 35 shows the combined labor, materials, and midlife overhaul costs for the Baseline scenario for each year of the transition.

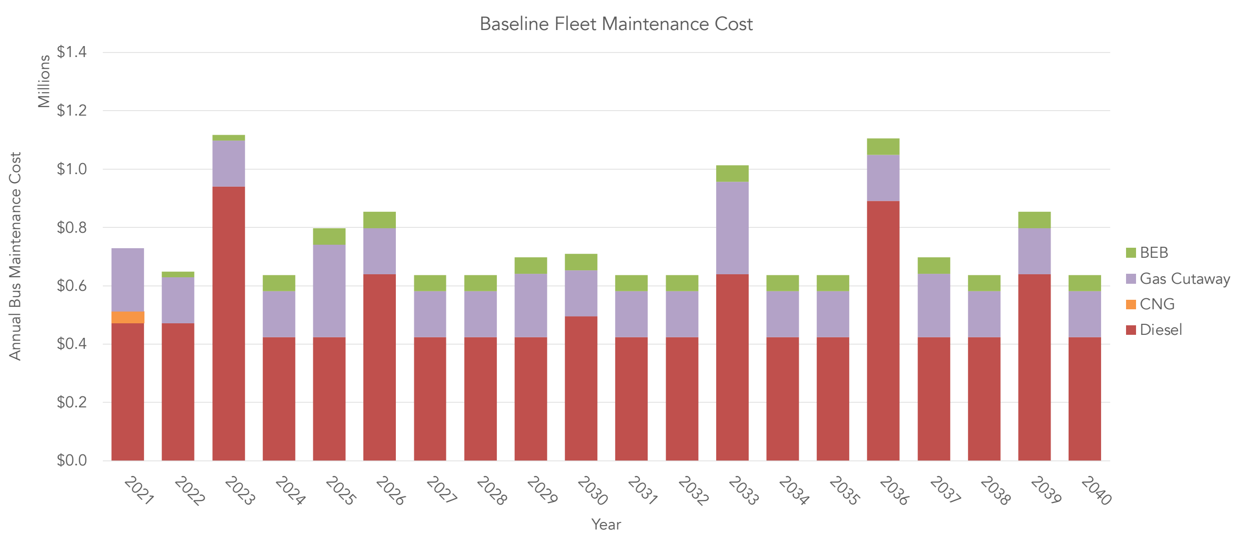


Figure 35 - Annual Fleet Maintenance Costs, Baseline

BEB Only

Figure 36 shows the combined labor and materials for the BEB Only scenario for each year of the transition. For the BEB Only scenario, the cost of the battery warranty is used to reflect the midlife battery replacement. In the assessment, these warranty costs are incurred at the time of the bus purchase and were included in the capital costs seen in the Fleet Assessment and are therefore not included in the costs shown below. The spikes in expected maintenance costs that would be expected for this scenario to occur in the same years that large bus procurements take place such as in 2030 and in its midlife purchase year of 2036 does not appear as it does for FCEB and diesel purchases.

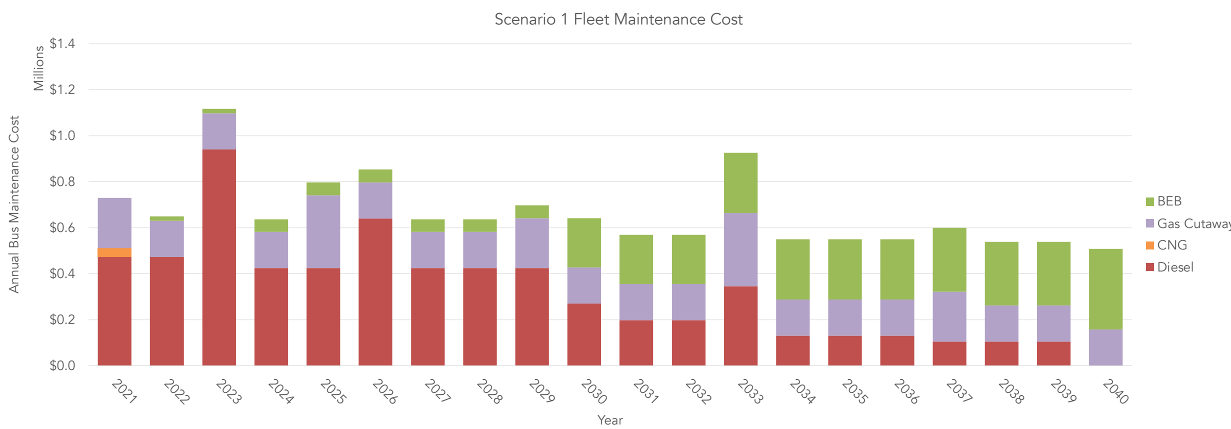


Figure 36 - Annual Fleet Maintenance Costs, BEB Depot-Only

Mixed Fleet – BEB Majority

Figure 37 shows the combined labor, materials, and midlife overhaul costs for the Mixed Fleet – BEB Majority scenario for each year of the transition. Similar to the above scenario, anticipated midlife battery replacements for ZEBs are covered in the extended battery warranty purchased in the year of purchase and can be seen in the Fleet Assessment. In this scenario, the largest procurement of 8 FCEBs and 4 fuel cell electric cutaways is expected to take place in 2030. As such overhaul costs are incurred in year 2033 when the cutaways are at midlife and 2036 when the FCEBs are at midlife.

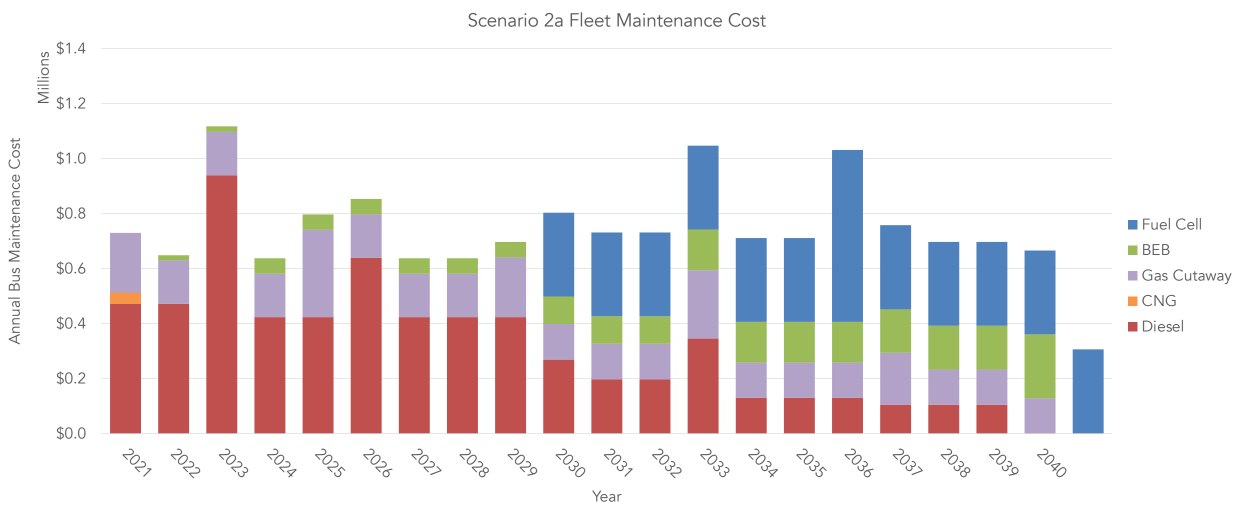


Figure 37 - Annual Fleet Maintenance Costs, Mixed Fleet – BEB Majority

Mixed Fleet – FCEB Majority

Figure 38 shows the combined labor, materials, and midlife overhaul costs for the Mixed Fleet – FCEB Majority scenario for each year of the transition. The pattern of high-cost years is very similar to the previous scenario with fuel cell electric cutaways incurring high costs in 3033 and FCEBs incurring high costs in 2036 when their respective midlives occur after being purchased in 2030.

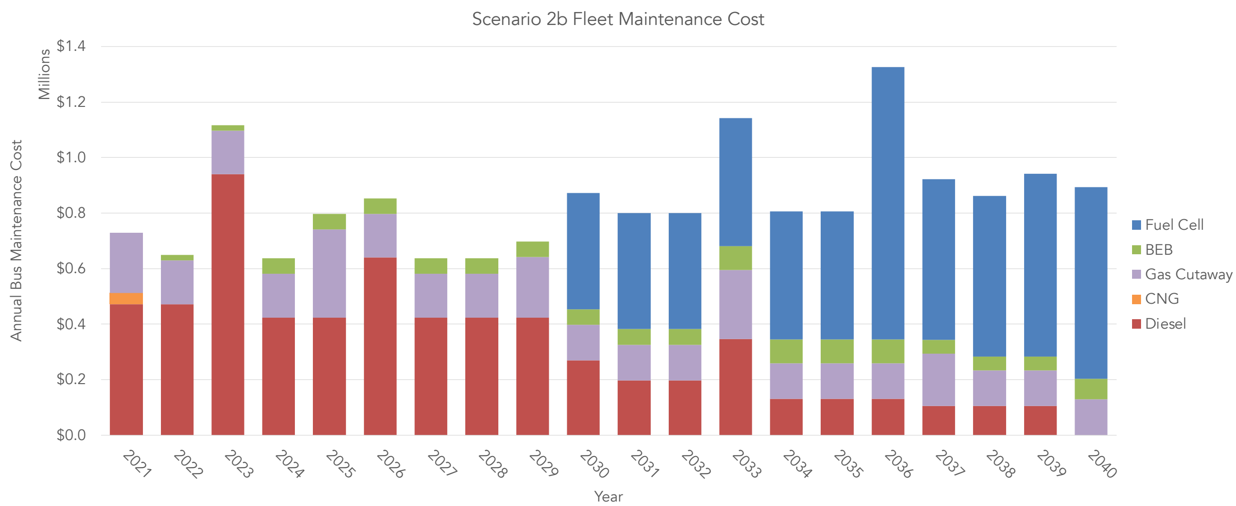


Figure 38 - Annual Fleet Maintenance Costs, Mixed Fleet - FCEB Majority

FCEB Only

Figure 39 shows the combined labor, materials and midlife overhaul costs for the FCEB Only scenario for each year of the transition. Maintenance costs for fuel cells were calculated using industry-reported maintenance costs per mile and maintenance costs reported by OCTA. The estimated cost for one fuel cell overhaul ($40,000) was based on the average cost for this activity as reported by bus and fuel cell manufacturers. The spike in 2036 is the result of mid-life fuel cell replacement.

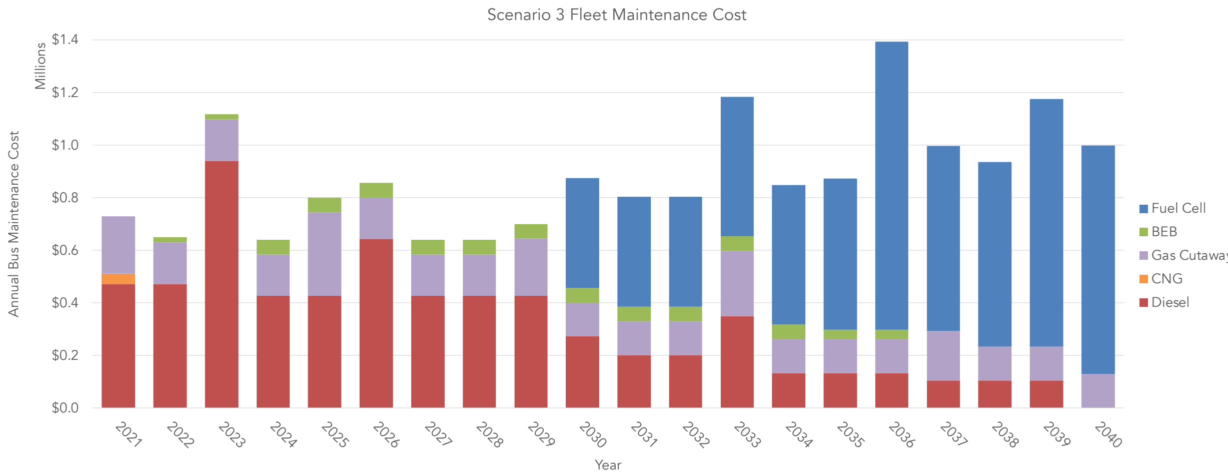


Figure 39 - Annual Maintenance Costs, FCEB Only

Maintenance Assessment Cost Comparison

Figure 40 shows the cumulative maintenance costs for each scenario. CTE's Maintenance Assessment projects that by 2040, the FCEB Only scenario will incur the highest cumulative maintenance cost ($18M) while the BEB Depot Only scenario will incur the least amount of maintenance cost ($13M) over the transition period. The cumulative maintenance cost for the Mixed Fleet – BEB Majority Scenario is on par with the Baseline scenario. The cumulative maintenance cost for the Mixed Fleet – FCEB Majority Scenario is only slightly lower than the FCEB Only Scenario at $17M.

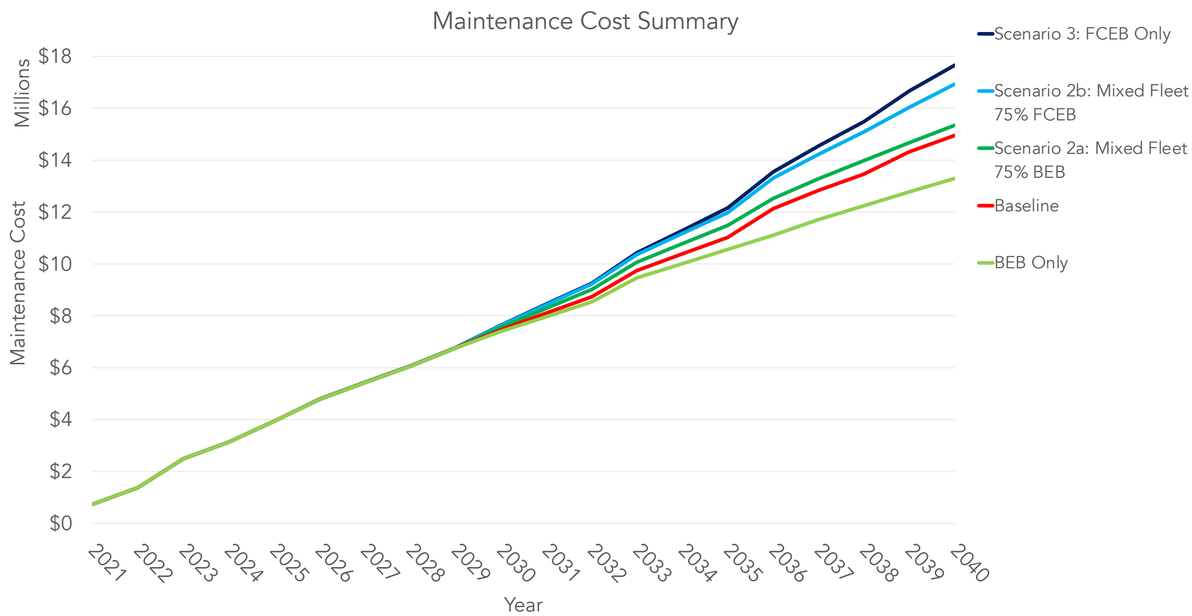


Figure 40 - Total Costs, Maintenance Assessment

Figure 41 shows the total maintenance costs for each scenario at the end of the 20-year transition period. The total maintenance cost for the FCEB Only scenario is shown to be the costliest because of its because of its higher average cost for fuel cell as well as higher estimated maintenance cost per mile. Overall, the zero-emission scenarios' maintenance costs are comparable with the Baseline scenario, all of which are within $3 million of the baseline scenario.

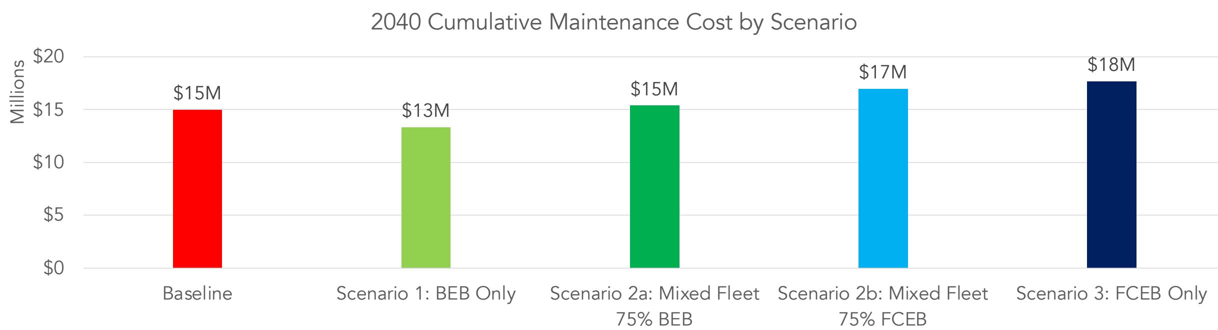


Figure 41 - Cumulative Maintenance Cost by Scenario

Facilities Assessment

The Facilities Assessment determines the scale of fueling infrastructure (charging stations for BEBs and hydrogen fueling stations for FCEBs) that is needed to meet the projected energy use for each scenario. It is informed by the Fleet and Fuel Assessments. Facilities costs are estimated based on the assessed infrastructure requirements for the given fleet and the selected fueling technology. The information in this section is organized according to the fueling technology explored in this transition plan: depot-charging and hydrogen storage and fueling station. Diesel and gas fueling station build and installation costs are not included in this assessment as BCAG has already invested in the fueling infrastructure necessary to support their current fleet.

Assessment Conducted in Collaboration with Stantec

CTE and Stantec developed estimates for components of the BEB infrastructure. In the near term, BCAG will procure six BEBs for their current fleet; however, their existing infrastructure does not currently include charging infrastructure. Therefore, all scenarios, including the baseline scenario, capture costs for the design, equipment, site construction, and installing of chargers. The capacity of the chargers and amount of equipment will vary depending on the BEB fleet size.

Stantec prepared conceptual layouts for the BEB and FCEB Scenarios and Mixed Fleet Scenarios, which are provided in **Appendices – BCAG Depot Site Plans.** When BCAG begins its ZEB transition in 2029, the Butte Regional Operations Center (BROC) depot will require modifications or re-purposing. Stantec also supplied a report including the power requirements, equipment and raceway routing, and phasing to convert the BROC depot to an electric charging and hydrogen fueling depot for the BEB Only, FCEB Only, and the Mixed Fleet: BEB and FCEB scenarios.

Current System Description

The BROC is served electrically by PG&E through a utility owned transformer located just north of the main bus maintenance building, adjacent to Aztec Drive. The existing service provides 1,000 kVA (1,200 Amp) of capacity to the main service switchboard ("SSB") located next to the transformer. Also adjacent to the transformer are two standby diesel generators "EGU-1" (750 kVA) and "EGU-2" (250 kVA). Fuel for the generators is stored in a nearby underground storage tank. There is reportedly enough onsite fuel to power the entire Operation Center current operations for more than one week.

The power output from switchboard SSB and the standby engines is fed into an automatic transfer switch (ATS). In the event of a utility power interruption, the ATS connects the site electrical loads to the standby engines and disconnects the feed from the SSB. The ATS is located next to the SSB near the main transformer and the standby engines.

Power from the ATS is fed to the main switchboard (MSB). Feeder breakers in MSB feed 480V electrical distribution panels and stepdown transformers in the Operations/Admin, Maintenance, and BCAG Buildings as well as the wash area.

Power from a 300 kVA photovoltaic generation system mounted on the parking area canopies is fed to the SSB where it can be used by the site operations. Excess power is exported to PG&E under a Net Energy Metering arrangement. Power demands in excess of the photovoltaic (PV) production is imported from PG&E.

The Operations Center electrical system is in excellent condition and was installed as part of the 2015 site development. The equipment has an estimated remaining service life in excess of 20 years.

System Capacities

The primary PG&E service feeding the facility is 1,000 kVA (900 kW), and the SSB is rated at 1,200 Amps. The eight 480-208/120 V transformers served by the SSB have a total capacity of 382 kVA. Actual site demand data was not available at the time of this writing but, based on the known connected loads, is estimated that the current coincident peak electrical demand is approximately 450 kVA (400 kW). Prior to the conversion of the bus fleet to BEBs or FCEBs, there are no expectations of significant demand growth on the site.

The existing standby generators have a combined capacity of 1,000 kVA and can fully replace the available utility power service.

Description of Depot-Charging Infrastructure Considered

Compared to smaller pilot deployments, scaling to a fleetwide BEB deployment requires substantial infrastructure upgrades and a significantly different approach to charging. With small BEB pilot deployments, charging requirements are met relatively easily with a handful of plug-in pedestal chargers and minimal infrastructure investment. For fleetwide BEB transitions, the preferred approach is to use overhead pantograph or reel dispensers attached to gantries installed above bus parking lanes to minimize the impact on available parking and reduce the potential for bus and equipment collisions. Stantec reviewed the structural calculations for the solar canopies and determined that they do not have structural capacity to accommodate the addition of overhead dispensers. Stantec also determined that retrofitting them to do so may be cost prohibitive.

The recommendation is that the underground duct banks be installed from the charger island to each dispenser that is mounted on the ground. BCAG will charge the buses using plug-in dispensers. The duct banks have adequate conduit capacity to support all of the anticipated BEB chargers, data communication, as well as spare conduit to provide paths for future needs. Installing the underground infrastructure at the outset will minimize operational disruptions in the future.

In addition to the installation of charging stations, improvements to existing electrical infrastructure, such as upgrades to switchgear or service connections, are required to support the deployment of BEBs. Planning and design work, including development of detailed electrical and construction drawings required for permitting, is necessary once specific charging equipment has been selected. To define the installation timeline and costs for charging equipment for each scenario, the scope of work is broken into three key project types:

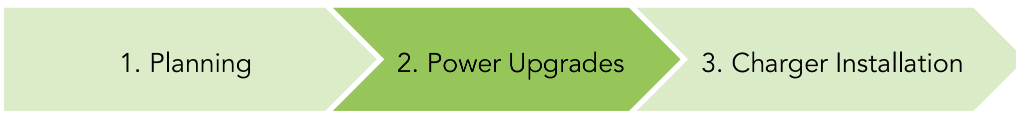
These projects are typically sized and scheduled to meet near-term charging requirements rather than immediately building out all necessary infrastructure for a full fleet transition.

The following key assumptions were applied in BCAG's Facilities Assessment for BEB deployments:

- One dual cable BEB charging dispensers with power connections for every bus;
- One BEB charging cabinet and associated feeders per two dual cable BEB charging dispenser;
- New 480V panel or switchgear. Feeder from 480V panel/switchgear to charging cabinets rated at 20A per cabinet;
- Charging cabinets to dual dispenser via vault C is assumed at 350A per dispenser;
- Pairing and ethernet connections is assumed for dual dispensers;
- Two buses per 150 kW charger;
- Two charge windows (meaning that no more than half of the fleet will ever be charging at a given time);
- Off-peak, overnight charging with automated charge management software to help reduce demand on the grid;
- Dispenser capacity to serve up to 80% of the fleet at a time;
- No movement of buses overnight.

Infrastructure Planning Project

Charging infrastructure for a large BEB fleet has significant power and space requirements. Large-scale fleets may require bus depot redesigns to accommodate the additional equipment. Planning is an essential step in understanding the best solutions to keep electricity costs down while meeting service requirements. The estimated planning cost for the infrastructure transition at the BROC depot is $200,000, which is scheduled to occur in the year prior to installation of the first charging infrastructure project.



Power Upgrade Projects

Power upgrade projects include construction of transformer foundations and installation of transformers. It is assumed that transformers will be modular and that incremental power requirements will be met over time. These costs are variable by scenario, but all Power Upgrade project costs assume that PG&E will install the transformer for BCAG's service, as well as several additional costs as seen in **Table 17**.

Table 17 - Depot Power Upgrade Cost Assumptions, BEB Only Scenario

Transformer/Switchback Pad	Cost	Unit
Transformer	PG&E Cost (Not Passed to Agency)	
Electrical Upgrades on Site	Dependent on Scenario	Total
General Requirements	15%	per project costs
Design Contingency	20%	on project costs
Market Factor	7%	on project costs
Bonds	2%	on project costs and contingency
Insurance	6.5%	on project costs and contingency

Power upgrades are consolidated to occur in selected years, in accordance with the required demand.

Charger Installation Projects

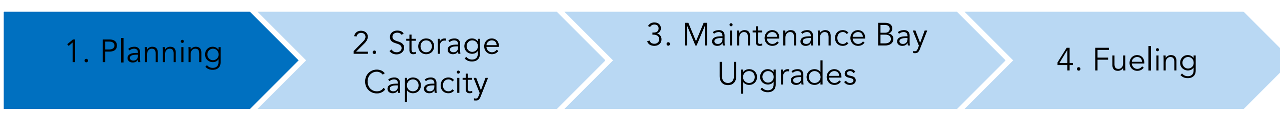
Charging projects include purchase and installation of 150 kW power cabinets with two dispensers each. Since there are two dispensers per charger, every two buses will require one charger. **Table 18** provides the costs assumed for charger installs.

Table 18 - Charger Project Cost Assumptions

Electric Charging Station Costs	Unit Cost
BEB Charging Cabinet with 2 Dispensers	$ 389,000

Description of Hydrogen Fueling Infrastructure Considered

To define the timeline and costs to build hydrogen fueling infrastructure for each scenario, CTE breaks the scope of work into four key project types: (1) planning, (2) structural, (3) maintenance bay upgrades, and (4) fueling. Projects are sized and scheduled to meet near-term fueling requirements.



Infrastructure Planning Project

Building hydrogen infrastructure requires planning at each depot. The total projected cost of planning for BCAG's project is $200,000.

Storage Capacity

The total cost for permanent hydrogen fueling infrastructure project is approximately $5.4 million over the transition period. The first planning project is scheduled in 2029, with installation in 2030, which will add the initial 50-bus capacity tank.

Table 19 –Hydrogen Storage Infrastructure Elements

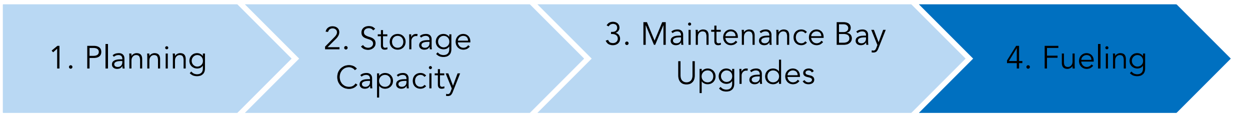
Infrastructure Element	Cost	Unit
Hydrogen Storage	$500,000	Total
General Requirements	15%	per project costs
Design Contingency	20%	on project costs
Market Factor	7%	on project costs
Bonds	2%	on project costs and contingency
Insurance	6.5%	on project costs and contingency

Maintenance Bay Upgrade Projects

Maintenance bays at each depot require hydrogen detection and exhaust equipment to ensure safety. A total of 6 maintenance bays will require upgrades. CTE assumes about $58,000 per bay for the required upgrades. This cost comes from the requirement of additional ventilation systems. For maintenance bay upgrade projects, CTE estimates a total cost of $350,000 for BCAG in 2030.

Table 20 – Maintenance Bay Upgrade Estimates

Infrastructure Element	Cost	Unit
Hydrogen Safety Upgrades	$350,000	Total
General Requirements	15%	per project costs
Design Contingency	20%	on project costs
Market Factor	7%	on project costs
Bonds	2%	on project costs and contingency
Insurance	6.5%	on project costs and contingency



For hydrogen fueling equipment, it is economical to build a station in a single project with all necessary mechanical and fueling components. Storage tanks can be added in a modular fashion as demand increases, separately from other fueling components if needed. What is referred to as "fueling projects" include:

1. Dispenser(s);
2. All mechanical process equipment and hydrogen wetted components;
3. Design, engineering, and permitting;
4. Construction;
5. Demolition of existing pavement, and excavation;
6. Installation of new equipment foundations;
7. All electrical conduit, conductors, and termination;
8. Emergency shut down and notification system;
9. Mechanical installation;
10. Electrical utilities and switchgear.

The number of dispensers varies between the BEB Majority Mixed Fleet and the FCEB Only and FCEB Majority Mixed Fleet Scenarios, so the cost for dispensers is variable between scenarios.

Table 21 – Hydrogen Fueling Element Cost Estimates

Infrastructure Element	Cost	Unit
Dispensers	Dependent on Scenario	Total
General Requirements	15%	per project costs
Design Contingency	20%	on project costs
Market Factor	7%	on project costs
Bonds	2%	on project costs and contingency
Insurance	6.5%	on project costs and contingency

Scenario 1: BEB Depot-Only Charging Infrastructure Projects

BEB Charging Infrastructure Cost Summary

The estimated total infrastructure costs for the BEB Only scenario is approximately $8.1 million. **Figure 42** shows the cumulative total cost breakdown. This total cost includes all power upgrade projects, all charger and dispenser installations, all planning projects, design engineering costs and the added contingencies on all costs.

- **INFRASTRUCTURE PLANNING.** Building charging infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **DISPENSERS AND CHARGERS.** A total of 32 dispensers will be needed at BCAG's depot in to accommodate 32 BEBs in the fleet. In total, this scenario requires 16 chargers, assuming two dispensers per charger. Charging projects include purchase and installation of 150 kW chargers and dispensers. These projects total $6.1 million for BCAG by 2040.
- **MW SERVICE UPGRADE.** BCAG will need to add an estimated 3 MW of capacity to its system by 2040 to accommodate charging for 32 BEBs. To meet the growing demand of electricity, the BROC depot will need to upgrade its system to at least 1 MW of capacity by 2022 and up to 2 MW of capacity by 2033. These upgrades are estimated to cost around $1.8 million over the transition period.
- **GENERAL CONDITIONS / GENERAL REQUIREMENTS:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **CONTINGENCY.** A 20% contingency is added on all project costs.
- **MARKET FACTOR.** 7% is added on all project costs, conditions, and contingency.
- **BONDS AND INSURANCE.** 2% is added on all project costs, conditions, contingency, and market factors.
- **CONTRACTOR'S FEE.** 6.5% is added on all project costs, conditions, contingency, and market factors.

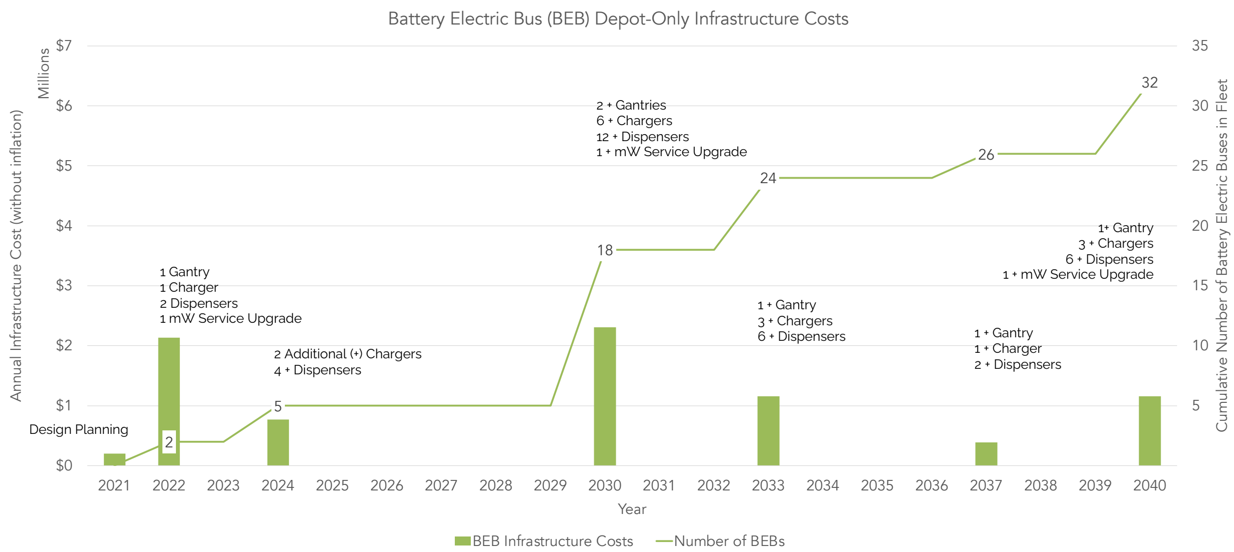


Figure 42 - Infrastructure Costs, BEB Only Scenario

Scenario 2a: Mixed Fleet – BEB Majority Infrastructure Cost Summary

In the Mixed Fleet: BEB Majority scenario, charging infrastructure is required to service a total of 24 BEBs and additional hydrogen fueling infrastructure for eight FCEBs and four fuel cell electric cutaways to support a completely zero-emission bus fleet by 2040. Because there are separate costs associated with each type of ZEB technology, the facilities assessment for this scenario is broken down by each fuel type. The total cost of this scenario would be slightly more than $11.2M.

BEB Charging Infrastructure Cost Summary

The estimated total BEB infrastructure costs for the Mixed Fleet scenario are approximately $6.7 million (see **Figure 43**). The estimated infrastructure costs for the BEB technology & infrastructure includes the following costs:

- **Infrastructure planning.** Building charging infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **Dispensers and Chargers.** A total of 24 dispensers will be needed at BCAG's depot to accommodate 24 BEBs in the fleet. In total, this scenario would require 12 chargers since we assumed two dispensers per chargers. Charging projects include purchase and installation of 150 kW chargers and dispensers. This would come to $4.6 million for BCAG by 2040.

- **MW Service Upgrade.** BCAG will need to add an estimated additional 2 MW of capacity to its system by 2040 to accommodate charging for 24 BEBs. To meet the growing demand for electricity, the BROC depot will need to upgrade its system to at least 1 MW of capacity by 2022 and up to 2 MW of capacity by 2033. This is estimated to cost around $1.9 million over the transition period.
- **General Conditions / General Requirements:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **Contingency.** A 20% contingency is added on all project costs.
- **Market Factor.** 7% is added on all project costs, conditions, and contingency.
- **Bonds and Insurance.** 2% is added on all project costs, conditions, contingency, and market factors.
- **Contractor's Fee.** 6.5% is added on all project costs, conditions, contingency, and market factors.

FCEB Fueling Infrastructure Cost Summary

In addition to BEB charging, hydrogen fueling is required to support the Mixed Fleet: BEB Majority Scenario. Infrastructure is built out over time as necessary to support FCEB deployment. **Figure 43** shows the estimated infrastructure costs for the FCEB technology, which includes the following costs and reaches a sum of $4.6 million:

- **Infrastructure planning.** Building hydrogen infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **Storage Capacity Projects.** The total cost for storage capacity projects at BCAG is approximately $500,000 over the transition period.
- **Maintenance bay upgrades.** Maintenance bay upgrades are required to make the bays compliant with hydrogen safety regulations. At BCAG, CTE integrated Stantec's estimated cost for each bay upgrade at $58,000. This cost estimate stems from the requirement of additional ventilation systems necessary for hydrogen detection. With six maintenance bay and gas detection upgrades, the total cost for hydrogen infrastructure in this scenario is estimated at $1.2 million.
- **H2 Fueling infrastructure.** The number of dispensers is a variable that can be scaled to fit the number of vehicles that need to be fueled. A single dispenser is capable of fueling a single bus every 15 minutes. Therefore, having two dispensers

will allow vehicles to be fueled twice as fast as a single dispenser. Because this scenario requires fueling only 12 vehicles, which could be fueled in three hours with a single dispenser and since this three-hour fueling window is acceptable to BCAG, a single dispenser and associated fueling elements was assumed, which is estimated to cost $1.9 million.

- **General Conditions / General Requirements:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **Contingency.** A 20% contingency is added on all project costs.
- **Market Factor.** 7% is added on all project costs, conditions, and contingency.
- **Bonds and Insurance.** 2% is added on all project costs, conditions, contingency, and market factors.
- **Contractor's Fee.** 6.5% is added on all project costs, conditions, contingency, and market factors.

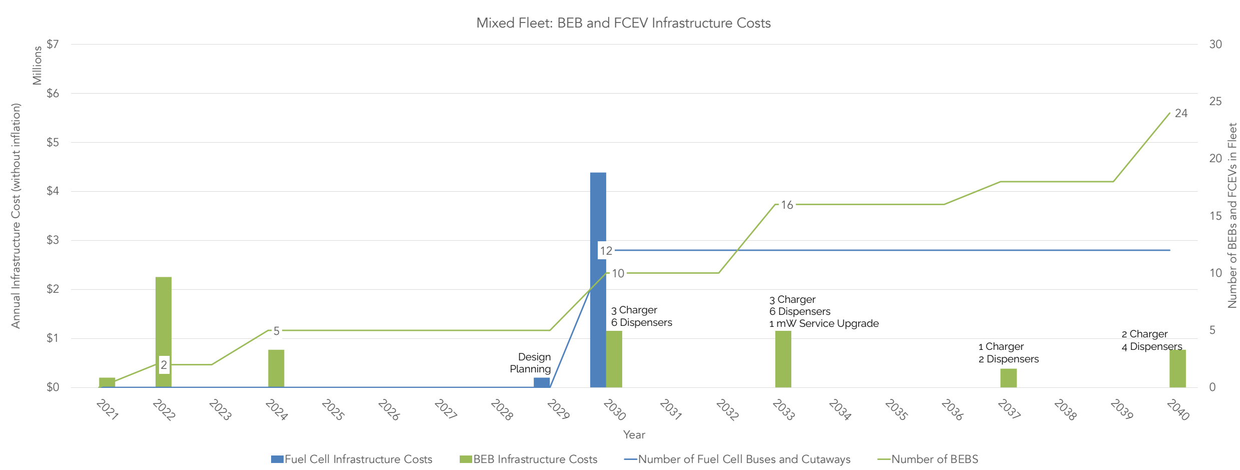


Figure 43 - Infrastructure Costs, Mixed Fleet - BEB Majority Charging Scenario

Scenario 2b: Mixed Fleet – FCEB Majority Infrastructure Cost Summary

In the Mixed Fleet: FCEB Majority scenario, charging infrastructure is required to service a total of eight BEBs, and hydrogen fueling infrastructure is required to fuel 24 FCEBs and four fuel cell electric cutaways to support a completely zero-emission bus fleet by 2040. Because there are separate costs associated with each type of ZEB technology, the facilities assessment for this scenario is broken down by each bus type beginning with BEB. The total infrastructure cost for this scenario is estimated at $8.4 million.

BEB Charging Infrastructure Cost Summary

The estimated total BEB infrastructure costs for the Mixed Fleet scenario are approximately $3.0 million (see **Figure 44**). The estimated infrastructure costs for the BEB technology & infrastructure includes the following costs:

- **INFRASTRUCTURE PLANNING.** Building charging infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **DISPENSERS AND CHARGERS.** A total of eight dispensers will be needed at BCAG's depot in this scenario, to accommodate eight BEBs in the fleet. In total, this scenario would require four chargers, assuming two dispensers per chargers. Charging projects include purchase and installation of 150 kW chargers and dispensers. This would come to $1.6 million for BCAG by 2040.
- **MW SERVICE UPGRADE.** BCAG will need to add an estimated additional 1 MW of capacity to its system by 2040 to accommodate charging for eight BEBs. To meet the growing demand of electricity, the BROC depot will need to upgrade its system to at least 1 MW of capacity by 2022. This is estimated to cost $1.3 million.
- **GENERAL CONDITIONS / GENERAL REQUIREMENTS:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **CONTINGENCY.** A 20% contingency is added on all project costs.
- **MARKET FACTOR.** 7% is added on all project costs, conditions, and contingency.
- **BONDS AND INSURANCE.** 2% is added on all project costs, conditions, contingency, and market factors.
- **CONTRACTOR'S FEE.** 6.5% is added on all project costs, conditions, contingency, and market factors.

FCEB Fueling Infrastructure Cost Summary

In addition to BEB charging, hydrogen fueling is required to support the Mixed Fleet: FCEB Majority Scenario. Infrastructure is built out over time as necessary to support FCEB deployment. **Figure 44** shows the estimated infrastructure costs for the FCEB technology, which includes the following costs and reaches a sum of $5.4 million:

- **INFRASTRUCTURE PLANNING.** Building hydrogen infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.

- **Storage Capacity Projects.** The total cost for storage capacity projects at BCAG is approximately $500,000 over the transition period.
- **Maintenance bay upgrades.** Maintenance bay upgrades are required to make the bays compliant with hydrogen safety regulations. At BCAG, CTE integrated Stantec's estimated cost for each bay upgrade at $200,000. This cost estimate stems from the requirement of additional ventilation systems necessary for hydrogen detection. With 6 maintenance bay and gas detection upgrades, the total cost for hydrogen infrastructure in this scenario is estimated at $1.2 million.
- **H2 Fueling infrastructure.** The number of dispensers present on the station is a variable that can allow hydrogen fueling equipment to be scaled to fit the number of vehicles that need to be fueled. A single dispenser is capable of fueling a single bus every 15 minutes. Therefore, having two dispensers will allow vehicles to be fueled twice as fast as a single dispenser. Since this scenario requires fueling 28 vehicles, which would take 7 hours with a single dispenser, two dispensers and associated fueling elements was assumed, which is estimated to cost $2.4 million.
- **General Conditions / General Requirements:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **Contingency.** A 20% contingency is added on all project costs.
- **Market Factor.** 7% is added on all project costs, conditions, and contingency.
- **Bonds and Insurance.** 2% is added on all project costs, conditions, contingency, and market factors.
- **Contractor's Fee.** 6.5% is added on all project costs, conditions, contingency, and market factors.

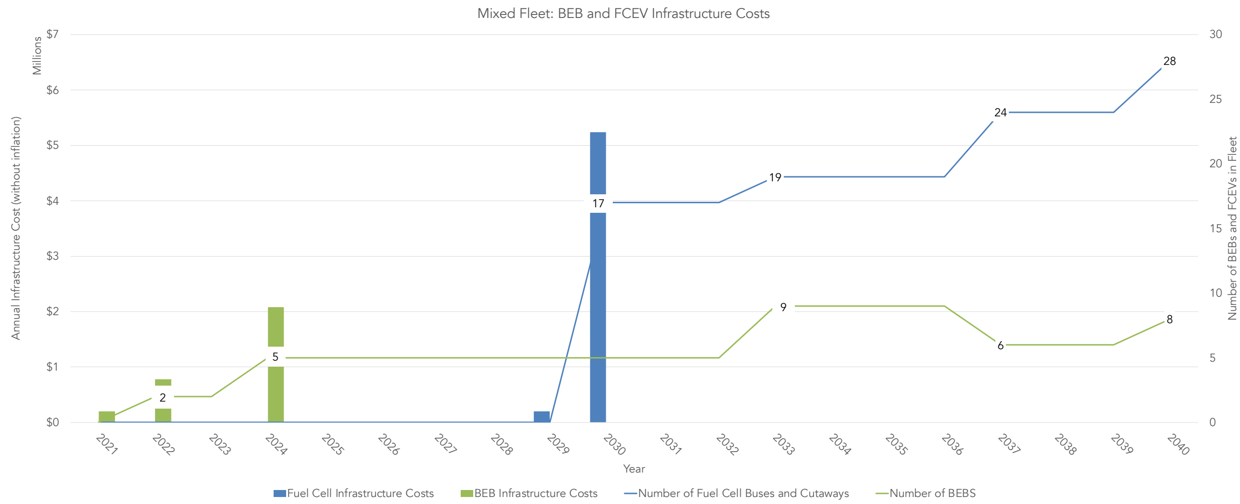


Figure 44 - Infrastructure Costs, Mixed Fleet - FCEB Majority Charging Scenario

Scenario 3: FCEB Only

The FCEB Only scenario assumes a fuel cell bus fleet and four fuel cell cutaways. As in the case of the Baseline scenario, the five known BEB procurements will require electric charging infrastructure. Therefore, while this scenario plans for a full transition to hydrogen fueling, electric depot charging infrastructure, equipment, and installation are considered. In the FCEB Only scenario, BCAG will have procured 32 FCEBs and 4 fuel cell cutaways by 2040. The total infrastructure cost for this scenario would be slightly over $8.0 million.

BEB Charging Infrastructure Cost Summary

The estimated total BEB infrastructure costs for the Mixed Fleet scenario are approximately $2.7 million (see **Figure 45**). The estimated infrastructure costs for the BEB technology & infrastructure includes the following costs:

- **Infrastructure planning.** Building charging infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 and occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **Dispensers and Chargers.** A total of six dispensers will be needed at BCAG's depot in this scenario, to accommodate 5 BEBs in the fleet that. In total, this scenario would require 3 chargers since we assumed two dispensers per chargers. Charging projects include purchase and installation of 150 kW chargers and dispensers. This would come to $1.6 million for BCAG by 2040.

- **MW Service Upgrade.** BCAG will need to add an estimated additional 2 MW of capacity to its system by 2040 to accommodate charging for 24 BEBs. To meet the growing demand of electricity, the BROC depot will need to upgrade its system to at least 1 mW of capacity by 2022. This cost is estimated at $1.3M.
- **General Conditions / General Requirements:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **Contingency.** A 20% contingency is added on all project costs.
- **Market Factor.** 7% is added on all project costs, conditions, and contingency.
- **Bonds and Insurance.** 2% is added on all project costs, conditions, contingency, and market factors.
- **Contractor's Fee.** 6.5% is added on all project costs, conditions, contingency, and market factors.

FCEB Fueling Infrastructure Cost Summary

In addition to BEB charging, hydrogen fueling is required to support the FCEB Only Scenario. Infrastructure is built out over time as necessary to support FCEB deployment. **Figure 45** shows the estimated infrastructure costs for the FCEB technology, which includes the following costs and reaches a sum of $5.4 million:

- **Infrastructure planning.** Building hydrogen infrastructure requires planning at the depot. This assessment assumes that a planning project costs $200,000 occurs only once per depot. The total cost of planning projects for BCAG's single depot is approximately $200,000.
- **Storage Capacity Projects.** The total cost for storage capacity projects at BCAG is approximately $500,000 over the transition period.
- **Maintenance bay upgrades.** Maintenance bay upgrades are required to make the bays compliant with hydrogen safety regulations. At BCAG, CTE integrated Stantec's estimated cost for each bay upgrade at $58,000. This cost estimate stems from the requirement of additional ventilation systems necessary for hydrogen detection. With 6 maintenance bay and gas detection upgrades, the total cost for hydrogen infrastructure in this scenario is estimated at $1.2M.
- **H2 Fueling infrastructure.** The number of dispensers present on the station is a variable that can allow hydrogen fueling equipment to be scaled to fit the number of vehicles that need to be fueled. A single dispenser is capable of fueling a single bus every 15 minutes. Therefore, having two dispensers will allow vehicles to be fueled

twice as fast as a single dispenser. Since this scenario requires fueling 32 vehicles, which would take 8 hours with a single dispenser, two dispensers and associated fueling elements was assumed, which is estimated to cost $2.4 million.

- **General Conditions / General Requirements:** A 15% General Conditions and Requirements cost was applied to all projects to account for costs incurred by the contractor that are not directly construction costs, such as business operations.
- **Contingency.** A 20% contingency is added on all project costs.
- **Market Factor.** 7% is added on all project costs, conditions, and contingency.
- **Bonds and Insurance.** 2% is added on all project costs, conditions, contingency, and market factors.
- **Contractor's Fee.** 6.5% is added on all project costs, conditions, contingency, and market factors.

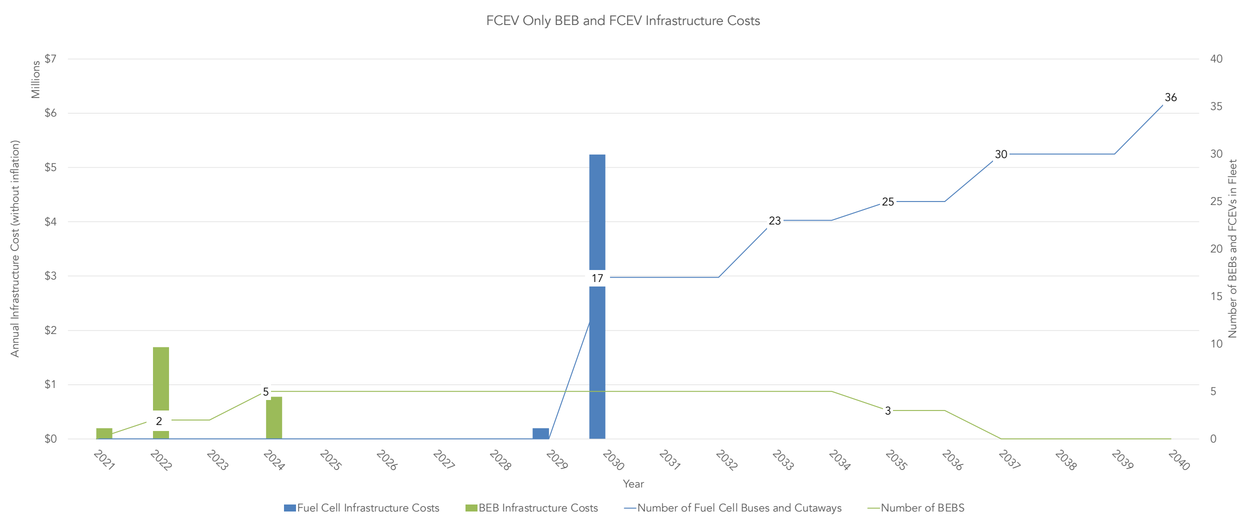


Figure 45 - Infrastructure Costs, FCEB Only Scenario

Facilities Assessment Cost Comparison

The Facilities Assessment includes all infrastructure-related costs over the transition for each scenario. **Figure 46** shows the cumulative infrastructure costs for each scenario.

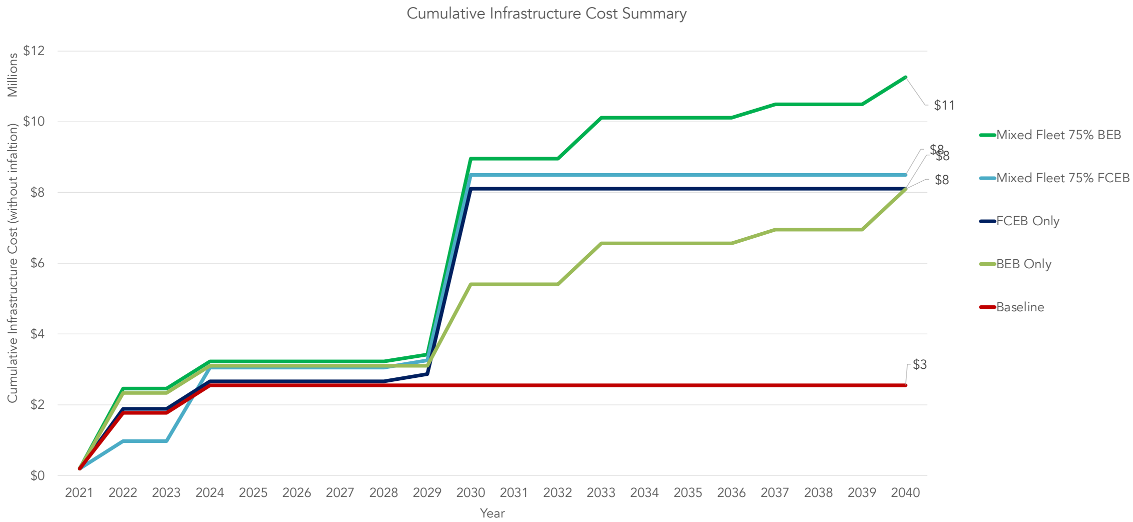


Figure 46 - Total Cumulative Costs, Facilities Assessment

Redundancy, Resilience, and Emergency Response Assessment

The Redundancy, Resilience, and Emergency Response (3R) Assessment investigates the new risks to an agency's ability to provide service during power outages or fuel disruptions and the ability to support required emergency response activities, such as community evacuation with a full ZEB fleet. The project team applied a risk assessment methodology to evaluate various adaptation measures that reduce risks from identified threats under each transition scenario. The effectiveness of adaptation measures is informed by factors such as cost, risk reduction capabilities, a transit agency's risk tolerances, facility constraints, and environmental impacts.

BCAG's primary concerns are addressing ZEB fleet operation in the event of a fuel interruption (i.e., power outage or hydrogen fuel delivery disruption) and planning for evacuation support. BCAG has previously been impacted by severe wildfires, which required community evacuation, and may also put BCAG at risk from planned power outages. It is expected that severe wildfires and flooding events will become more likely and more extreme in the future due to climate change impacts.

B-Line provides community evacuation and re-population support during disaster response, as directed by the Butte County Sheriff. A large evacuation effort would likely require 75% of fixed route vehicles to be staged around the service area and available to evacuate residents for 24-72 hours, and a moderate evacuation effort would require about 25-50% of the fixed route vehicles to be staged and available for 24 hours. During any evacuation effort, some reduced service may be provided in the community with whatever vehicles are available. BCAG expects that all re-population efforts can be accomplished with cutaway vehicles. One round trip for evacuation support could be up to 50 miles, taking about 90 minutes, with about 75% of the trip on the highway. The various ZEB transition scenarios will require different fueling and deployment strategies to meet the first responder needs during disaster response. BCAG will coordinate with the County Sherriff's department and other local emergency response agencies to review the fleet's capabilities and plan for supporting community evacuation.

3R Methodology

Risks are calculated using the following formula:

$$Risk\ Score = Threat\ Likelihood \times Vulnerability \times Consequences$$

Threat likelihood is the probability of a threat occurring in a given year. Evaluated from Low to Very High, with a maximum value of 1. CTE worked with BCAG to assess the likelihood of each defined threat, utilizing information on past disasters in B-Line's service area, climate data trends, and the experiences of other transit agencies deploying ZEBs.

Vulnerability is the probability that a transit agency will experience consequences if a threat occurs, based on internal capabilities to prepare for, respond to, and recover from threats. Evaluated from Low to Very High, with a maximum value of 1. CTE collected information on BCAG's existing internal capabilities, and evaluated potential improvements to those capabilities from the implementation of adaptation options.

Consequences are the level of impacts that a transit agency would experience if a threat occurs. Evaluated from Low to Very High within different categories, with a maximum value of 4. The Consequences Matrix used in this 3R Assessment is shown in **Table 22**. CTE reviewed the matrix with BCAG and customized the categories, category weightings, and definitions of severity levels to accurately reflect BCAG's tolerances for different types of impacts or consequences.

Table 22 - 3R Consequences Matrix

Consequences Matrix						
Category	**Category Definition**	**Category Weight**	**Low**	**Medium**	**High**	**Very High**
Regional Economic and Customer Impacts	Impacts to ridership and the regional economy from missed or modified service.	**30%**	< 1 day of impacts to ridership and regional economic impacts	1 day of impacts to ridership and regional economic impacts	1 day < duration of impacts < 1 week to ridership and regional economic impacts	> 1 week of service impacts to ridership and regional economic impacts
Staffing Impacts	Impacts to staff due to stress put on workforce needs to support disaster response.	**20%**	<5% of buses require special fueling logistics or 5% of operators required to alter schedules	5% - 25% of buses require special fueling logistics or 5% - 25% of operators required to alter schedules	25% - 50% of buses require special fueling logistics or 25% - 50% of operators required to alter schedules	> 50% of buses require special fueling logistics or > 50% of operators required to alter schedules
Public Safety Impacts	Impacts to public safety if the ability to fulfill first responder responsibilities are impacted during an emergency response.	**25%**	Able to fulfill all requested emergency response support during incident	Able to fulfill 80% of requested emergency response support during incident)	Able to fulfill 50% of requested emergency response support during incident	Able to fulfill <50% of requested emergency response support during incident
Financial and Operating Impacts	The loss of revenue from missed service, as well any operational costs required modify or adapt service based on available resources and response requirements.	**15%**	No delays to service	< 4 hour delay in service	4 - 24 hour delay in service	> 24 hour delay in service
Equipment Damage	Loss of or damage to transit agency equipment from a hazard.	**10%**	< $3K of equipment damage	$3K-$25K of equipment damage	$25K - $750K of equipment damage	>$750K of equipment damage

The maximum possible risk score is 4; a higher risk score indicates a higher level of risk. A matrix showing overall risk level by risk score is shown in **Table 23.** In this matrix, the color indicated by the intersection of the threat likelihood and consequences x vulnerability indicates the relative risk value with green meaning less than 0.19 out of 4, yellow indicating 0.2 to 1.9 out of a possible 4 points, light orange indicating a high risk of 1.2 to 2.9 and dark orange indicating a very high risk value of 3 to 4.

Table 23 – Risk Matrix

		Consequences x Vulnerability			
		Low	**Medium**	**High**	**Very High**
Threat Likelihood	**Low**	Low Risk	Low Risk	Low Risk	Medium Risk
	Medium	Medium Risk	Medium Risk	Medium Risk	High Risk
	High	Medium Risk	High Risk	High Risk	Very High Risk
	Very High	Medium Risk	High Risk	Very High Risk	Very High Risk

Low Risk	**< 0.19**
Medium Risk	**0.2 to 1.19**
High Risk	**1.2 to 2.99**
Very High Risk	**3 to 4**

The following parameters are key components of the 3R Assessment methodology:

- **ZEB Transition Scenarios:** Future fleet composition alternatives at a specific year.
- **Threats:** An event that will impact the transit agency's ability to provide service or meet first responder capabilities if it occurs. Threats can be natural disasters, equipment failures, intentional attacks, or accidents.
- **Adaptation Measures:** Any activity, procedure, or equipment that can reduce the likelihood of a threat occurring, reduce the vulnerability from experiencing threats, or reduce the level of consequences experienced if a threat occurs.

Assessments are conducted by assessing the threat likelihood, vulnerability, and consequences for a specific scenario-threat pair with no adaptation options. Then, the threat likelihood, vulnerability, and consequences are re-assessed for the same scenario-threat pair with each adaptation option. This approach is summarized in **Figure 47.**

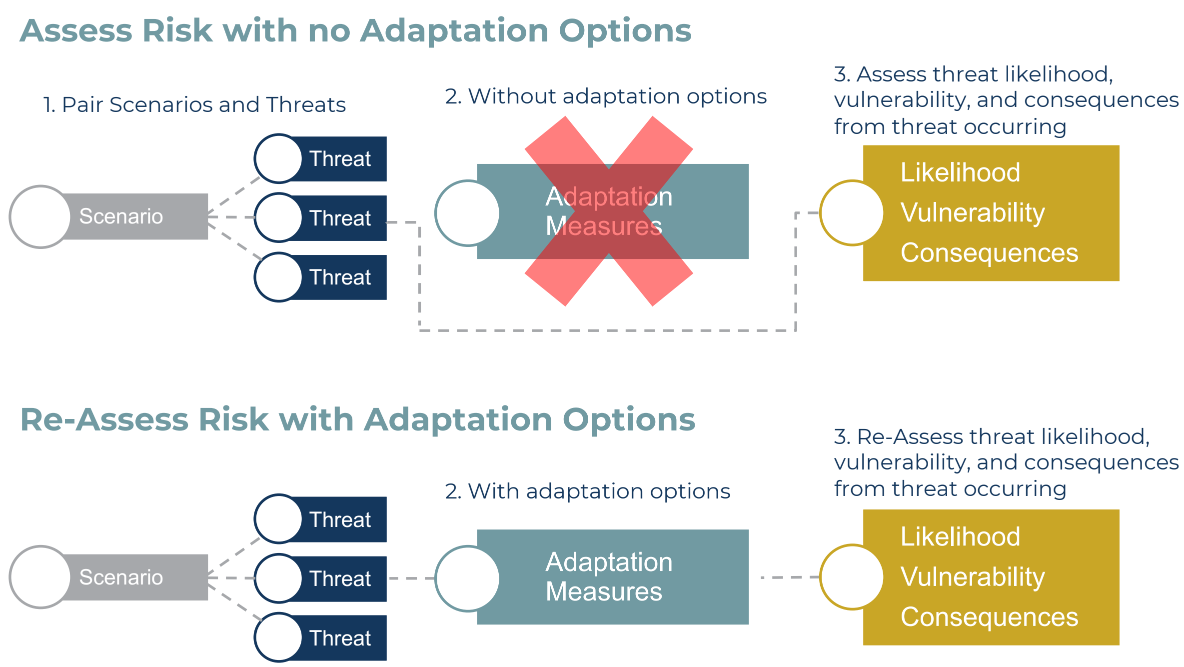


Figure 47 - 3R Risk Assessment Process

The following metrics are used to summarize the results of the 3R Risk Assessment:

- **Risk Score:** Level of risk for an analysis, with or without adaptation measure (**Figure 48 - Illustrative Example of Risk Scores**)
    - Risk score = Likelihood x Vulnerability x Consequences
    - Higher risk score = higher risk
    - Lower risk score = lower risk

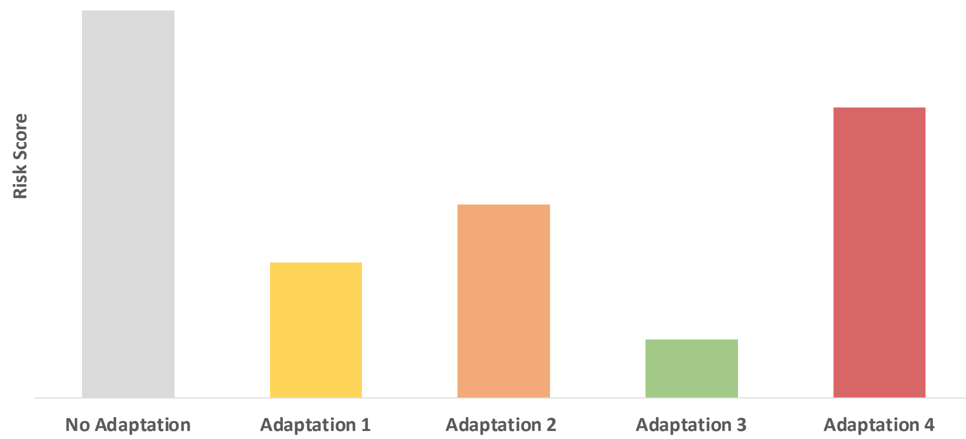


Figure 48 - Illustrative Example of Risk Scores (Note: This Graph is Provided as an Example and is Not Specific to this Transition Plan)

- **Risk Reduction Units (RRUs):** Effectiveness of an adaptation measure or package at reducing risk **(Figure 49)**
  - RRU = Risk Score without adaptation measures - Risk Score with adaptation measure or package
  - Higher RRU = more risk reduction
  - Lower RRU = less risk reduction

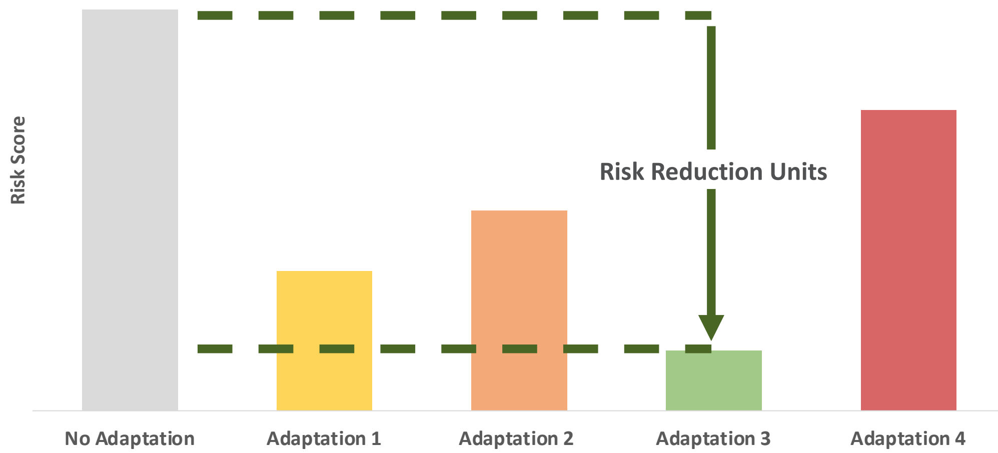


Figure 49 - Illustrative Example of RRUs (Note: This Graph is Provided as an Example and is Not Specific to this Transition Plan)

- **$/RRU:** Cost effectiveness of adaptation measures or packages (**Figure 50**)
  - $/RRU = Cost of adaptation measure or package / RRUs
  - Higher $/RRU = less cost effective
  - Lower $/RRU = more cost effective

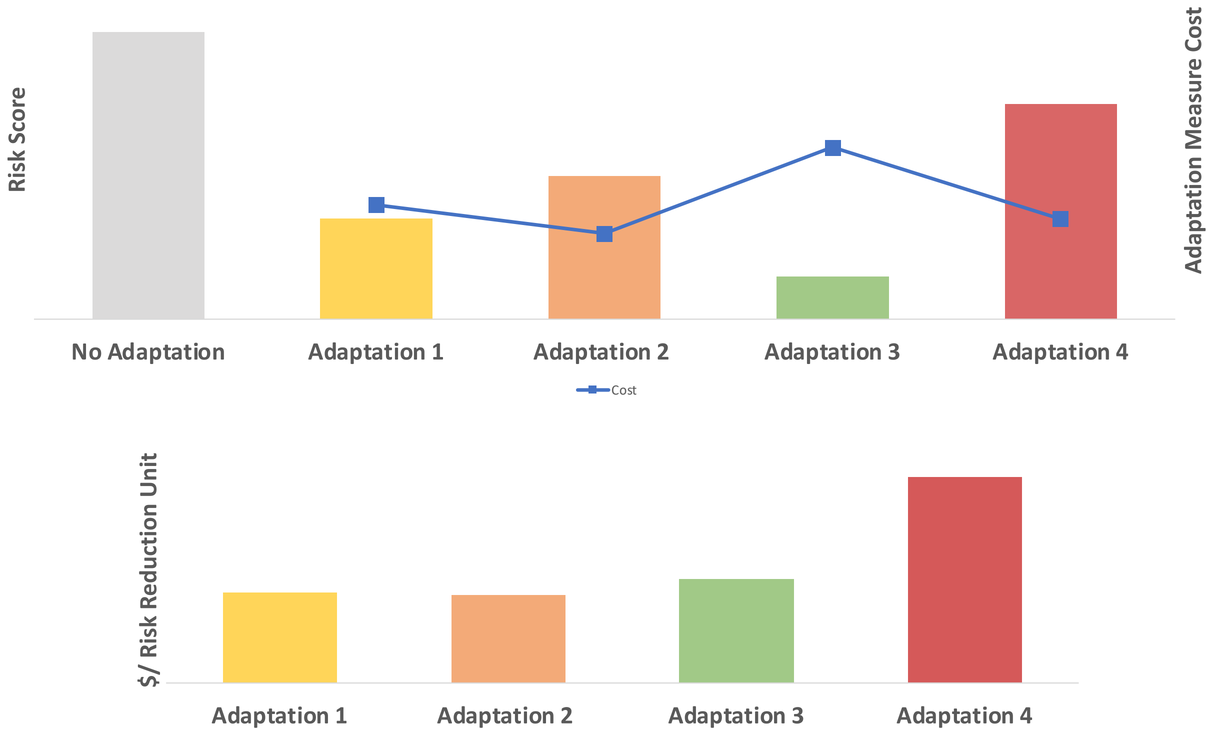


Figure 50 - Illustrative Example of Using Adaptation Measure Costs to Calculate $/RRU (Note: This Graph is Provided as an Example and is Not Specific to this Transition Plan)

Analysis Inputs

Analysis inputs were defined during workshops with CTE and BCAG. Details on the threats considered in the analysis are shown in **Table** 24**.**

Table 24 - Threats Included in 3R Assessment

Threat	Definition	Duration of Impacts	Service Expectation	Threat Likelihood
Power outage due to grid overload/other event	Power outage in B-Line's service area during ZEB fueling window; no compounding natural disaster impacts to the community.	8 hours	Normal service	High
Wildfire or flood with large evacuation effort	Evacuations requiring 75% of fleet on 24/7 basis. Round trip about 40-50 miles; 75% freeway driving, duration about 90 minutes.	72 hours of evacuation support	Reduced service (Requires 8 buses)	Medium
Wildfire or flood with moderate evacuation effort	Evacuations requiring 25-50% of the fleet or vehicles required to be staged around the service area.	24 hours of evacuation support	Baseline service (Requires 17 buses)	Very High
Hydrogen delivery disruption	Hydrogen shortage due to equipment malfunction or force majeure at production facility interrupts hydrogen deliveries.	1 week 1 month	Normal service Normal service	High Medium
Charging equipment failure	Charging equipment failure due to software update or electrical issue, all charging equipment impacted.	1 week	Normal Service	High

Based on the fleet composition, not every threat is assessed for every scenario. For example, the hydrogen disruption threat was not assessed for the BEB Only scenario. The threat relevance by scenario is shown in **Table 25.**

Table 25 - Threat Relevance by Scenario

Threat	BEB Only	Mixed Fleet - BEB Majority	Mixed Fleet - FCEB Majority	FCEB Only
Power Outage due to Grid overload/other event	✓	✓	✓	✓
Wildfire or Flood with large evacuation effort	✓	✓	✓	✓
Wildfire or Flood with moderate evacuation effort	✓	✓	✓	✓
Hydrogen delivery disruption		✓	✓	✓
Charging equipment failure	✓	✓	✓	

Adaptation measures are any activity, procedure, or equipment that can reduce the likelihood of a threat occurring, reduce the vulnerability from experiencing threats, or reduce the level of consequences experienced if a threat occurs. The details of the adaptation measures considered in this analysis are listed in **Table 26** . Note that generator size corresponds to the peak demand, not the actual required generator size to provide that level of power continuously.

Table 26 - Adaptation Measures Used in the 3R Assessment

Adaptation Measure	Definition	Estimated Capital Costs	Source
750 kW Generator	750 kW peak demand: 4 x 120 kW chargers + hydrogen fueling station (Or 6 x 120 kW chargers)	Diesel: $220,000 Natural gas: $720,000 Natural gas microturbine: $1,230,000	Stantec estimate
300 kW Generator	300 kW peak demand: Hydrogen fueling station only (or 2 x 120 kW chargers)	Diesel: $85,000 Natural gas: $165,000 Natural gas microturbine: $600,000	Stantec estimate
Solar + Storage	Additional battery storage for power equipment during a power outage. Assume 750 kW capacity. 1 MWh capacity with 750 kW output would be enough to recharge about 4 buses or could operate the hydrogen fueling station for about 3-4 hours, which could fuel 32 buses back-to-back in 4 hours with two dispensers.	$2,089,000 (Does not include operational savings from peak shaving or net metering)	Stantec estimate
Secondary Charging Site	Two 150 kW chargers with two dispensers each at a secondary location to facilitate keeping vehicles charged while staged for evacuation support; capabilities to charge 4 buses. Assume chargers are locate at an alternate BCAG facility or at the local school district and can be used during a power outage impacting BCAG's bus depot.	$500,000	CTE estimate of design, construction, and capital costs of charger installation
ICE vehicle contingency fleet	Retaining 8 retired ICE vehicles to serve as the contingency fleet beyond 2040 (may require a waiver from CARB)	$800,000	CARB[18]
Additional hydrogen Storage	7 days of hydrogen storage on-site (industry standard 3 days)	$830,000	Stantec estimate

[18] https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2018/ict2018/appg.pdf

Adaptation measures were grouped into packages to assess the combined capabilities of multiple adaptation measures. **Table 27** shows the adaptation measures considered for the analysis. The three backup power adaptation packages (i.e., Small Backup Power, Medium Backup Power + Solar, Large Backup Power) are included to compare risk reduction capabilities and cost effectiveness. Only one of these packages should be selected for implementation. The other two adaptation packages, ICE Contingency Fleet and Additional Hydrogen Storage can be implemented independently of any of the other package options.

Table 27 - Selected Adaptation Packages for 3R Assessment

Adaptation Package Name	Adaptation Measures Included	Estimated Capital Cost
Small Backup Power	750 kW Generator Secondary charging site	$581,000 - $1,730,000
Medium Backup Power + Solar	300 kW Generator* 750 kW Solar array + 750 kW/1 MWh battery storage Secondary charging site	$2,225,000 - $3,189,000
Large Backup Power	750 kW Generator* 750 kW Solar array + 750 kW/1 MWh battery storage Secondary charging site	$2,330,000 - $4,119,000
ICE Contingency Fleet	ICE Contingency Fleet	$400,000 - $800,000
Additional Hydrogen Storage	One week of hydrogen storage	$810,000 - $830,000

Analysis Results

The risk scores by threat and scenario with no adaptation measures are shown in **Figure 51**. Risk scores without adaptation measures represent the worst-case scenario for each threat.

The risk scores for the power outage threat are the same across all scenarios because if this threat occurs and no adaptation measures are implemented, buses will be unable to fuel and will be unavailable for service. Neither chargers nor hydrogen fueling infrastructure can operate during a power outage.

The BEB Only scenario has the highest level of risk for the evacuation effort threats because the BEBs can only conduct three round trips of the defined evacuation route before having to charge. For the Wildfire or Flood with large evacuation effort threat, BEB Only is the only scenario where the required evacuation needs cannot be met. Meeting the required evacuation needs with the BEB Majority scenario will require all buses, therefore no vehicle will be available to provide any reduced service that may be planned during the evacuation. The scenarios with FCEBs can meet the required evacuation needs and service levels with no adaptation. For the Wildfire or Flood with moderate evacuation effort threat, the evacuation needs can all be met with the fleet composition, but provide varying levels of service.

Higher risk scores are seen for the FCEB Majority and FCEB Only threats for the hydrogen delivery disruption threats because less or no service will be provided once the available hydrogen storage runs out, respectively.

The charging equipment failure threat has the highest risk score overall due to the high threat likelihood and high consequences of not being able to charge any BEBs for one week, which would have significant service impacts based on the number of BEBs in the fleet.

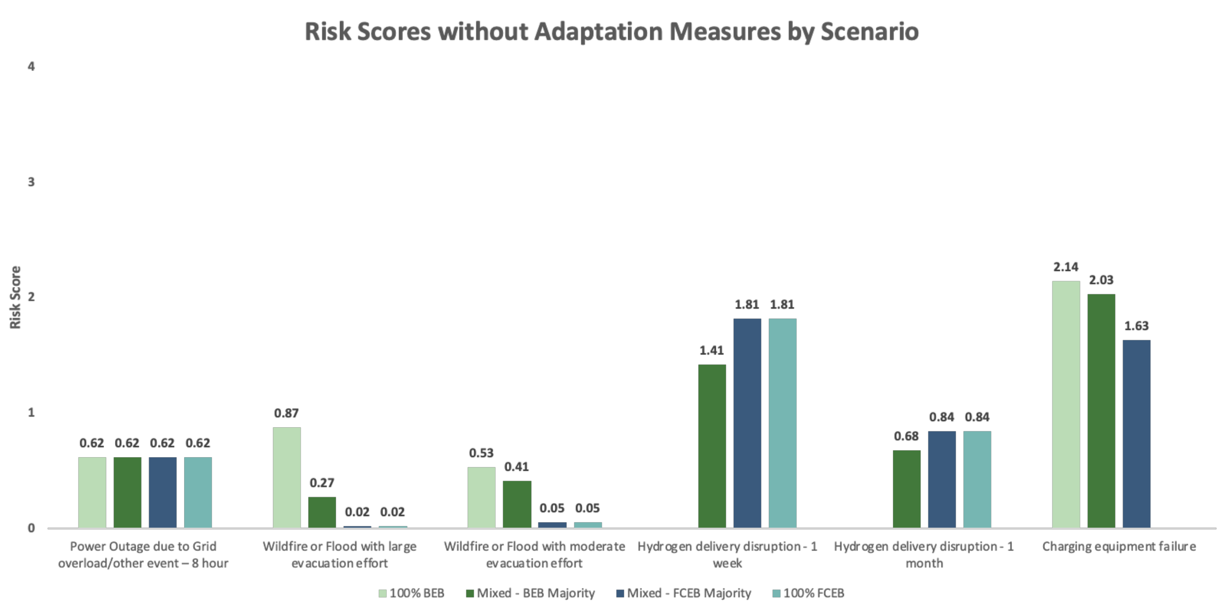


Figure 51 - Risk Scores without Adaptation Measures by Scenario and Threat

R3 Assessment results by scenario are shown below.

BEB Only

Risk scores for all BEB Only assessments, without adaptation and with each adaptation package are shown in **Figure 52.**

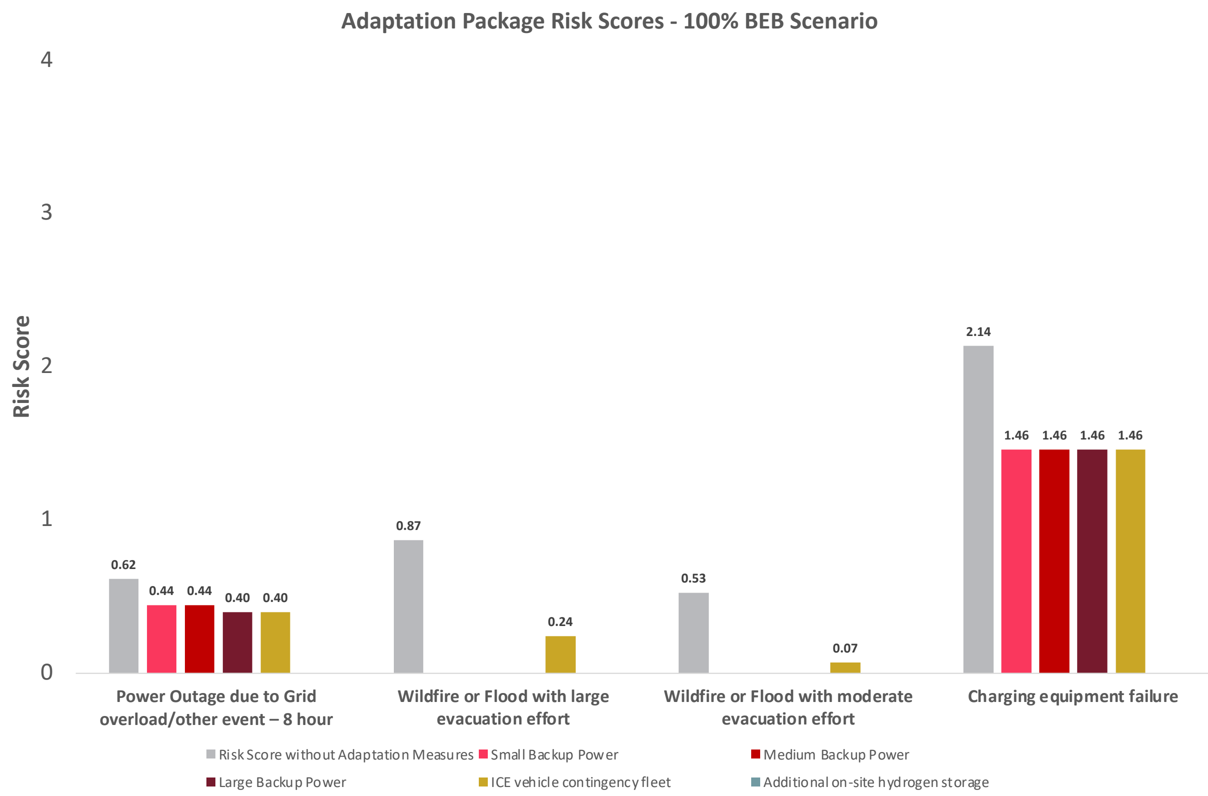


Figure 52 - Risk Scores for BEB Only Scenario, with and without Adaptation Packages

The cumulative RRUs for each adaptation package across all threats in the BEB Only scenario are shown in **Figure 53**. The dashed line represents the cumulative risk score for this scenario. While it is not possible to completely reduce risk, this line represents the maximum possible amount of risk reduction from adaptation. The higher the RRUs, the more effective that adaptation package is at reducing risk from threats. The ICE Contingency Fleet adaptation package provides cumulative risk reduction capabilities across all threats.

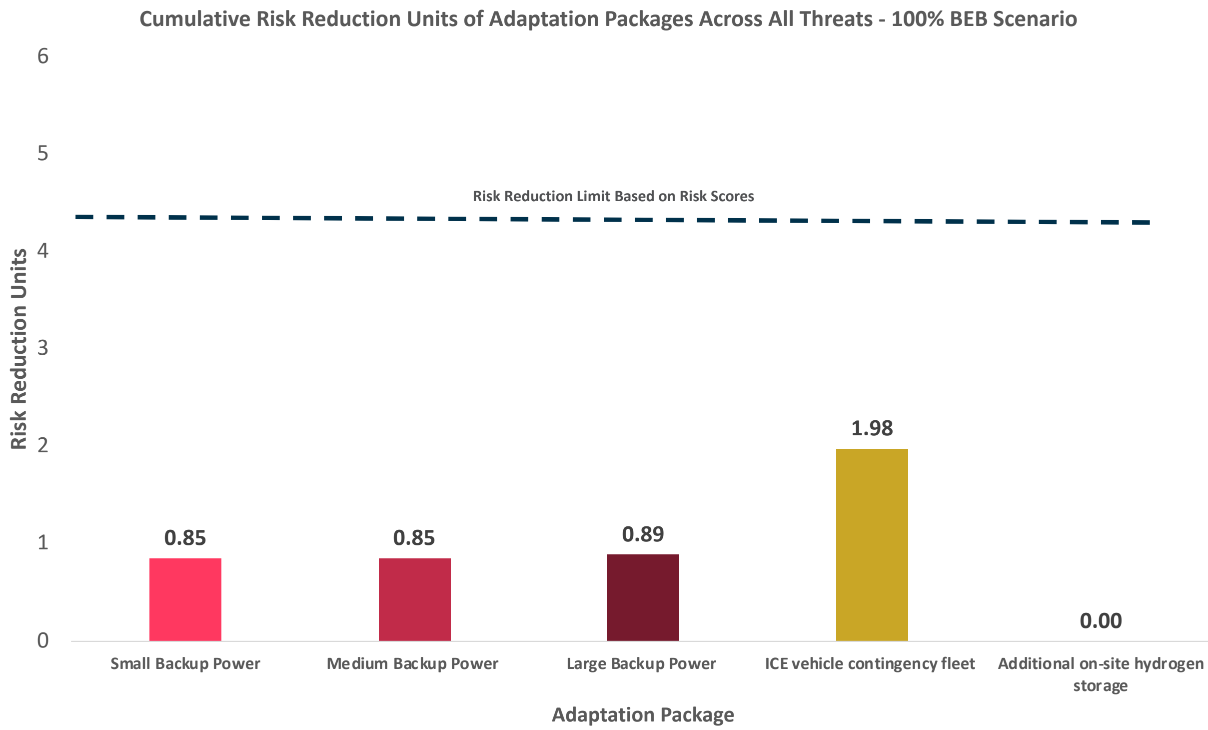


Figure 53 - Cumulative RRUs for Adaptation Packages for BEB Only Scenario

The cost effectiveness of the adaptation packages ($/RRU) are shown in **Figure 54**. The costs of diesel, natural gas, and natural gas microturbine backup generators were considered. The fuel type of the generator has no impact on its risk reduction capabilities.

The lower the $/RRU, the more cost effective an adaptation package is. The results of the analysis show the ICE contingency fleet as the most cost effective adaptation package for this scenario.

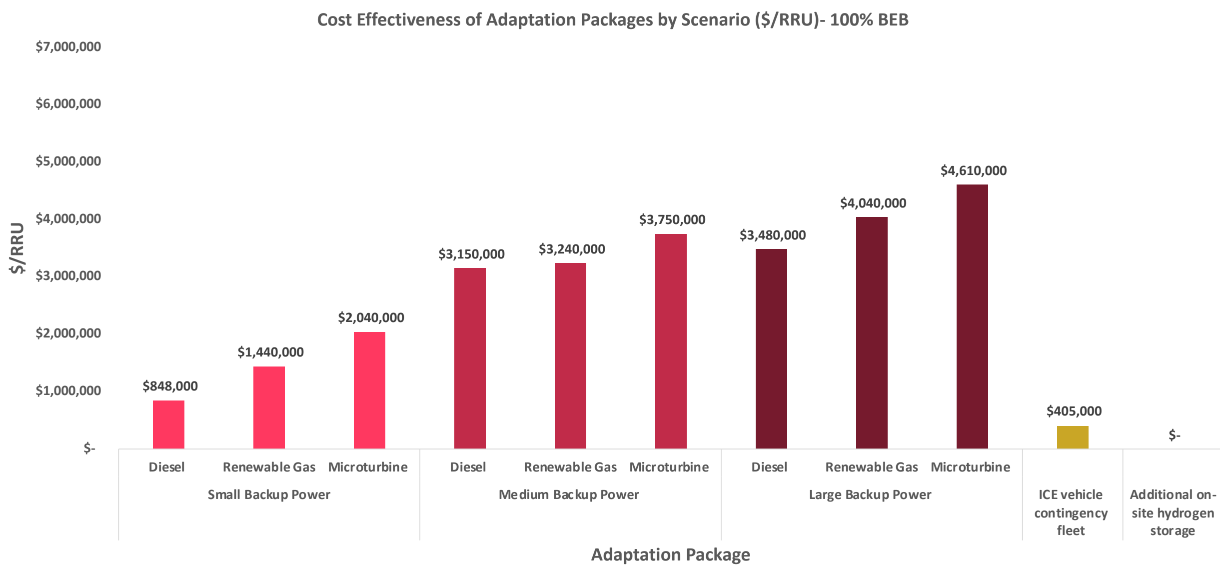


Figure 54 - $/RRU for Adaptation Packages in the BEB Only Scenario

Mixed Fleet - BEB Majority Scenario

Risk scores for all Mixed Fleet - BEB Majority scenario assessments, without adaptation and with each adaptation package are shown in **Figure 55**.

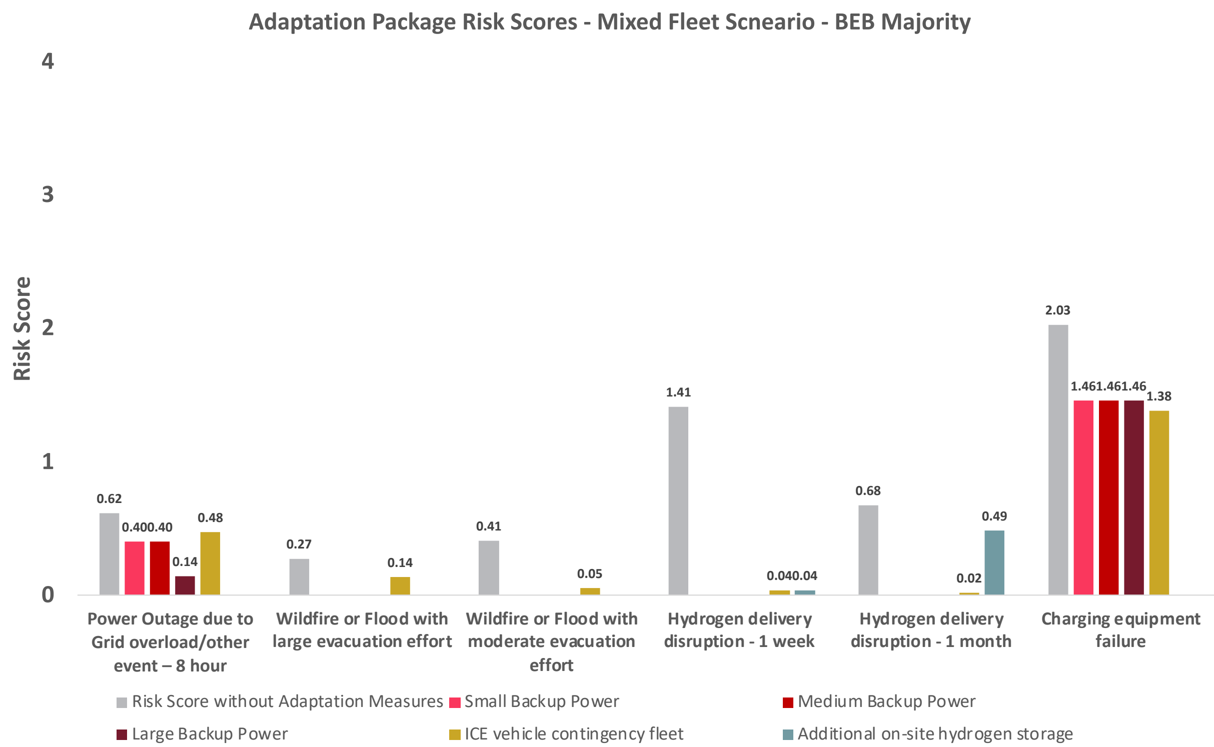


Figure 55 - Risk Scores for Mixed Fleet - BEB Majority Scenario, with and without Adaptation Packages

The cumulative RRUs for each adaptation package across all threats in the Mixed Fleet - BEB Majority scenario are shown in **Figure 56**. The dashed line represents the cumulative risk score for this scenario. While it is not possible to completely reduce risk, this line represents the maximum possible amount of risk reduction from adaptation. The higher the RRUs, the more effective that adaptation package is at reducing risk from threats. The ICE Contingency Fleet adaptation package provides cumulative risk reduction capabilities across all threats.

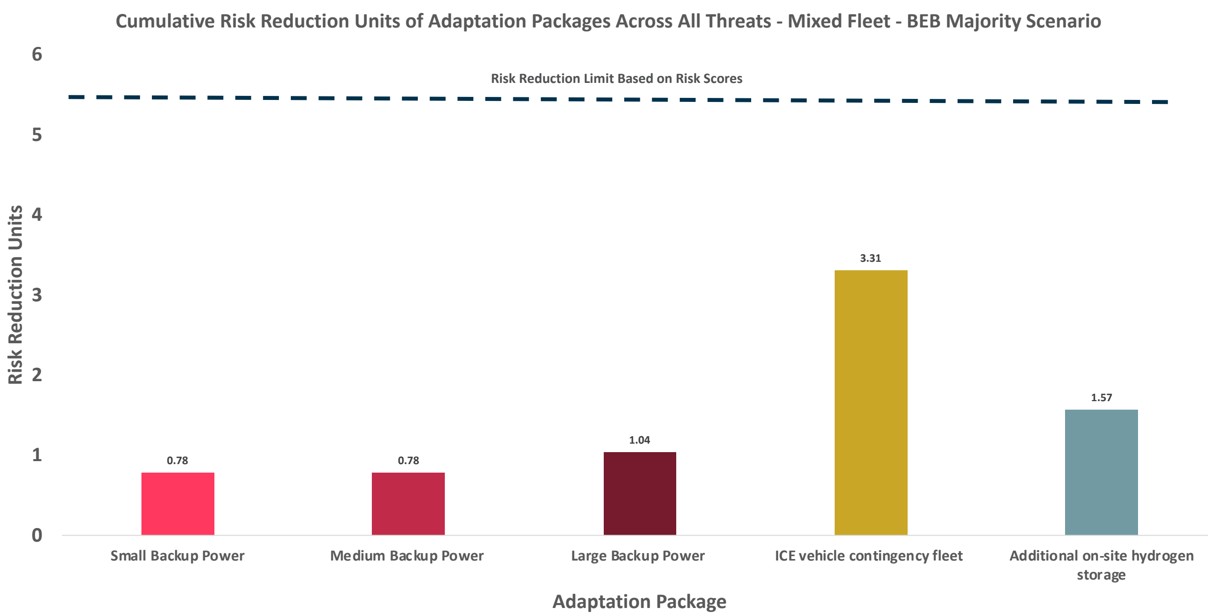


Figure 56 - Cumulative RRUs for Adaptation Packages for Mixed Fleet - BEB Majority Scenario

The cost effectiveness of the adaptation packages ($/RRU) are shown in **Figure 57.** The costs of diesel, natural gas, and natural gas microturbine backup generators were considered. The fuel type of the generator has no impact on its risk reduction capabilities.

The lower the $/RRU, the more cost effective an adaptation package is. The results of the analysis show the ICE contingency fleet as the most cost effective.

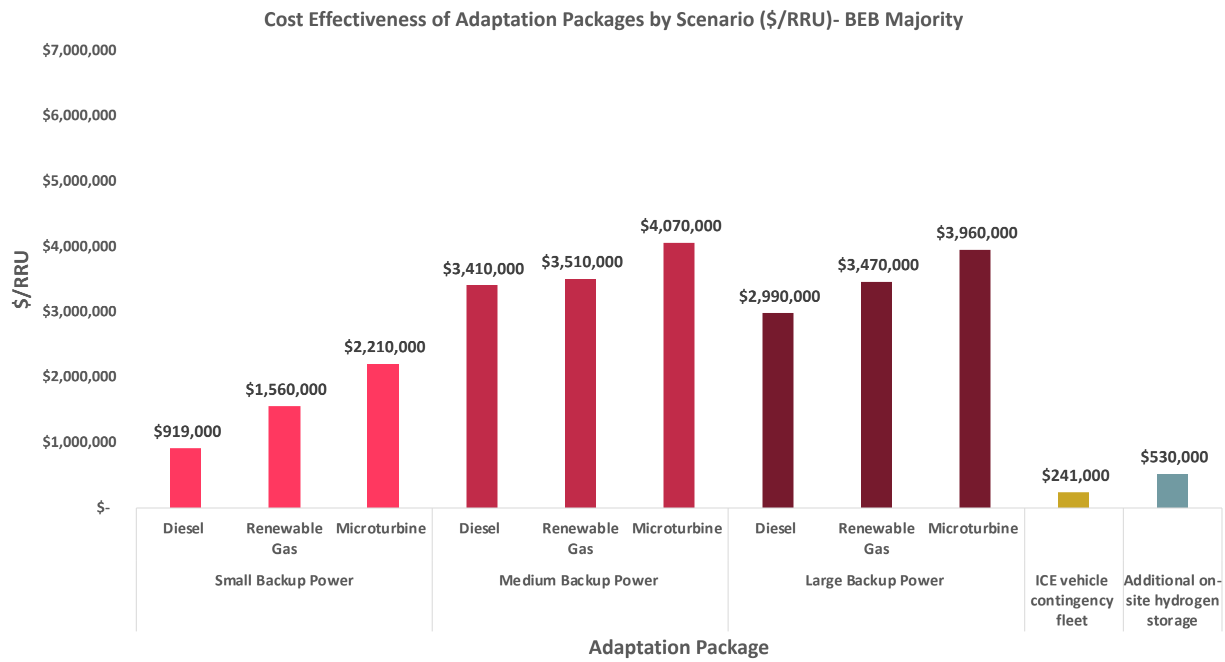


Figure 57 - $/RRU for Adaptation Packages in the Mixed Fleet - BEB Majority Scenario

Mixed Fleet - FCEB Majority Scenario

Risk scores for all Mixed Fleet - FCEB Majority scenario assessments, without adaptation and with each adaptation package are shown in **Figure 58**.

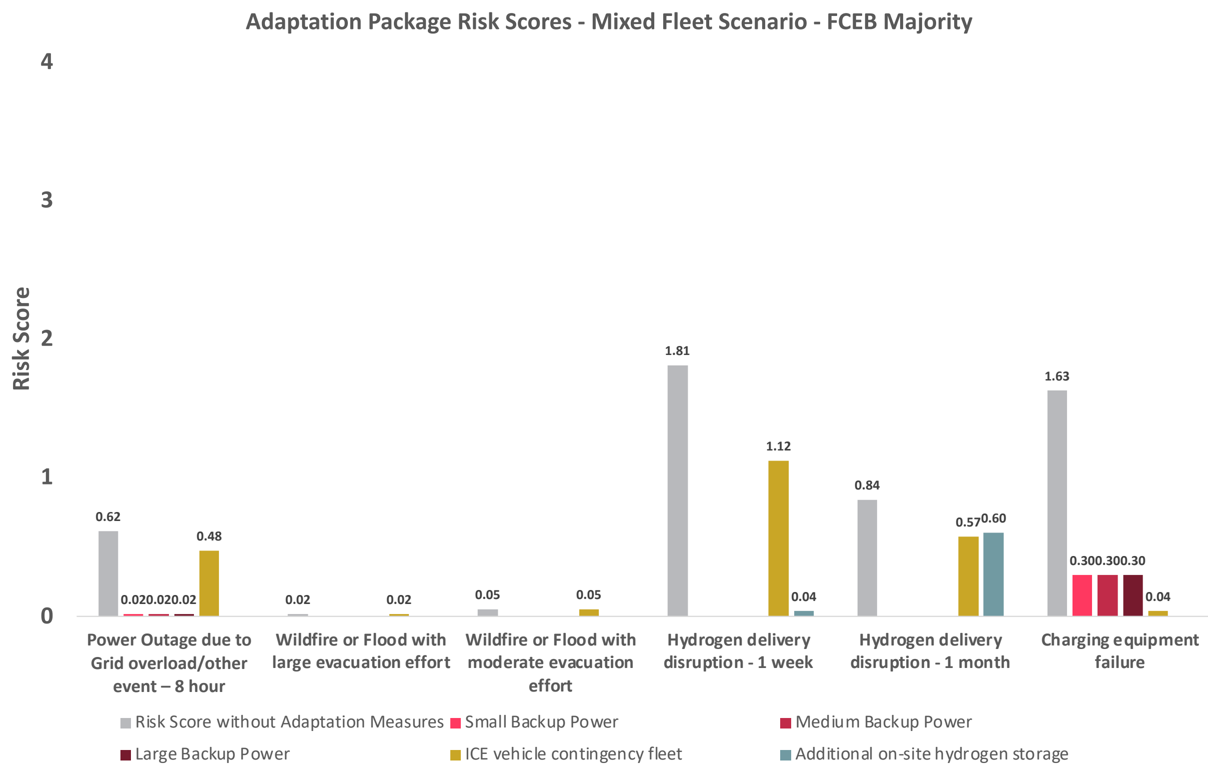


Figure 58 - Risk Scores for Mixed Fleet - FCEB Majority Scenario, with and without Adaptation Measures

The cumulative RRUs for each adaptation package across all threats in the Mixed Fleet – FCEB Majority scenario are shown in **Figure 59**. The dashed line represents the cumulative risk score for this scenario. While it is not possible to completely reduce risk, this line represents the maximum possible amount of risk reduction from adaptation. The higher the RRUs, the more effective that adaptation package is at reducing risk from threats. The ICE Contingency Fleet adaptation package provides cumulative risk reduction capabilities across all threats.

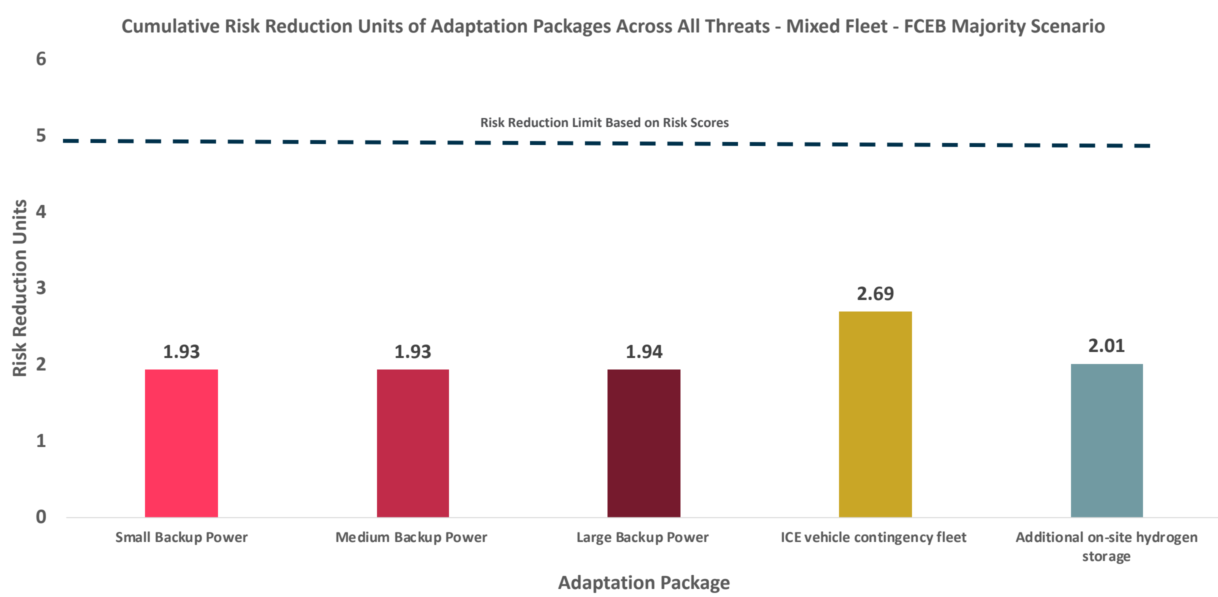


Figure 59 - Cumulative RRUs for Adaptation Packages for Mixed Fleet - FCEB Majority Scenario

The cost effectiveness of the adaptation packages ($/RRU) are shown in **Figure 60**. The costs of diesel, natural gas, and natural gas microturbine backup generators were considered. The fuel type of the generator has no impact on its risk reduction capabilities.

The lower the $/RRU, the more cost effective an adaptation package is. The results of the analysis show the ICE contingency fleet as the most cost effective.

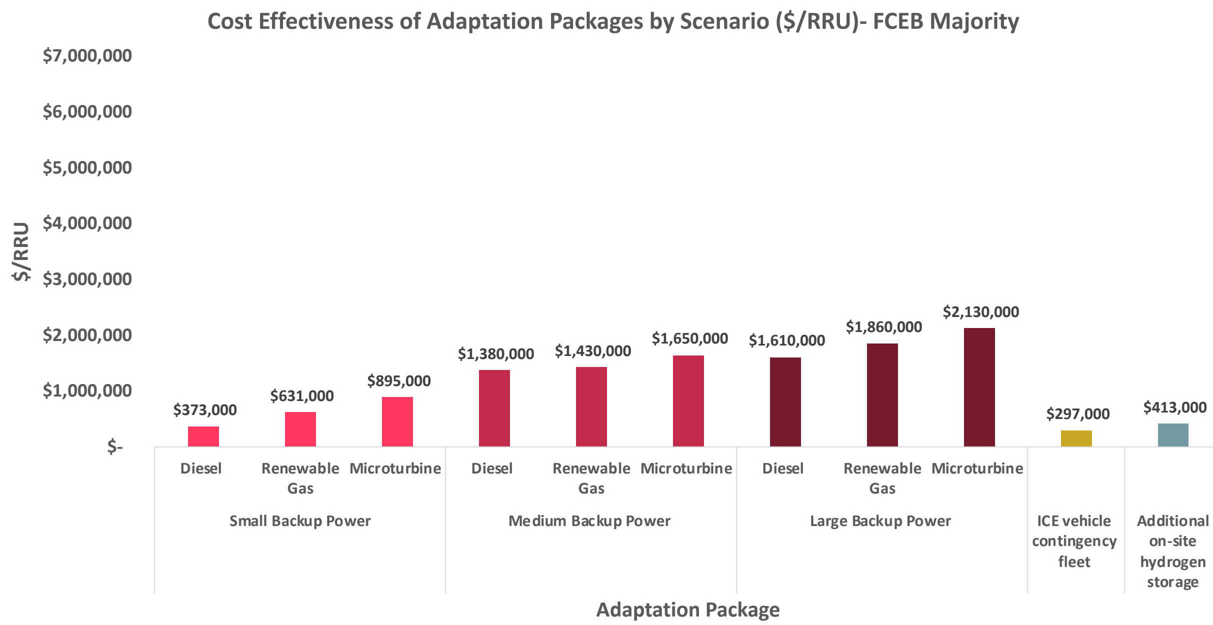


Figure 60 - $/RRU for Adaptation Packages in the Mixed Fleet - FCEB Majority Scenario

FCEB Only

Risk scores for all FCEB Only scenario assessments, without adaptation and with each adaptation package are shown in **Figure 61.**

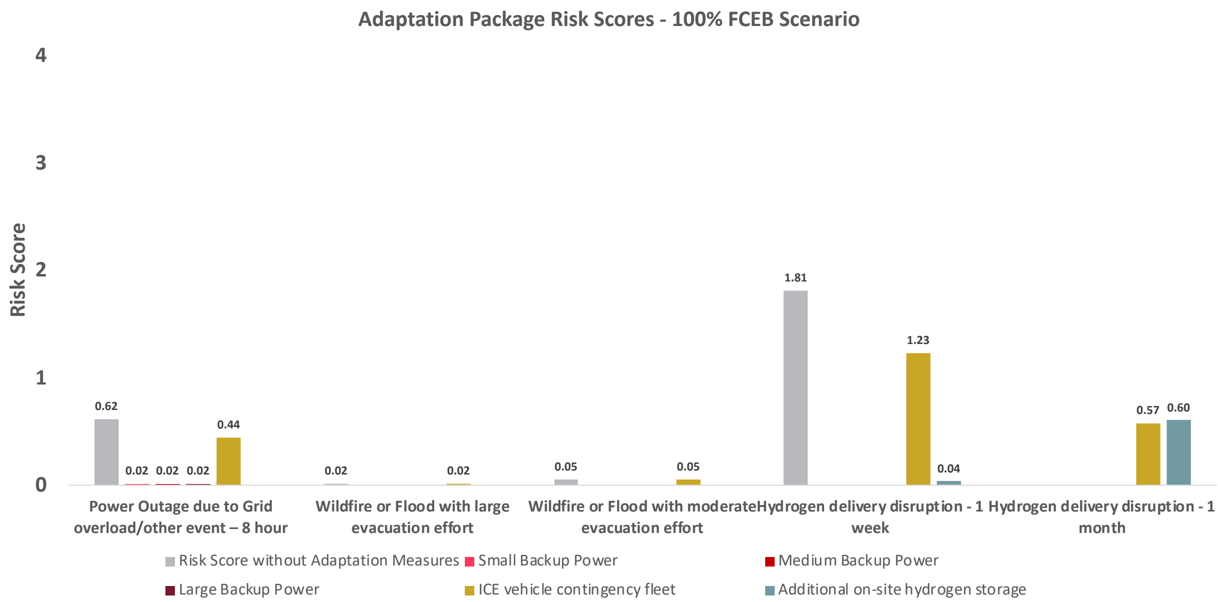


Figure 61 - Risk Scores for FCEB Only Scenario, with and without Adaptation Packages

The cumulative RRUs for each adaptation packages across all threats in the FCEB Only scenario are shown in **Figure 62.** The dashed line represents the cumulative risk score for this scenario. While it is not possible to completely reduce risk, this line represents the maximum possible amount of risk reduction from adaptation. The higher the RRUs, the more effective that adaptation package is at reducing risk from threats. The ICE Contingency Fleet adaptation package provides cumulative risk reduction capabilities across all threats.

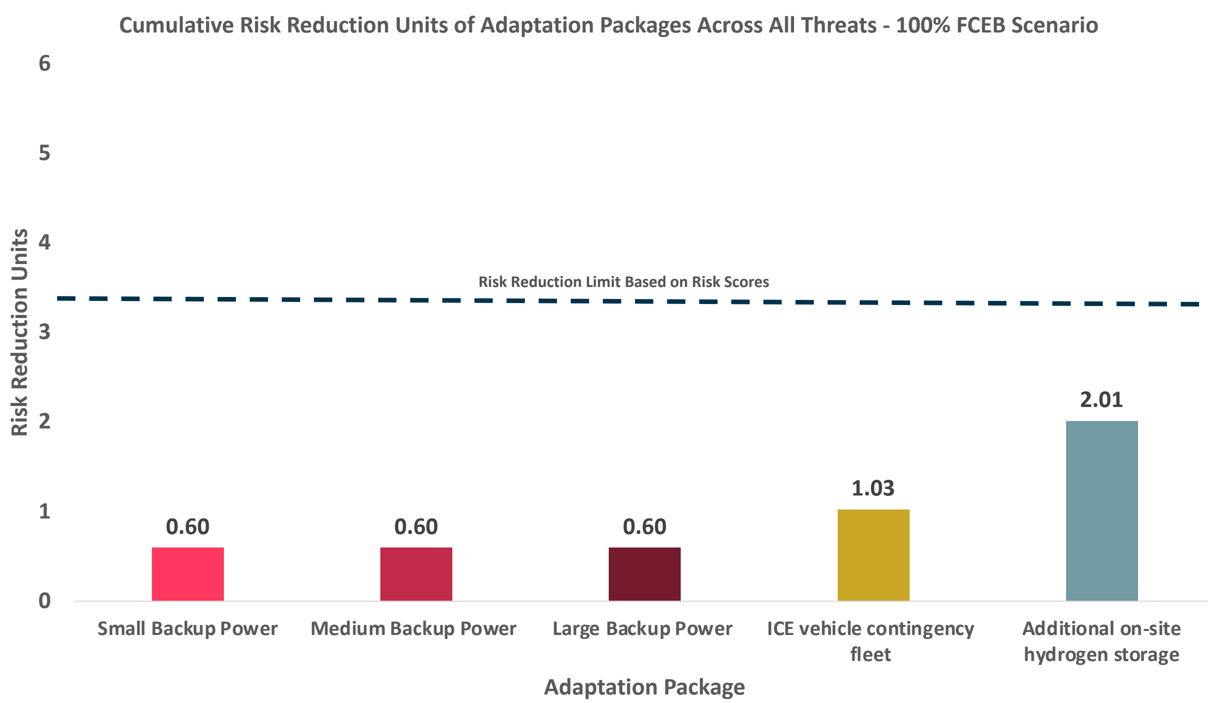


Figure 62 - Cumulative RRUs for Adaptation Packages for FCEB Only Scenario

The cost effectiveness of the adaptation packages ($/RRU) are shown in **Figure 63**. The costs of diesel, natural gas, and natural gas microturbine backup generators were considered. The fuel type of the generator has no impact on its risk reduction capabilities.

The lower the $/RRU, the more cost effective an adaptation package is. The results of the analysis show the ICE contingency fleet as the most cost effective.

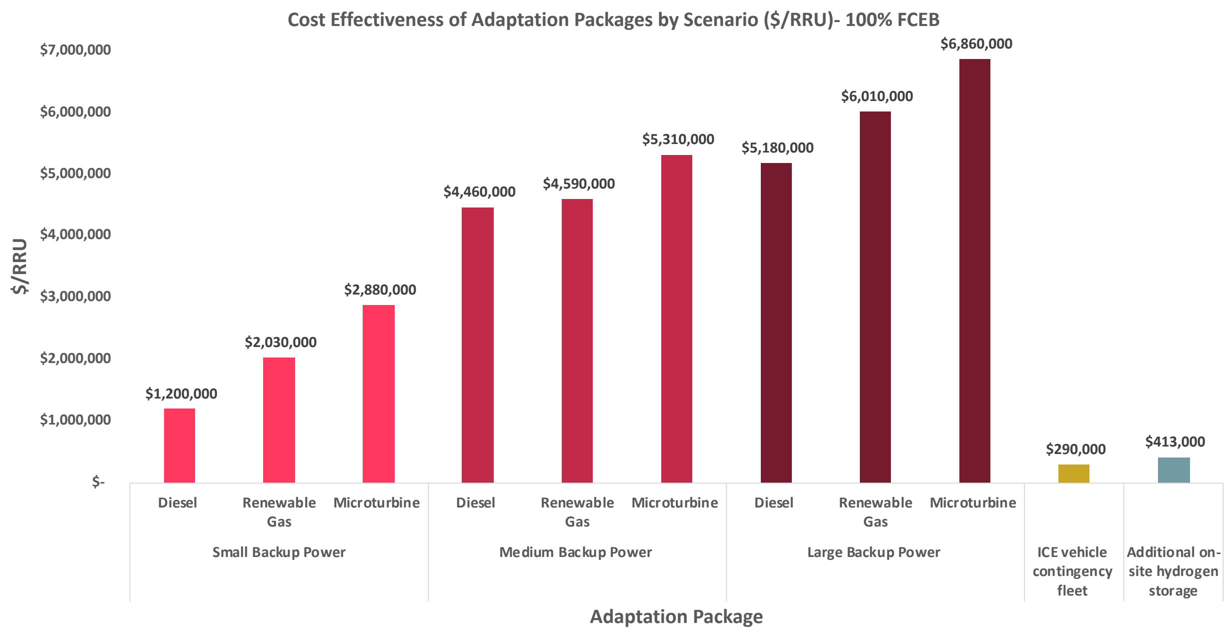


Figure 63 - $/RRU for Adaptation Packages in the FCEB Only Scenario

3R Assessment Summary

Careful consideration is required to prioritize adaptation package(s) to implement once the ZEB transition scenario is selected. Adaptation package selection will be informed by risk reduction capabilities, cost, operational feasibility, and environmental impacts.

Based on BCAG's transition timeline, no immediate action is required. Adaptation measures should be implemented in advance of when meeting the desired service levels for a threat is at risk, based on the fleet composition.

BCAG is reviewing the assessment results and will use the outcomes to evaluate adaptation measure needs in the future.

Total Cost of Ownership Assessment

The Total Cost of Ownership Assessment compiles the results from the Fleet, Fuel, Facilities, and Maintenance Assessments to show cumulative and annual costs throughout the transition period for each scenario. It includes selected capital and operating costs of each fleet scenario over the transition timeline. Other costs may be incurred (e.g., incremental operator and maintenance training) during a fleet transition; however, these four assessment categories are the key drivers in ZEB transition decision-making.

This study assumes no cost escalation or any cost reduction due to economies of scale for ZEB technology because there is no historical basis for these assumptions. Future changes to BCAG's service level, depot locations, route alignments, block scheduling, or other operations are unknown. The analyses below provide best estimates using the information currently available and the assumptions detailed throughout this report.

The following sections show total costs per scenario, broken down by assessment type.

Baseline

Figure 64 shows the combined fleet, fuel, facilities, and maintenance costs for the Baseline scenario. Since bus capital costs represent the most expensive cost examined, the peaks in these expenses occur during large purchasing years. Compared to bus costs, the fluctuations in fueling and maintenance cost are minimal and appear fairly stable from one year to the next. This scenario assumes necessary infrastructure is needed for the six BEBs currently in BCAG's procurement schedule, there are charging infrastructure costs associated are included in the Baseline scenario. The total combined cost is approximately $76 million from 2021 to 2040. This scenario estimates a total of 27 diesel buses, 5 BEBs and 22 gasoline cutaways in service in 2040 and demonstrates the capital and operation costs BCAG could expect to incur over this period in the absence of the ICT regulation.

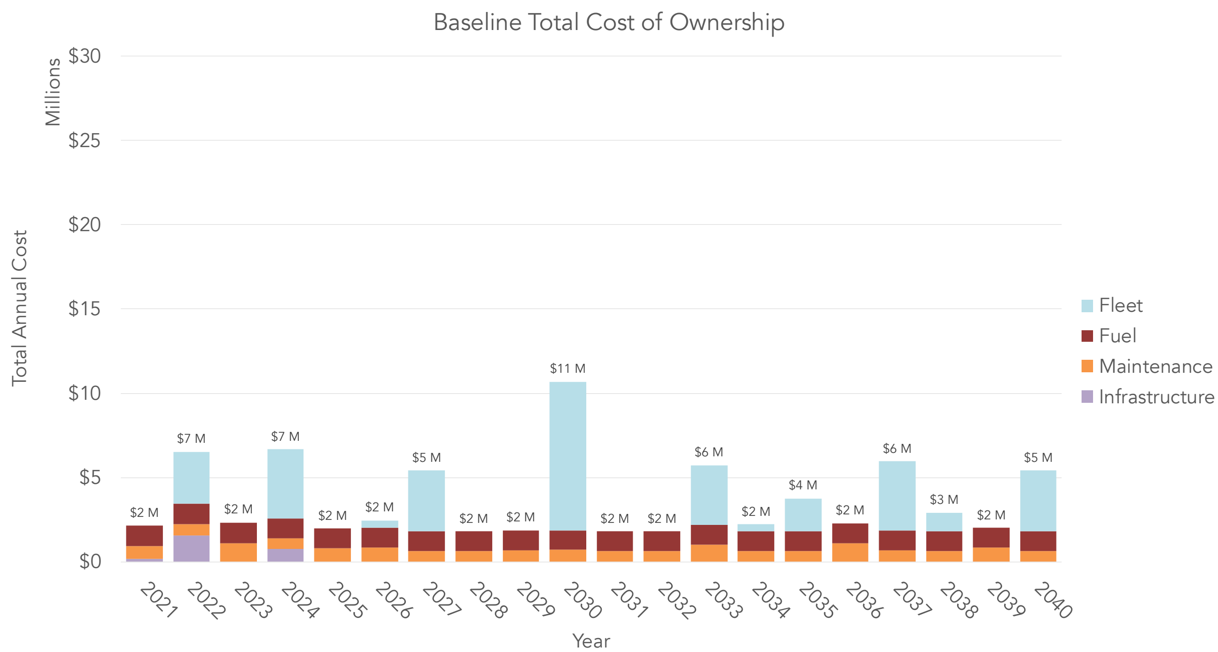


Figure 64 - Total Costs by Type, Baseline Scenario

BEB Only

Figure 65 shows the combined fleet, fuel, facilities, and maintenance costs for the BEB Only scenario in 2021 dollars. The total combined cost is approximately $88 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 32 total BEBs in the fleet in 2040, as well as 22 gasoline cutaways. The trends in the total cost fluctuations between years are largely the same as the Baseline scenario, with costs peaking in years with large bus procurements. Bus capital costs are the main component of yearly costs with a large spike of bus capital costs occurring in 2030 due to the purchase of 13 BEBs and 16 cutaways. Infrastructure costs are a significant portion of projected annual expenses towards the middle and latter half of the transition period while maintenance and fueling costs remain relatively stable from year to year. The costs of this scenario are significantly lower than any other zero-emission scenario because of lower vehicle costs and the relatively lower cost of electricity compared to hydrogen at present day pricing. As explored in the Sensitivity Analysis though, there is significant potential for this relationship to switch in the future, with electricity increasing in price as the cost of hydrogen falls.

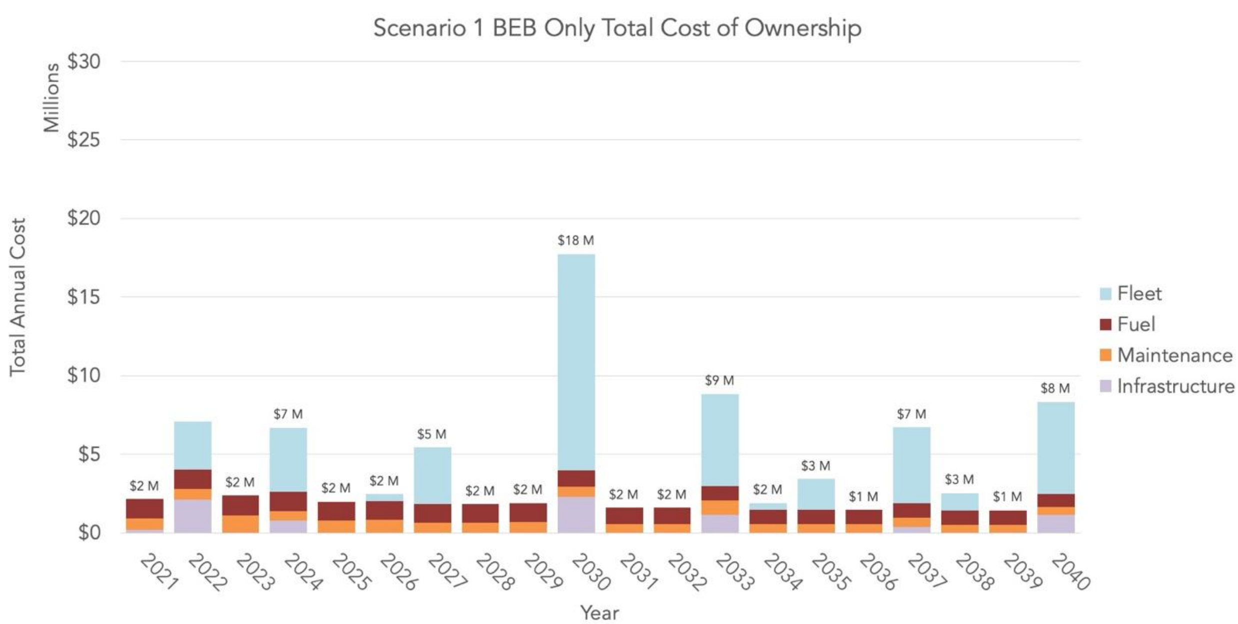


Figure 65 - Total Costs by Type, BEB Only Scenario

Mixed Fleet - BEB Majority

Figure 66 shows the combined fleet, fuel, facilities, and maintenance costs for the Mixed Fleet – BEB Majority. The total combined cost is approximately $101 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 24 BEBs, 8 FCEBs, and 4 fuel cell cutaways, and 18 gas cutaways in service by 2040.The high projected annual expense in 2030 is a result of the procurement schedule for this scenario. In 2030, 5 BEBs and 12 FCEBs are scheduled for purchase, as well as 12 cutaways.

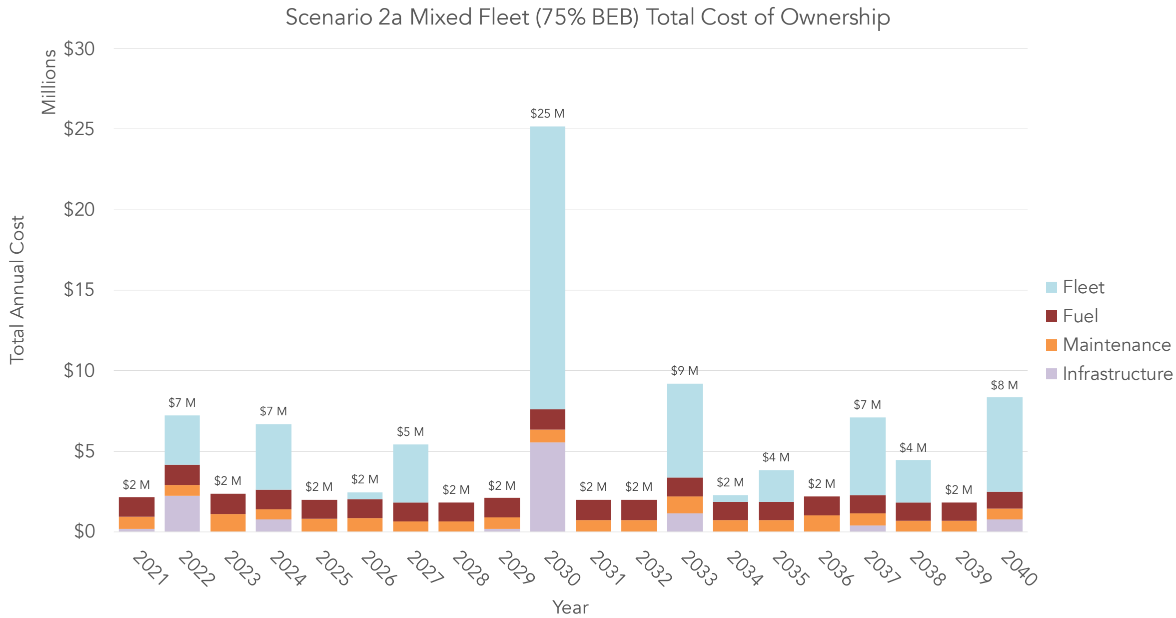


Figure 66 - Total Costs by Type, Mixed Fleet - BEB Majority Scenario

Mixed Fleet - FCEB Majority

Figure 67 shows the combined fleet, fuel, facilities, and maintenance costs for the Mixed Fleet – FCEB Majority Scenario. The total combined cost is approximately $106 million over the length of the transition, from 2021 to 2040. This scenario estimates 24 FCEBs, 8 BEBs, 4 fuel cell cutaways, and 18 gas cutaways in service by 2040. Similarly, as above, the spikes seen here correlate with the procurement schedule for this scenario. In 2030, 13 FCEBs are scheduled for purchase, as well as 4 fuel cell electric cutaways and 12 gas cutaways.

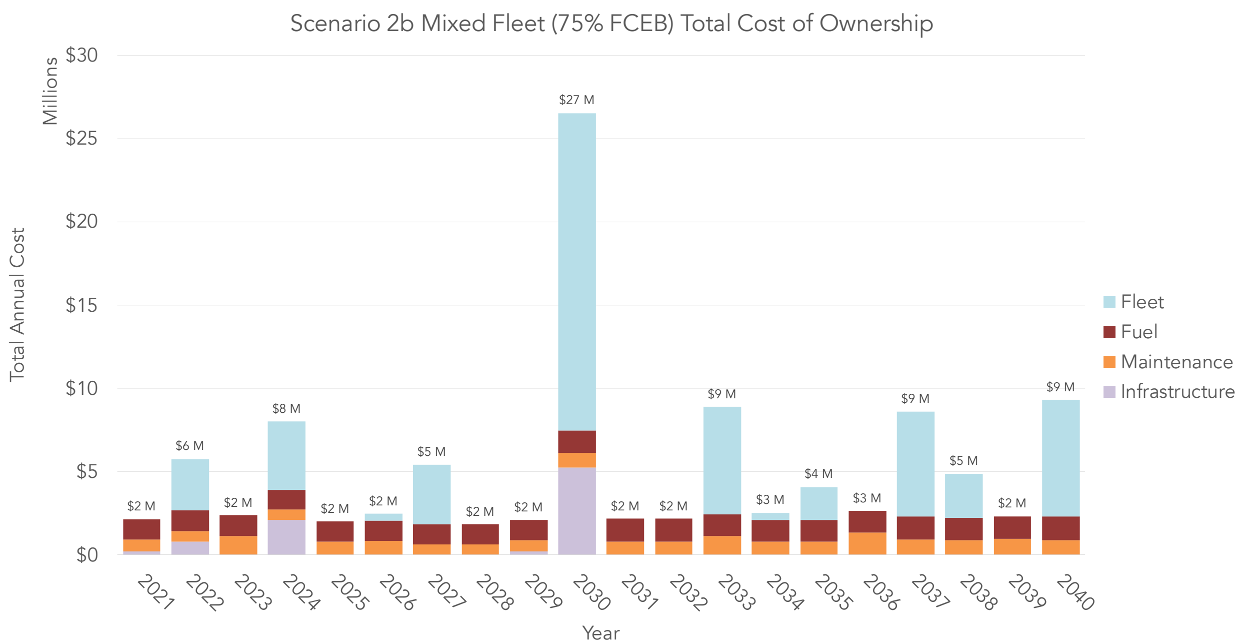


Figure 67 - Total Costs by Type, Mixed Fleet - FCEB Majority Scenario

FCEB Only

Figure 68 shows the combined fleet, fuel, facilities, and maintenance costs related to the FCEB Only scenario in 2021 dollars. The total combined cost is approximately $110 million over the length of the transition, from 2021 to 2040. This scenario estimates a total of 32 FCEBs and 4 fuel cell cutaways and 18 gas cutaways in service by 2040. The general trends of this scenario are similar to the previous ZEB scenarios discussed, with costs peaking in large procurement years.

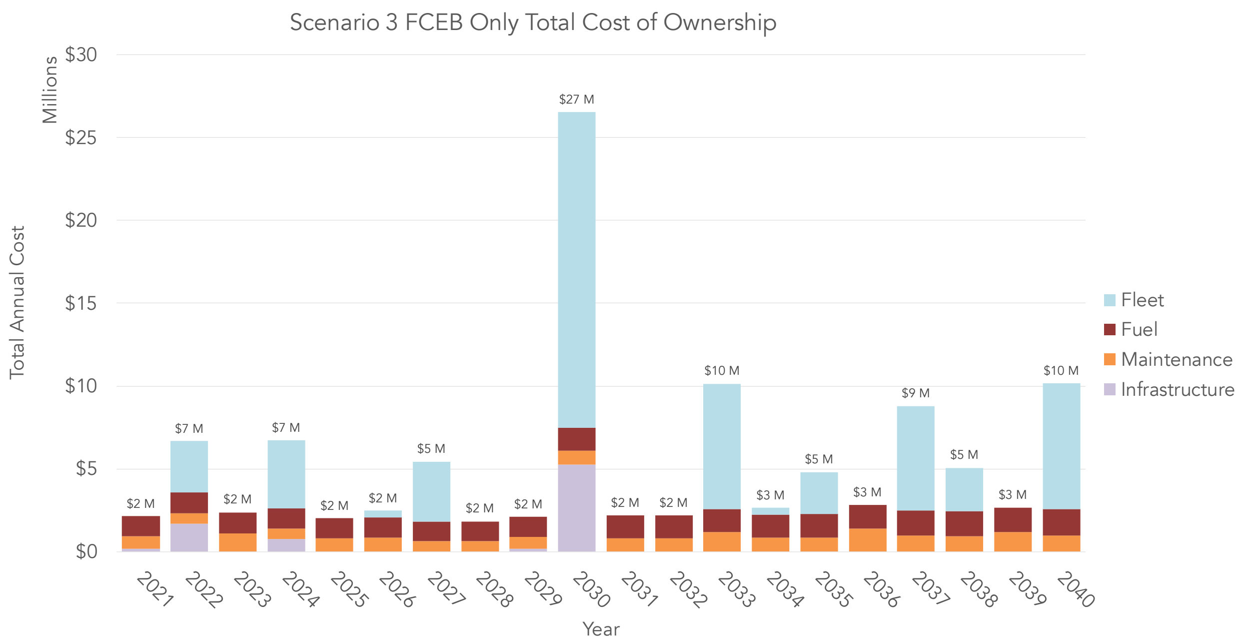


Figure 68 - Total Costs by Type, FCEB Only Scenario

Total Estimated Costs

Figure 69 shows the combined total costs from the assessments above, broken down by scenario. **Table 28** shows the detailed cost totals. As noted throughout the document, this analysis was completed based on the best available fleet data and procurement schedule available as of 2021. Since the completion of the analysis and the completion of this report, the agency's procurement schedule has changed slightly to include procuring at least 6 BEBs in the near future. Although this change will create a deviation from the Total Cost of Ownership estimates shown below, the impact on the relative cost differentials between scenarios would be fairly negligible as all scenarios would be equally impacted and it would not cause a significant change in the cost comparison of one scenario to the next.

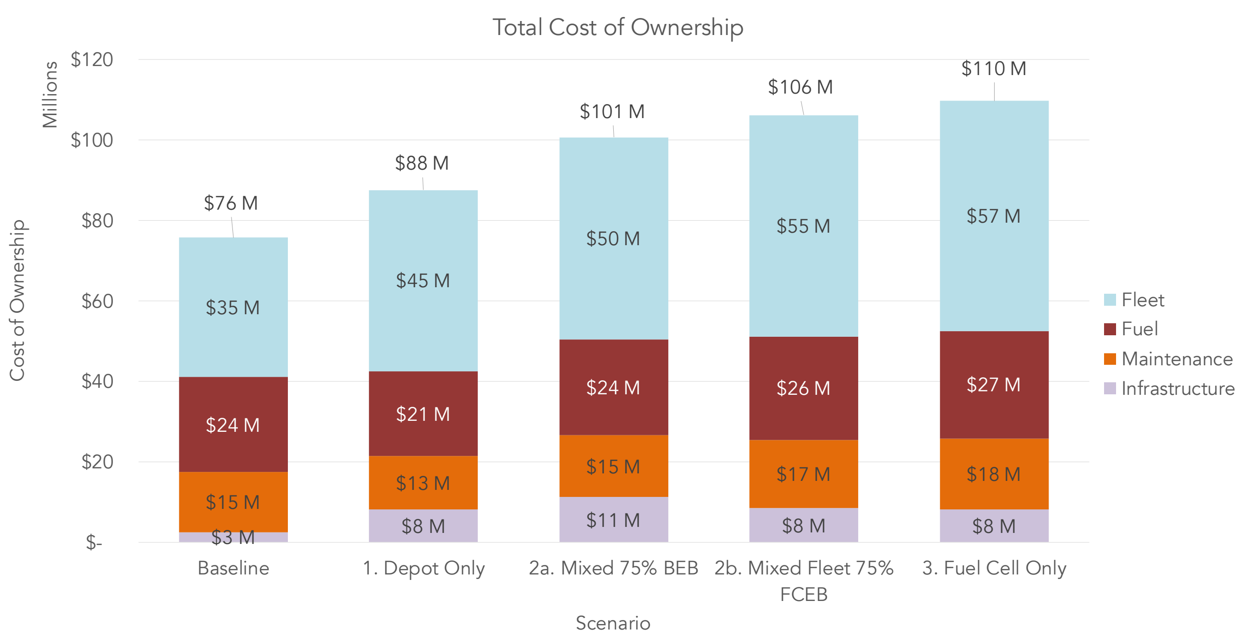


Figure 69 - Total Cost of Ownership, by Scenario

Table 28 - Total Cost of Ownership, by Scenario

	0. Baseline (Current Technology)	1. BEB Only	2. Mixed Fleet - (BEB Majority)	3. Mixed Fleet (FCEB Majority)	4. FCEB Only
Fleet	$ 35M	$ 45M	$ 50M	$ 55M	$ 57M
Fuel	$ 24M	$21M	$ 24M	$ 26M	$ 27M
Maintenance	$ 15M	$ 13M	$ 15M	$ 17M	$ 18M
Infrastructure	$ 3	$ 8M	$ 11M	$ 8M	$ 8M
TOTAL	**$ 76M**	**$ 88M**	**$ 101M**	**$106M**	**$ 110M**

*Assumes near-term costs with no sensitivity analysis applied.

Conclusions and Recommendations

ZEB technologies are in a period of rapid development. While the technologies have been proven in many pilot deployments, they are not yet matured to the point where they can easily replace current ICE technologies on a large scale. BEBs require significant investment in facilities and infrastructure and may require changes to service and operations to manage their range constraints. On the other hand, FCEBs can provide an operational equivalent to diesel buses, but the cost of buses, fueling infrastructure, and fuel remain a significant barrier to mass adoption.

CARB's ICT regulation is an achievement in addressing the challenges of climate change and improving local air quality through the goal of 100% zero-emission transit fleets by 2040. However, as demonstrated in this analysis, there will be substantial costs and technical challenges to overcome.

The BEB Only scenario meets the CARB ICT regulation. Total transitional costs under this scenario are likely to be around $88 million. The difference in cost between this scenario and the Baseline scenario is largely the result of the price difference between diesel buses and BEBs and up-front capital costs for new fueling infrastructure. This scenario is projected to cost approximately $12 million more than the baseline over the transition period.

In a Mixed Fleet – BEB Majority scenario, the total cost is estimated at $101 million. Managing a mixed fleet through a transition presents its own complexities, such as installing new BEB charging infrastructure and new FCEB fueling infrastructure in a time frame that does not disrupt service or depot access. A mixed fleet does, however, provide enhanced resilience as it means that portions of the fleet would still be able to operate in the event that fuel delivery of either fuel was disrupted. This scenario also allows the agency to benefit from the lower cost of BEBs compared to FCEBs as much as possible, while still maintaining the benefits that come with a diverse fleet. This scenario is projected to cost approximately $25 million more than the baseline over the transition period and meets the requirements of the ICT regulation.

The Mixed Fleet – FCEB Majority scenario achieves the transition of B-Line's fleet to 100% zero-emission by 2040 with an estimated total cost of $106 million. This scenario has similar costs and benefits as the last scenario in terms of requiring two kinds of fueling infrastructure at the depot, but provided enhanced resilience. While this scenario results in higher fleet, fuel and maintenance costs than the BEB Majority Scenario at present pricing, this scenario's advantage is that having more FCEBs in the fleet allows the agency to take advantage of the lower infrastructure costs that come from installing a single FCEB station and fewer chargers than the previous scenario. This scenario is projected to cost approximately $30 million more than the baseline over the transition period and meets the requirements of the ICT regulation.

Total cost for the FCEB Only scenario is estimated at approximately $110 million and result in an entirely fuel cell electric bus fleet by 2040. While only accommodating a single technology, the FCEB Only scenario has a larger total cost due to higher bus capital, maintenance, and fuel cost as compared to diesel or BEBs. A primary assumption for the FCEB analysis is that FCEBs are already available for all bus types and lengths during the transition period. Due to the lack of market diversity of FCEBs and hydrogen availability in the United States, fuel costs and bus capital costs remain high. These costs are largely expected to decrease in the future as more buses are deployed; however, more data is needed to understand how much they may decrease. Additionally, data for FCEB maintenance costs reflect higher costs than what might be expected as agencies become more familiar with the technology. As such, there are more unknowns associated with costs for the FCEB Only scenario, and costs are more subject to change. This scenario is projected to cost approximately $34 million more than the baseline over the transition period and meets the requirements of the ICT regulation.

Given these considerations, the recommendations for BCAG are as follows:

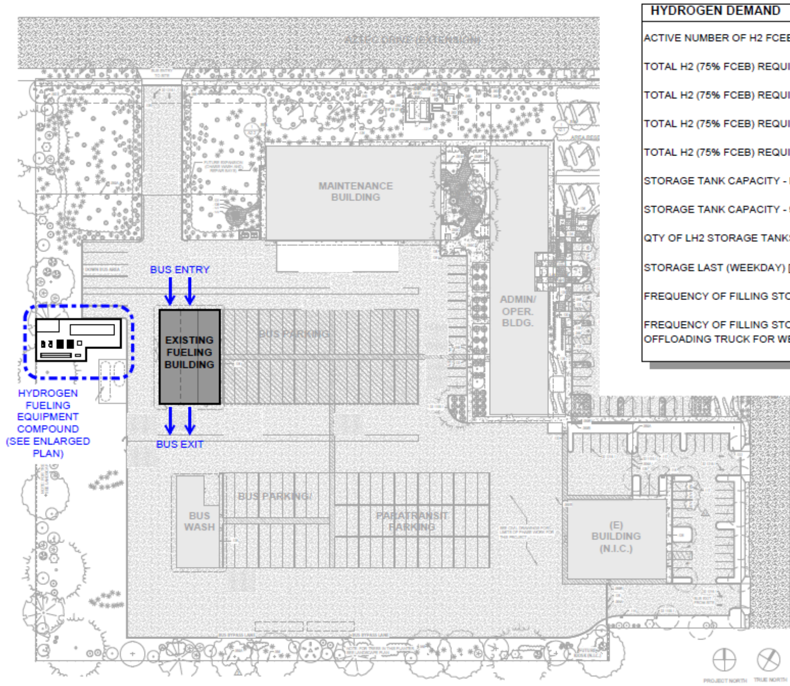
1) **Select a preferred scenario to refine in ICT Plan development and remain proactive with ZEB deployment grants:** This Master Plan was developed to present BCAG with options for transitioning to a fully zero-emission fleet. Following BCAG's selection of a preferred ZEB Transition Scenario, the ICT Rollout Plan will be developed for submittal to CARB in compliance with the ICT Regulation. This document will put forth BCAG's vision for a ZEB Transition and will act as a living document to help the agency plan out grant funding

requirements. As a greater proportion of B-Line's fleet converts to ZEB technology, auxiliary equipment, hardware, and software will be needed to ensure a successful fleet transition. BCAG should continue to remain proactive in the purchase and deployment of ZEBs and their associated systems by taking advantage of various grant and incentive programs.

2) **Apply learnings from emergency disaster response:** Evaluate the tradeoffs for various alternatives to reduce the risk from power outages and fuel disruptions, and allow BCAG to meet all first responder requirements from the 3R Assessment.
3) **Match the individual bus technology to the individual route and blocks:** BCAG should consider the strengths of given ZEB technologies and focus those technologies on routes and blocks that take advantage of their efficiencies and minimize the impact of the constraints related to the respective technologies. These technologies cannot follow a one-size-fits-all approach from either a performance or cost perspective. Matching the present technology to the present service levels will be a critical best practice.
4) **Monitor local and regional developments:** In the zero-emission technology sector, developments at the local level can have the ability to catapult the industry forward. When local bus OEMs or fuel providers enter the zero-emission market, it can spark technological innovation or cost reduction. Neighboring transit agencies can also work together through group purchasing agreements and lobbying efforts to bring about reduced purchase costs or more funding opportunities.

The transition to ZEB technologies represents a paradigm shift in bus procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission public transit. Widespread adoption of zero-emission bus technology has the potential to significantly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. BCAG is committed to implementing environmentally-friendly policies and reducing its carbon footprint.

Appendices – BCAG Depot Site Plans



HYDROGEN DEMAND	
ACTIVE NUMBER OF H2 FCEB VEHICLES (40' / CUTAWAY)	24 / 4
TOTAL H2 (75% FCEB) REQUIRED/DAY (WEEKDAY) [KG]	626
TOTAL H2 (75% FCEB) REQUIRED/DAY (WEEKDAY) [GAL]	2,335
TOTAL H2 (75% FCEB) REQUIRED/DAY (WEEKEND) [KG]	178
TOTAL H2 (75% FCEB) REQUIRED/DAY (WEEKEND) [GAL]	664
STORAGE TANK CAPACITY - NOMINAL [GAL]	12,000
STORAGE TANK CAPACITY - 90% USABLE [GAL]	10,800
QTY OF LH2 STORAGE TANKS	1
STORAGE LAST (WEEKDAY) [DAYS]	4.5
FREQUENCY OF FILLING STORAGE PER WEEK	1.0
FREQUENCY OF FILLING STORAGE DELIVERED BY OFFLOADING TRUCK FOR WEEKDAY CONSUMPTION	ONE FUEL DELIVERY EVERY 4-5 WEEKDAYS

NOTES:

1. HYDROGEN DISPENSERS MAY BE LOCATED IN EXISTING FUELING STATION. DISPENSERS SHOULD BE LOCATED IN AN OPEN-AIR LOCATION. DETAILS WILL BE STUDIED IN DESIGN PHASE FOR BEST LOCATION.

2. PER ABOVE TABLE, 24 (40-FT) BUSES AND 4 CUTAWAYS ARE CONSIDERED FOR CALCULATING STORAGE AND FREQUENCY OF DELIVERY.

3. PER ABOVE TABLE A 12,000 GAL STORAGE TANK WILL LAST ABOUT 4 TO 5 DAYS PER WEEKDAY CONSUMPTION.

4. CONSIDERING LESS FUEL CONSUMPTION OVER WEEKENDS, ONE FUEL DELIVERY WOULD BE NEEDED EVERY 4 TO 5 WEEKDAYS.

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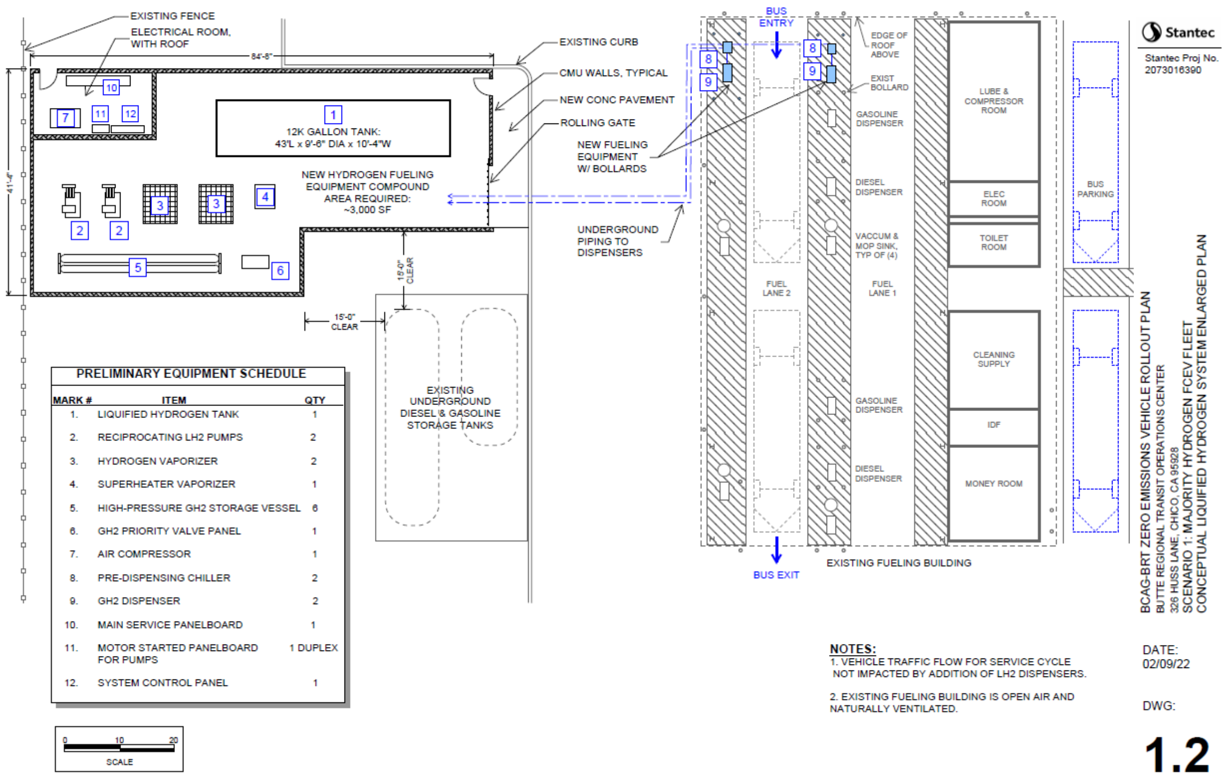
2073016390

BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 1: MAJORITY HYDROGEN FCEV FLEET
CONCEPTUAL LIQUIFIED HYDROGEN SYSTEM SITE PLAN

DATE:
02/09/22

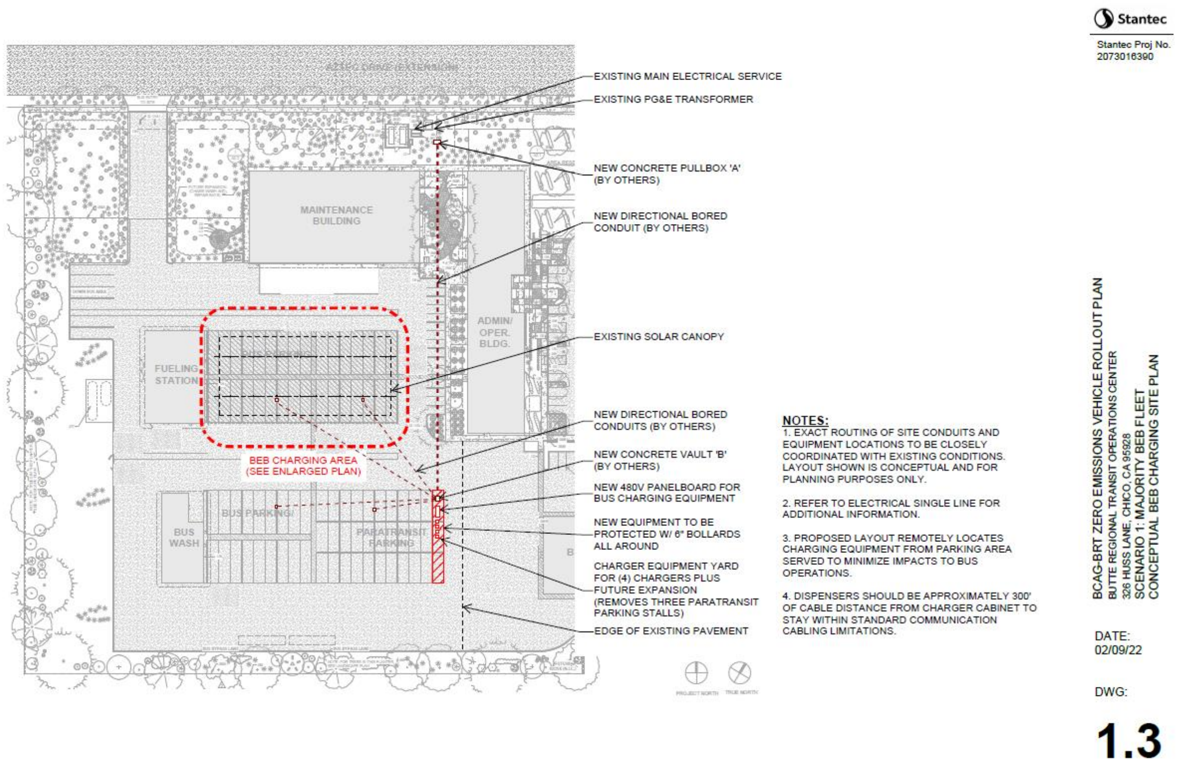
DWG:

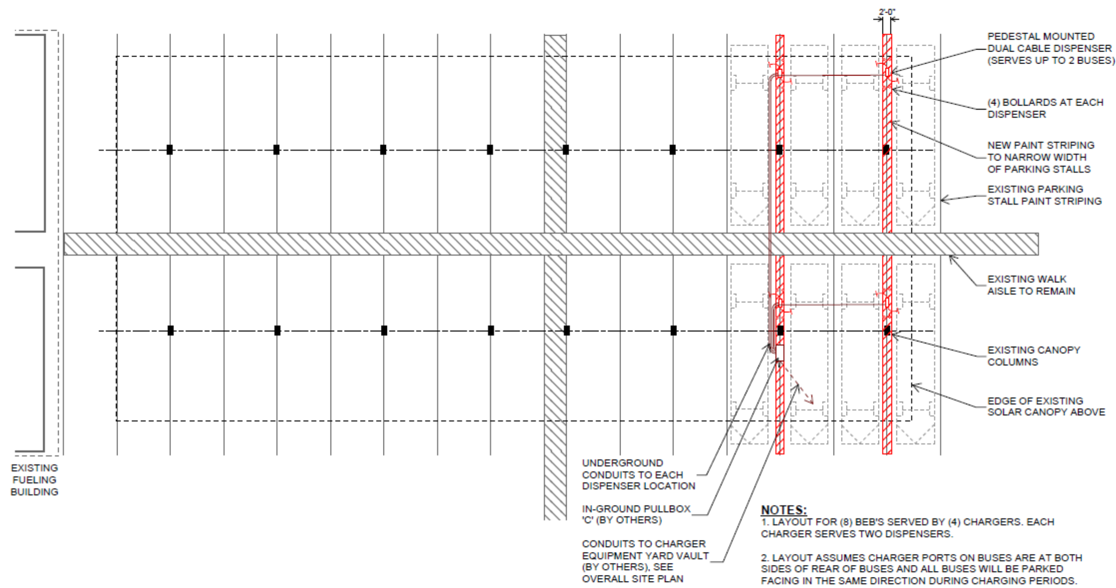
1.1



PRELIMINARY EQUIPMENT SCHEDULE

MARK #	ITEM	QTY
1.	LIQUIFIED HYDROGEN TANK	1
2.	RECIPROCATING LH2 PUMPS	2
3.	HYDROGEN VAPORIZER	2
4.	SUPERHEATER VAPORIZER	1
5.	HIGH-PRESSURE GH2 STORAGE VESSEL	6
6.	GH2 PRIORITY VALVE PANEL	1
7.	AIR COMPRESSOR	1
8.	PRE-DISPENSING CHILLER	2
9.	GH2 DISPENSER	2
10.	MAIN SERVICE PANELBOARD	1
11.	MOTOR STARTED PANELBOARD FOR PUMPS	1 DUPLEX
12.	SYSTEM CONTROL PANEL	1


Stantec
Stantec Proj No.
2073016390
MAINTENANCE BUILDING
FUELING STATION
ADMIN/ OPER. BLDG.
BUS WASH
BUS PARKING
PARATRANSIT PARKING
BEB CHARGING AREA (SEE ENLARGED PLAN)
EXISTING MAIN ELECTRICAL SERVICE
EXISTING PG&E TRANSFORMER
NEW CONCRETE PULLBOX 'A' (BY OTHERS)
NEW DIRECTIONAL BORED CONDUIT (BY OTHERS)
EXISTING SOLAR CANOPY
NEW DIRECTIONAL BORED CONDUITS (BY OTHERS)
NEW CONCRETE VAULT 'B' (BY OTHERS)
NEW 480V PANELBOARD FOR BUS CHARGING EQUIPMENT
NEW EQUIPMENT TO BE PROTECTED W/ 6" BOLLARDS ALL AROUND
CHARGER EQUIPMENT YARD FOR (4) CHARGERS PLUS FUTURE EXPANSION (REMOVES THREE PARATRANSIT PARKING STALLS)
EDGE OF EXISTING PAVEMENT
NOTES:
1. EXACT ROUTING OF SITE CONDUITS AND EQUIPMENT LOCATIONS TO BE CLOSELY COORDINATED WITH EXISTING CONDITIONS. LAYOUT SHOWN IS CONCEPTUAL AND FOR PLANNING PURPOSES ONLY.
2. REFER TO ELECTRICAL SINGLE LINE FOR ADDITIONAL INFORMATION.
3. PROPOSED LAYOUT REMOTELY LOCATES CHARGING EQUIPMENT FROM PARKING AREA SERVED TO MINIMIZE IMPACTS TO BUS OPERATIONS.
4. DISPENSERS SHOULD BE APPROXIMATELY 300' OF CABLE DISTANCE FROM CHARGER CABINET TO STAY WITHIN STANDARD COMMUNICATION CABLING LIMITATIONS.
BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 1: MAJORITY BEB FLEET
CONCEPTUAL BEB CHARGING SITE PLAN
DATE:
02/09/22
DWG:
1.3



NOTES:

1. LAYOUT FOR (8) BEB'S SERVED BY (4) CHARGERS. EACH CHARGER SERVES TWO DISPENSERS.

2. LAYOUT ASSUMES CHARGER PORTS ON BUSES ARE AT BOTH SIDES OF REAR OF BUSES AND ALL BUSES WILL BE PARKED FACING IN THE SAME DIRECTION DURING CHARGING PERIODS.

3. ADDITIONAL DISPENSER LOCATION FLEXIBILITY IS POSSIBLE IF VEHICLES ARE PROCURED WITH CHARGER PORTS AT CURB-SIDE REAR AND STREET-SIDE FRONT WHICH WILL ALLOW FOR BUSES TO PARK IN EITHER DIRECTION AND STILL HAVE ACCESS TO DISPENSERS.

4. CHARGERS ARE REMOTELY LOCATED, SEE OVERALL SITE PLAN.

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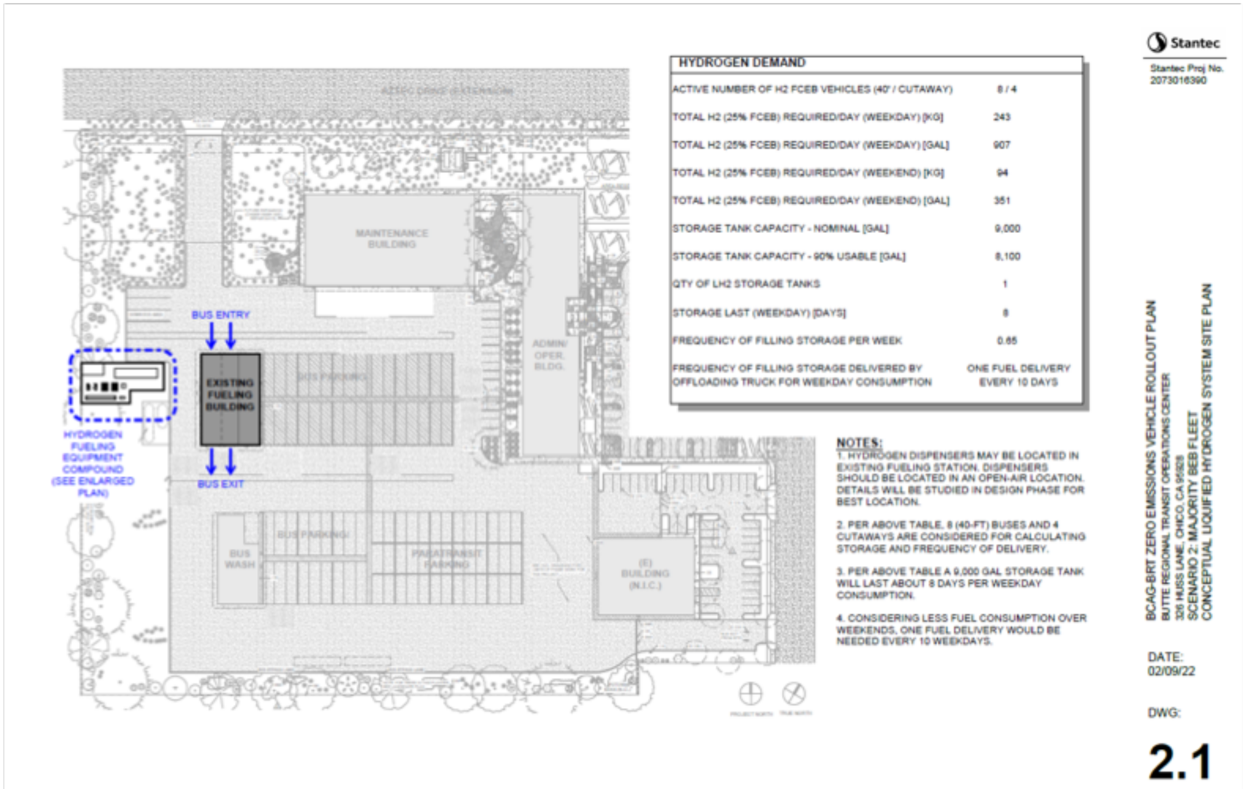
2073016390

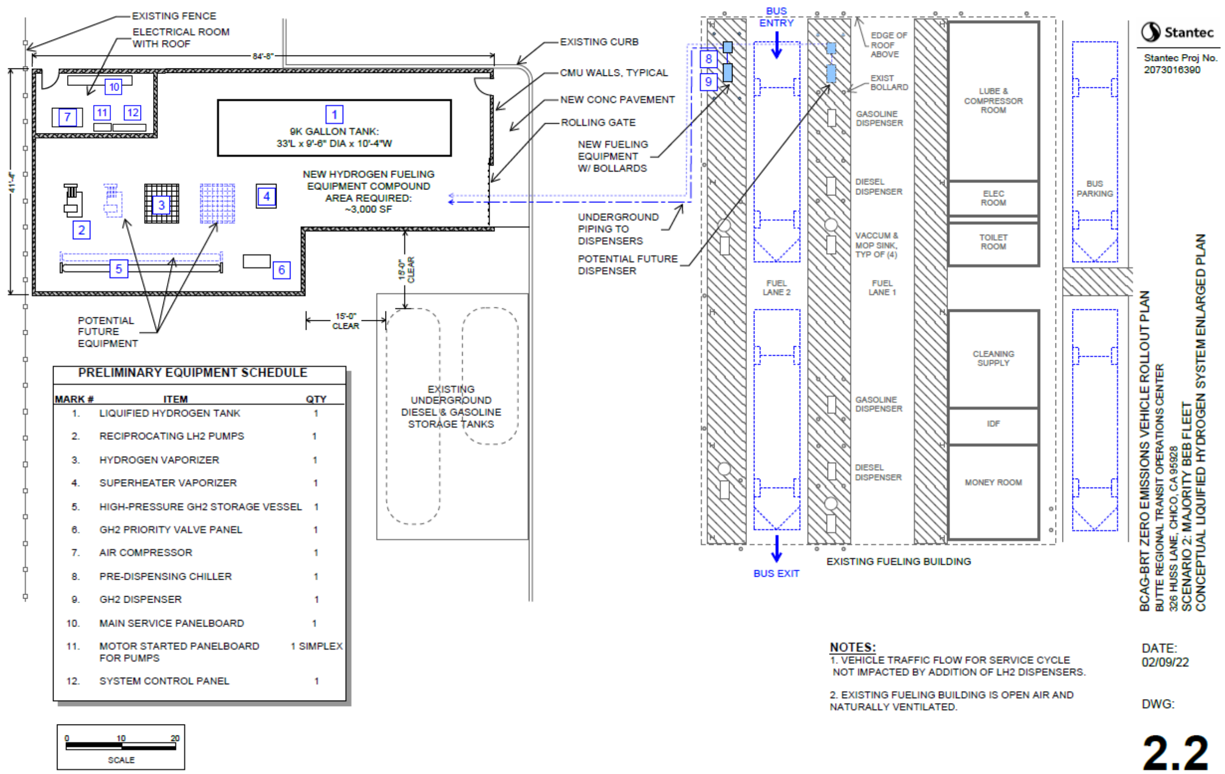
BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 1: MAJORITY BEB FLEET
CONCEPTUAL BEB CHARGING ENLARGED PLAN

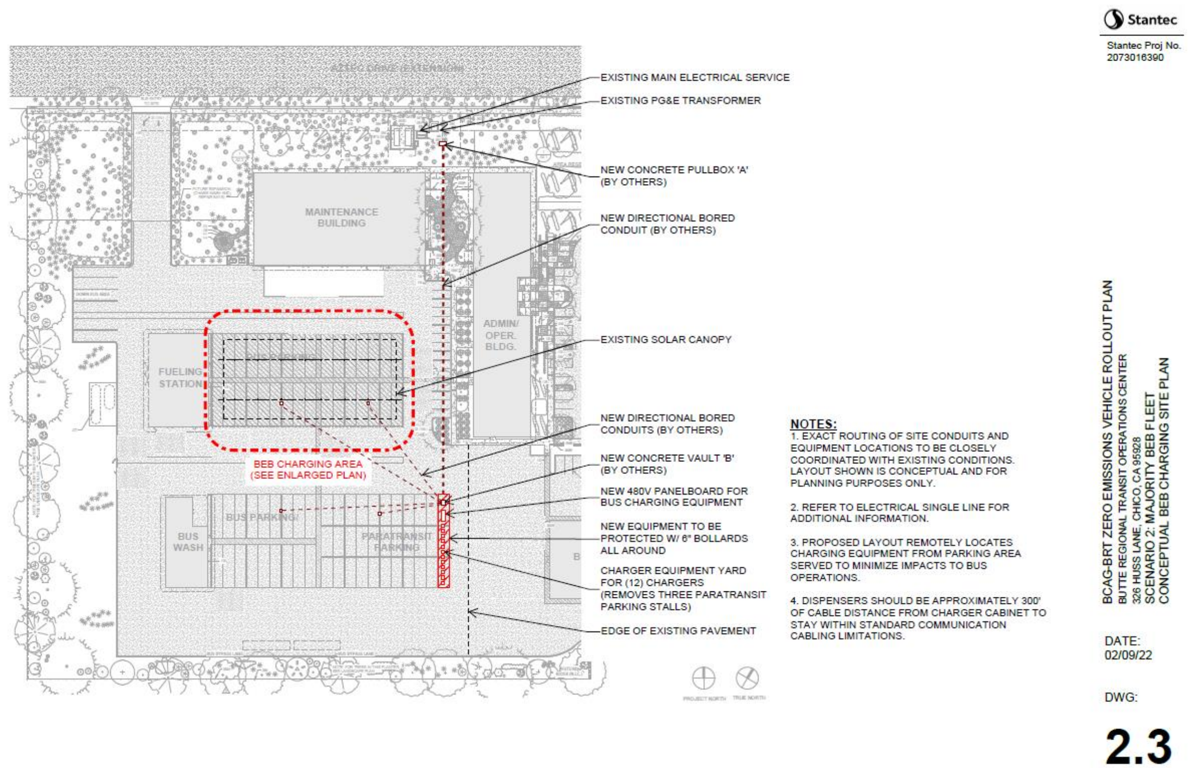
DATE:
02/09/22

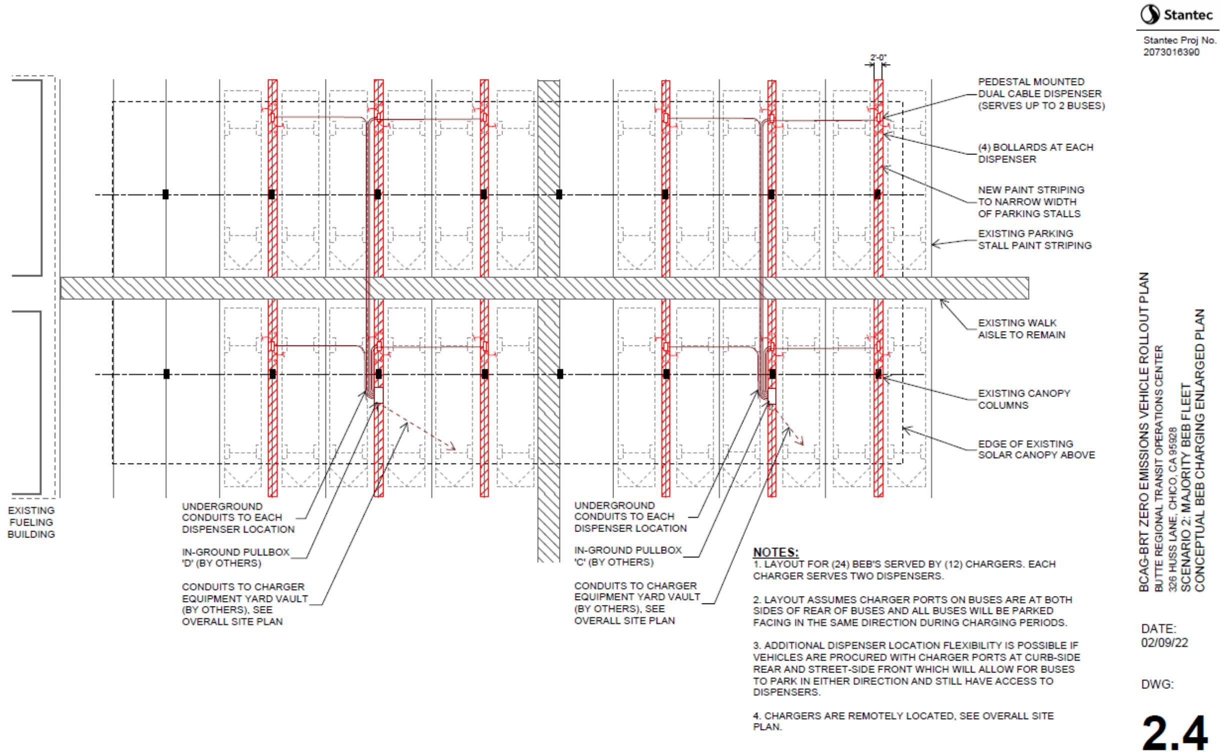
DWG:

1.4


Stantec
Stantec Proj No.
2073016390
HYDROGEN DEMAND
ACTIVE NUMBER OF H2 FCEB VEHICLES (40' / CUTAWAY) 8 / 4
TOTAL H2 (25% FCEB) REQUIRED/DAY (WEEKDAY) [KG] 243
TOTAL H2 (25% FCEB) REQUIRED/DAY (WEEKDAY) [GAL] 907
TOTAL H2 (25% FCEB) REQUIRED/DAY (WEEKEND) [KG] 94
TOTAL H2 (25% FCEB) REQUIRED/DAY (WEEKEND) [GAL] 351
STORAGE TANK CAPACITY - NOMINAL [GAL] 9,000
STORAGE TANK CAPACITY - 90% USABLE [GAL] 8,100
QTY OF LH2 STORAGE TANKS 1
STORAGE LAST (WEEKDAY) [DAYS] 8
FREQUENCY OF FILLING STORAGE PER WEEK 0.65
FREQUENCY OF FILLING STORAGE DELIVERED BY OFFLOADING TRUCK FOR WEEKDAY CONSUMPTION ONE FUEL DELIVERY EVERY 10 DAYS
MAINTENANCE BUILDING
BUS ENTRY
EXISTING FUELING BUILDING
BUS EXIT
HYDROGEN FUELING EQUIPMENT COMPOUND (SEE ENLARGED PLAN)
ADMIN/ OPER. BLDG.
BUS WASH
(E) BUILDING (N.I.C.)
NOTES:
1. HYDROGEN DISPENSERS MAY BE LOCATED IN EXISTING FUELING STATION. DISPENSERS SHOULD BE LOCATED IN AN OPEN-AIR LOCATION. DETAILS WILL BE STUDIED IN DESIGN PHASE FOR BEST LOCATION.
2. PER ABOVE TABLE, 8 (40-FT) BUSES AND 4 CUTAWAYS ARE CONSIDERED FOR CALCULATING STORAGE AND FREQUENCY OF DELIVERY.
3. PER ABOVE TABLE A 9,000 GAL STORAGE TANK WILL LAST ABOUT 8 DAYS PER WEEKDAY CONSUMPTION.
4. CONSIDERING LESS FUEL CONSUMPTION OVER WEEKENDS, ONE FUEL DELIVERY WOULD BE NEEDED EVERY 10 WEEKDAYS.
BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 2: MAJORITY BEB FLEET
CONCEPTUAL LIQUIFIED HYDROGEN SYSTEM SITE PLAN
DATE:
02/09/22
DWG:
2.1


EXISTING FENCE
ELECTRICAL ROOM WITH ROOF
EXISTING CURB
CMU WALLS, TYPICAL
NEW CONC PAVEMENT
ROLLING GATE
NEW FUELING EQUIPMENT W/ BOLLARDS
UNDERGROUND PIPING TO DISPENSERS
POTENTIAL FUTURE DISPENSER
9K GALLON TANK: 33'L x 9'-6" DIA x 10'-4"W
NEW HYDROGEN FUELING EQUIPMENT COMPOUND AREA REQUIRED: ~3,000 SF
POTENTIAL FUTURE EQUIPMENT
15'-0" CLEAR
EXISTING UNDERGROUND DIESEL & GASOLINE STORAGE TANKS
BUS ENTRY
BUS EXIT
EDGE OF ROOF ABOVE
EXIST BOLLARD
GASOLINE DISPENSER
DIESEL DISPENSER
VACCUM & MOP SINK, TYP OF (4)
FUEL LANE 2
FUEL LANE 1
LUBE & COMPRESSOR ROOM
ELEC ROOM
TOILET ROOM
CLEANING SUPPLY
IDF
MONEY ROOM
BUS PARKING
EXISTING FUELING BUILDING
PRELIMINARY EQUIPMENT SCHEDULE
MARK # | ITEM | QTY
1. LIQUIFIED HYDROGEN TANK 1
2. RECIPROCATING LH2 PUMPS 1
3. HYDROGEN VAPORIZER 1
4. SUPERHEATER VAPORIZER 1
5. HIGH-PRESSURE GH2 STORAGE VESSEL 1
6. GH2 PRIORITY VALVE PANEL 1
7. AIR COMPRESSOR 1
8. PRE-DISPENSING CHILLER 1
9. GH2 DISPENSER 1
10. MAIN SERVICE PANELBOARD 1
11. MOTOR STARTED PANELBOARD FOR PUMPS 1 SIMPLEX
12. SYSTEM CONTROL PANEL 1
SCALE
NOTES:
1. VEHICLE TRAFFIC FLOW FOR SERVICE CYCLE NOT IMPACTED BY ADDITION OF LH2 DISPENSERS.
2. EXISTING FUELING BUILDING IS OPEN AIR AND NATURALLY VENTILATED.
Stantec
Stantec Proj No. 2073016390
BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 2: MAJORITY BEB FLEET
CONCEPTUAL LIQUIFIED HYDROGEN SYSTEM ENLARGED PLAN
DATE: 02/09/22
DWG:
2.2


Stantec
Stantec Proj No.
2073016390
MAINTENANCE BUILDING
FUELING STATION
ADMIN/ OPER. BLDG.
BUS WASH
BUS PARKING
PARATRANSIT PARKING
BEB CHARGING AREA (SEE ENLARGED PLAN)
EXISTING MAIN ELECTRICAL SERVICE
EXISTING PG&E TRANSFORMER
NEW CONCRETE PULLBOX 'A' (BY OTHERS)
NEW DIRECTIONAL BORED CONDUIT (BY OTHERS)
EXISTING SOLAR CANOPY
NEW DIRECTIONAL BORED CONDUITS (BY OTHERS)
NEW CONCRETE VAULT 'B' (BY OTHERS)
NEW 480V PANELBOARD FOR BUS CHARGING EQUIPMENT
NEW EQUIPMENT TO BE PROTECTED W/ 6" BOLLARDS ALL AROUND
CHARGER EQUIPMENT YARD FOR (12) CHARGERS (REMOVES THREE PARATRANSIT PARKING STALLS)
EDGE OF EXISTING PAVEMENT
NOTES:
1. EXACT ROUTING OF SITE CONDUITS AND EQUIPMENT LOCATIONS TO BE CLOSELY COORDINATED WITH EXISTING CONDITIONS. LAYOUT SHOWN IS CONCEPTUAL AND FOR PLANNING PURPOSES ONLY.
2. REFER TO ELECTRICAL SINGLE LINE FOR ADDITIONAL INFORMATION.
3. PROPOSED LAYOUT REMOTELY LOCATES CHARGING EQUIPMENT FROM PARKING AREA SERVED TO MINIMIZE IMPACTS TO BUS OPERATIONS.
4. DISPENSERS SHOULD BE APPROXIMATELY 300' OF CABLE DISTANCE FROM CHARGER CABINET TO STAY WITHIN STANDARD COMMUNICATION CABLING LIMITATIONS.
BCAG-BRT ZERO EMISSIONS VEHICLE ROLLOUT PLAN
BUTTE REGIONAL TRANSIT OPERATIONS CENTER
326 HUSS LANE, CHICO, CA 95928
SCENARIO 2: MAJORITY BEB FLEET
CONCEPTUAL BEB CHARGING SITE PLAN
DATE:
02/09/22
DWG:
2.3


Stantec
Stantec Proj No. 2073016390
2'-0"
PEDESTAL MOUNTED DUAL CABLE DISPENSER (SERVES UP TO 2 BUSES)
(4) BOLLARDS AT EACH DISPENSER
NEW PAINT STRIPING TO NARROW WIDTH OF PARKING STALLS
EXISTING PARKING STALL PAINT STRIPING
EXISTING WALK AISLE TO REMAIN
EXISTING CANOPY COLUMNS
EDGE OF EXISTING SOLAR CANOPY ABOVE
EXISTING FUELING BUILDING
UNDERGROUND CONDUITS TO EACH DISPENSER LOCATION
IN-GROUND PULLBOX 'D' (BY OTHERS)
CONDUITS TO CHARGER EQUIPMENT YARD VAULT (BY OTHERS), SEE OVERALL SITE PLAN
UNDERGROUND CONDUITS TO EACH DISPENSER LOCATION
IN-GROUND PULLBOX 'C' (BY OTHERS)
CONDUITS TO CHARGER EQUIPMENT YARD VAULT (BY OTHERS), SEE OVERALL SITE PLAN
NOTES:
1. LAYOUT FOR (24) BEB'S SERVED BY (12) CHARGERS. EACH CHARGER SERVES TWO DISPENSERS.
2. LAYOUT ASSUMES CHARGER PORTS ON BUSES ARE AT BOTH SIDES OF REAR OF BUSES AND ALL BUSES WILL BE PARKED FACING IN THE SAME DIRECTION DURING CHARGING PERIODS.
3. ADDITIONAL DISPENSER LOCATION FLEXIBILITY IS POSSIBLE IF VEHICLES ARE PROCURED WITH CHARGER PORTS AT CURB-SIDE REAR AND STREET-SIDE FRONT WHICH WILL ALLOW FOR BUSES TO PARK IN EITHER DIRECTION AND STILL HAVE ACCESS TO DISPENSERS.
4. CHARGERS ARE REMOTELY LOCATED, SEE OVERALL SITE PLAN.
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SCENARIO 2: MAJORITY BEB FLEET
CONCEPTUAL BEB CHARGING ENLARGED PLAN
DATE: 02/09/22
DWG:
2.4