Zero-Emission Fleet Transition Plan

Roaring Fork Transportation Authority

Final Report
June 28, 2024

Stantec

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Prepared for:

Roaring Fork Transportation Authority

Prepared by:

Stantec Consulting Services Inc.

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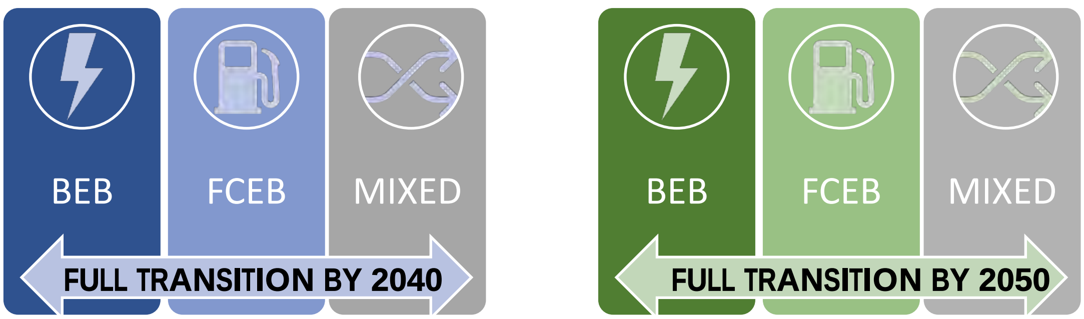
EXECUTIVE SUMMARY

Roaring Fork Transportation Authority (RFTA) has commissioned the Zero Emission Vehicle (ZEV) Fleet Transition Plan to determine the capital investments and operational changes required for successful implementation of ZEVs. The implementation of ZEV technologies aligns with the goals set forth in RFTA's Climate Action Plan and the State of Colorado's goal to transition the state transit fleet to 100% ZEV by 2050. Based on the modeling results and technology feasibility, RFTA has chosen to review six cases grouped in two timelines:



A transition to 100% ZEV by 2040 is considered an accelerated timeline. The three technology scenarios evaluated are: Battery electric buses (BEBs) only, fuel cell electric buses (FCEBs) only, and a mix of those two technologies. The second timeline assumes a full transition to ZEB by 2050, with the same three technology scenarios. All options were determined and refined through a collaborative optimization process with RFTA's operations and leadership staff.

This Plan also evaluates fleet energy requirements, power modeling, infrastructure upgrade requirements, and a fleet procurement schedule for each scenario. This Plan also provides an overview of the needed facility upgrades and modifications—primarily the installation of electric charging infrastructure and the construction of a hydrogen fueling station with associated gas leak detection and ventilation systems—required to support ZEV Fleet operations at the RFTA Glenwood Springs Maintenance Facility (GMF) and Aspen Maintenance Facility (AMF).

Furthermore, a financial model, in the form of a total cost of ownership (TCO) analysis, was developed for the six options, with each compared against the business-as-usual, or base-case, scenario. It is important to understand the inherent limitations of the financial modeling due to assumptions about costs, service levels, operations, asset life cycles, and other factors that are difficult to predict. Additionally, it is important to note the categories modeled are focused on the impacts of a change in propulsion type. They do not account for service delivery costs (such as driver salaries) as these costs would be comparable in all cases. This cost analysis is aimed to be a comparison between the different scenarios and not a detailed capital and operational forecast for RFTA.

While the accelerated timeline accomplishes a full transition by 2040, the TCO analysis maintains the same time horizon (2023-2050) across all scenarios for consistency. Implementing the ZEB transition under the accelerated timeline of 2040 will lead to higher costs compared to the 2050 timeline due to earlier procurement of zero emission vehicles and charging infrastructure, which will need to be replaced or refurbished through more cycles than under the 2050 timeline. Challenges with the accelerated timeline will include a condensed procurement timeline for infrastructure improvements, and procurement of vehicles and systems that are still maturing and have not reached a large share of market penetration. However, the higher costs under the accelerated timeline may be partially or fully mitigated by pursuing federal and state discretionary grants. The technical data projections and cost estimates used in this report are based on a 2023 baseline for RFTA and the ZEV industry. This planning document will need to be revisited periodically to check assumptions and make necessary updates.

RFTA can maximize the reduction of its fleet-related cumulative greenhouse gas (GHG) emissions under the Mixed-2040 option with a 52% (~144,100 tons over the lifetime of 2023-2050) reduction compared to the baseline case. The GHG reductions under the BEB-2040 case are 46% (~129,400 tons). The FCEB-2040 case renders a 44% GHG reduction (~123,230 tons) due to the residual carbon footprint of hydrogen fuel production and transportation. For the 2050 implementation timeline, the highest GHG reduction was also observed for the Mixed-2050 case with approximately 39% reduction (~108,400) tons over the lifetime of 2023-2050). The BEB-2050 case represents a 25% reduction (~70,300 tons) while the FCEB-2050 only shows a 17% reduction (~47,600 tons). The GHG emission reductions by scenario reflect the pace of ZEV adoption, the different utilities providing power to each facility and the utility provider's goals for decarbonization.

Beyond the financial and GHG impacts of the different scenarios, it is important to consider the operational flexibility of FCEB and a Mixed Fleet option. For example, the Mixed Fleet provides the technology diversification that RFTA prioritized with its Destination 2040 goal to attain a balanced split of CNG, diesel and ZEB. To evaluate all aspects of implementation between the different technologies, Stantec developed a Multi-Criteria Evaluation (MCE) and scoring system to select a preferred option. The MCE process determined that the Mixed Fleet 2050 was the best feasible approach to meets the agency's ZEV Transition goals. This preferred Mixed Fleet 2050 Case plans for transition to hydrogen fueling at GMF and transition to battery-electric charging at AMF.

This report also provides information on operational and planning considerations, phasing and implementation recommendations, workforce training, and potential funding strategies to create a successful transition.

Acronyms

ABS	Anti-lock Braking System
AC	Alternating Current
AHJ	Authority Having Jurisdiction
AHP	Analytic Hierarchy Process
AMF	Aspen Maintenance Facility
APTA	American Public Transportation Association
ASE	Automotive Service Excellence
ATS	Automatic Transfer Switch
BE	Battery Electric
BEV	Battery-Electric Vehicle
BEB	Battery-Electric Bus
BRT	Bus Rapid Transit
BTM	Behind the Meter
CAN	Controller Area Network
CARB	California Air Resources Board
CCS	Combined Charging System or Carbon Capture and Storage
CMAQ	Congestion Mitigation and Air Quality Improvement Program
CMU	Concrete Masonry Unit
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COA	City of Aspen
DAR	Dial-a-Ride, Demand Response
DC	Direct Current

DGE	Diesel Gallon Equivalent
DOE	Department of Energy
EV	Electric Vehicle
FCE	Hydrogen Fuel Cell Electric
FCEV	Hydrogen Fuel Cell Electric Vehicle
FCEB	Hydrogen Fuel Cell Electric Bus
FF	Fossil Fuel
FHWA	Federal Highway Administration
FOA	Funding Opportunity Announcement
FTA	Federal Transportation Administration
GH_2	Green Hydrogen
GHG	Greenhouse Gas Emissions
GMF	Glenwood Maintenance Facility
GVWR	Gross Vehicle Weight Rating
H_2	Hydrogen
HCE	Holy Cross Energy
HRS	Hydrogen Refueling Station
HVAC	Heating Ventilation Air Conditioning
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-Hour
kVA	Kilovolt-Ampere (Kilovolt-Amp)
LED	Light-Emitting Diode
LH_2	Liquid Hydrogen
LOTO	Lock-Out-Tag-Out

MCE	Multi Criteria Evaluation
MEAN	Municipal Energy Agency of Nebraska
MT	Metric Ton
MW	Megawatt
NFPA	National Fire Protection Association
NG	Natural Gas
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NTI	National Transit Institute
OCPP	Open Charge Point Protocol
OEM	Original Equipment Manufacturer
PM	Preventative Maintenance
RANGE	Rocky Mountain Alliance for Next Generation Energy
RFTA	Roaring Fork Transportation Authority
SAE	Society of Automotive Engineers
SH	State Highway
SOC	State of Charge
SMR	Steam Methane Reformation
TAM	Transit Asset Management
TCO	Total Cost of Ownership
TOU	Time of Use
TTC	Toronto Transit Commission
USDOT	United States Department of Transportation
VFD	Variable Frequency Drive
WISHH	Western Inter-States Hydrogen Hub

ZE	Zero Emission
ZEB	Zero-Emission Bus
ZEV	Zero-Emission Vehicle

1.0 INTRODUCTION AND BACKGROUND

Roaring Fork Transportation Authority (RFTA) has been in operation since 1983 and has grown to become the second largest transit system in Colorado, and the largest rural transit system in the United States. RFTA provides local fixed route, fixed route commuter, bus rapid transit (BRT), and paratransit services. The RFTA network spans 64 miles, connecting mountain resort communities along State Highway (SH) 82 in the Roaring Fork Valley to workforce communities along Interstate 70 and State Highway 6 in the Colorado River Valley. RFTA provided 5.4 million unlinked passenger trips in 2019 (pre-pandemic)[1]. RFTA's services are organized under three umbrellas:

- **Fixed-Route:** RFTA operates fixed-route, and tailored service contract services for the following routes: of City of Aspen, Grand Hogback, Maroon Bells, City of Glenwood Springs, Roaring Fork Valley commuter service, Snowmass Village, Woody Creek, and Carbondale.

- **Bus Rapid Transit:** The VelociRFTA (Up Valley and Down Valley) route, the first rural BRT system in the United States, covers a 42-mile corridor along SH 82 between Aspen and Glenwood Springs.

- **Paratransit:** RFTA operates complementary paratransit services for eligible passengers. The services are provided to residents and visitors who are unable to access the fixed-route bus system and meet the eligibility requirements, the services must be scheduled in advance. The ADA services include:
  - **ADA Complementary Paratransit Service** in Aspen, Carbondale, and Glenwood Springs within a ¾ mile radius from the fixed-route services (see RFTA's website for details).
  - **Garfield County Traveler** paratransit service in Garfield County covering two bases:
    - Glenwood Base consisting of a 2-mile radius from Hwy 82 between Carbondale and Glenwood Springs I-70 between Glenwood Springs and New Castle.
    - Rifle Base consisting of a 2-mile radius between Battlement Mesa and New Castle.

    Connecting or through-rides between Glenwood Base and Rifle Base are available through RFTA's Hogback regional bus service.
  - **Pitkin County Senior Van** provides services for Senior Citizens in Pitkin County throughout the Aspen, Old Snowmass, and the Snowmass Village areas. Any person who is age 60 or older residing or visiting Pitkin County is eligible for the service. The Senior Van also makes connections to RFTA buses operating in the Roaring Fork Valley corridor.

[1] 2019 NTD agency profile.

Figure 1: Current Roaring Fork Transportation Authority Services[2]

As of 2023, RFTA completed 4.8 million system-wide passenger trips with over 380 employees during peak winter and summer seasons. Steps in this planning process include:

- A review of existing conditions to understand characteristics and constraints to RFTA's operations and service area. This includes a primer on different ZEV technologies as well as a scan of the zero emission (ZE) market including battery electric buses (BEBs) and hydrogen fuel cell electric buses (FCEBs).
- Energy and power modeling to understand performance under different ZEV technology options as well as their viability and suitability to RFTA's needs. Quantitative and qualitative criteria were evaluated to determine RFTA's preferred ZEV fleet composition.

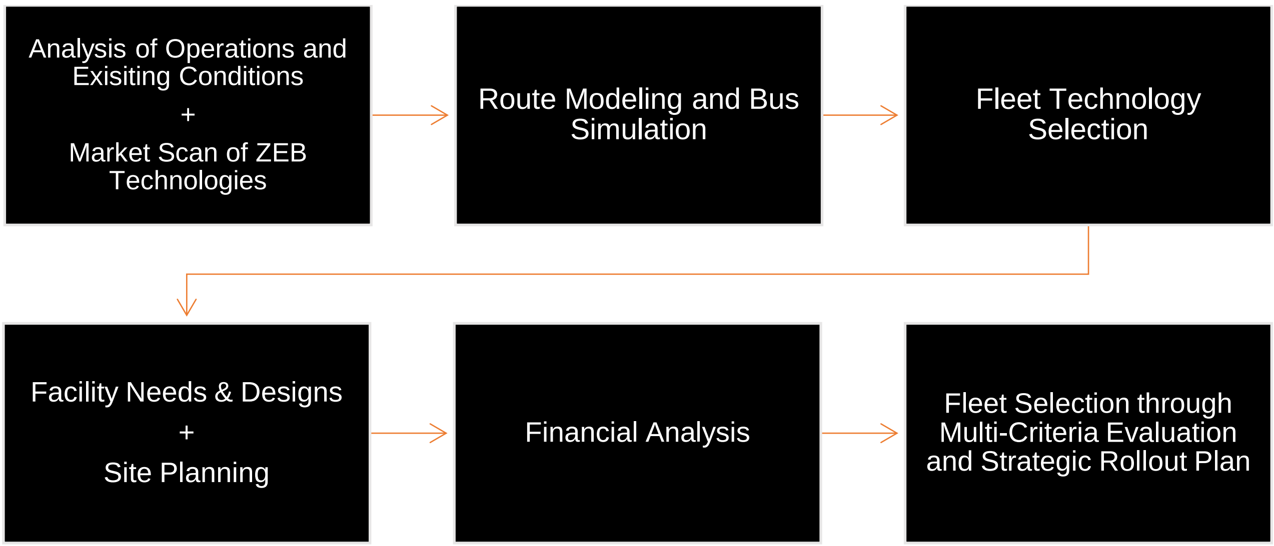
This report is intended to act as a roadmap to guide RFTA through its transition to a 100% ZEV implementation, aligned with climate action goals.

[2] bus-schedules-guide-to-ride-fall-2023-i.pdf (rfta.com)

2.0 APPROACH TO ZEB PLANNING

The graphic in Figure 2 provides a high-level schematic of the major steps in this project to derive a recommended fleet mix and implementation plan.

Figure 2: Schematic representation of the steps in the ZEB planning process



The first step involved a review of RFTA's existing conditions to provide a foundation and understanding of its operations, service, and business processes that would be impacted by a transition to a ZEB fleet. A summary of these findings is provided in Section 3.0. A site visit to the operating base and maintenance facilities provided insight into the constraints and opportunities for implementing ZEBs, as well as the condition of the facilities, buildings, and existing service cycle. A market scan was also conducted to analyze current ZEB technologies and their limitations as well as technologies in the research and development phase that could help shape RFTA's future ZEB fleet.

Next, Stantec modeled block-level and vehicle-level fuel economies to understand the predicted performance of different ZEB technologies under RFTA's operating parameters for fixed-route, demand response (DAR), and service fleet vehicles under six scenarios described as BEB-only, FCEB-only, and a mixed fleet grouped into two sets of implementation timelines – an accelerated timeline for a 100% ZEB transition by 2040 and a second timeline that achieves that goal by 2050 (Section 4.0).This report provides procurement timeline details for each scenario evaluated (Section 5.0).

Stantec designed conceptual site plans and an opinion of probable costs for the two maintenance facilities that demonstrate the layout of the yard, the service cycle, and required retrofits to accommodate BEB charging equipment and hydrogen fueling infrastructure (Section 6.0).

Stantec then provided a fuel demand and supply analysis (Section 7.0) and an evaluation of financial impacts (Section 0). With the site plans and identification of required facility modifications and impacts on capital and operating costs, the financial analysis for the ZEB rollout by case was developed in Section 9.0.

Operating and planning considerations (Section 10.0), workforce training (Section 11.0), and potential funding sources (Section 12.0) are also reviewed and discussed. Finally, GHG emission reductions are discussed across each timeline (Section 13.0).

3.0 SUMMARY OF KEY EXISTING CONDITIONS

The existing conditions review included a comprehensive review of RFTA's existing capital and operating status. It encompassed operations, facilities, and finances, and laid the groundwork for the modeling and understanding of operating conditions in the 2023 baseline year.

Major findings from the Existing Conditions evaluation that will affect the ZEB transition include:

- RFTA operates in a compact and mountainous service area from 8,000' elevation in Aspen to 5,519' elevation in Rifle.
- RFTA operates 45-ft, 40-ft, 35-ft, and 30-ft buses for fixed-route services.
- RFTA operates a fleet of 17 cutaways for fixed route and demand response operations. There are currently fewer ZE options for these smaller vehicle types, but more options are continuing to emerge onto the market.
- All fixed-route, demand response and service vehicles are fueled on-site at RFTA's maintenance facilities. However, AMF can only accommodate the fueling and maintenance of diesel and gasoline vehicles, leaving GMF to be the only facility that can fuel and maintain CNG buses.
- The existing fleet of 40-ft buses and 45-ft MCI coaches are operated interchangeably but there is a preference for 45-ft buses to be used on the Local Valley, VelociRFTA and Hogback blocks and routes. This is both due to high demand and higher capacity on the 45-ft buses and due to riders' preferences.
- Some of the fleet is directly owned and operated by RFTA and some is owned by regional partners such as City of Aspen and City of Glenwood Springs. All vehicles are maintained and operated by RFTA staff.
- Table 1 below summarizes the revenue fleet composition as of September 2023 at 117 active vehicles which was used as a baseline for the ZEB transition analysis. The fleet make up and totals continued to change as vehicles retired and got replaced during the course of the study and Table 2 shows the fleet make up as of June 2024.

Table 1: Current revenue fleet composition (September 2023)

Type	Vehicle #	Model Year	Delivery Year	Qty. Active	Qty. Active Surplus/ Prep	Department ID	Make	Fuel type	FTA min. useful life	Current age [based on delivery year]	Service type	Ownership
45' Bus	432-433	2009	2008	0	2	BUS-REV	MCI	Diesel	14	15	Fixed Route	RFTA
	435-442	2010	2009	2	6	BUS-REV	MCI	Diesel	14	14	Fixed Route	RFTA
	443	2015	2015	1	0	BUS-REV	MCI	CNG	14	8	Fixed Route	RFTA
	444-449	2016	2016	6	0	BUS-REV	MCI	CNG	14	7	Fixed Route	RFTA
	450	2017	2017	1	0	BUS-REV	MCI	CNG	14	6	Fixed Route	RFTA
	451	2018	2018	1	0	BUS-REV	MCI	CNG	14	5	Fixed Route	RFTA
	452-457	2021	2021	5	1	BUS-REV	MCI	CNG	14	2	Fixed Route	RFTA
40' Bus	101-110	2019	2019	10	0	BUS-REV	GILLIG	Diesel	14	4	Fixed Route	RFTA
	111-125	2021	2021	15	0	BUS-REV	GILLIG	Diesel	14	2	Fixed Route	RFTA
	126-139	2023	2023	8	6	BUS-REV	GILLIG	Diesel	14	0	Fixed Route	RFTA
	541-556	2007	2007	10	6	BUS-REV	NEWFLYER	Diesel	14	16	Fixed Route	RFTA
	631-638	2019	2019	4	0	BUS-REV	NEWFLYER	BEB	14	4	Fixed Route	RFTA
		2019	2019	4	0	BUS-REV	NEWFLYER	BEB	14	4	Fixed Route	COA
	701-704	2013	2013	4	0	BUS-REV	GILLIG	CNG	14	10	Fixed Route	RFTA
	721-738	2013	2013	17	0	BUS-REV	GILLIG	CNG	14	10	Fixed Route	RFTA
	739-740	2018	2018	2	0	BUS-REV	GILLIG	CNG	14	5	Fixed Route	RFTA
	741-750	2023	2023	0	10	BUS-REV	GILLIG	CNG	14	0	Fixed Route	RFTA
	791	2010	2010	1	0	BUS-REV	GILLIG	Diesel	14	13	Fixed Route	RGS
35' Bus	281	2012	2012	1	0	BUS-REV	GILLIG	Diesel	14	11	Fixed Route	COA
	282-285	2017	2017	4	0	BUS-REV	GILLIG	Diesel	14	6	Fixed Route	COA
30' Bus	792	2019	2019	1	0	BUS-REV	GILLIG	CNG	14	4	Fixed Route	RGS
	793	2020	2019	1	0	BUS-REV	GILLIG	CNG	14	4	Fixed Route	RGS
Cutaway	G08	2007	2008	0	1	TRAVELER	FORD	Unleaded	10	15	Demand Response	Garfield Co.
	G11-G12	2009	2009	1	1	TRAVELER	FORD	Unleaded	10	14	Demand Response	Garfield Co.
	G14-G15	2015	2015	2	0	TRAVELER	FORD	CNG	10	8	Demand Response	Garfield Co.
	G16-G17	2018	2018	2	0	TRAVELER	FORD	Unleaded	10	5	Demand Response	Garfield Co.
	G18-G19	2021	2021	2	0	TRAVELER	FORD	Unleaded	10	2	Demand Response	Garfield Co.
	G20	2023	2023	0	1	TRAVELER	FORD	Unleaded	10	0	Demand Response	Garfield Co.
	S29	2011	2018	1	0	VEH-REV	FORD	Unleaded	10	5	Fixed Route	RFTA
	S19-S21	2014	2014	3	0	VEH-REV	FORD	Unleaded	10	9	Fixed Route	COA
	S22	2015	2015	1	0	VEH-REV	FORD	Unleaded	10	8	Fixed Route	COA
	W01	2016	2015	1	0	VEH-REV	FORD	Unleaded	10	8	Fixed Route	RFTA
	R24	2016	2016	1	0	VEH-REV	FORD	Unleaded	10	7	Fixed Route	RFTA
	S25	2019	2018	1	0	VEH-REV	FORD	Unleaded	10	5	Fixed Route	COA
	S26-S28	2019	2018	3	0	VEH-REV	FORD	Unleaded	10	5	Fixed Route	COA
	S30	2019	2020	1	0	VEH-REV	FORD	Unleaded	10	3	Fixed Route	COA
Totals	TOTAL Fleet			117	34							
	RFTA Fleet			89	31							
	COA Fleet			18	0							
	Garfield County Fleet			7	3							
	RGS Fleet			3	0							
	Totals			234	68							
				302								

Table 2: Current revenue fleet composition (June 2024)

Type	Vehicle #	Model Year	Qty. Active	Qty. Active Surplus/ Prep	Department ID	Make	Fuel type	FTA min. useful life	Service type	Ownership
45' Bus	432-433	2009	0	2	BUS-REV	MCI	Diesel	14	Fixed Route	RFTA
	435-442	2010	2	6	BUS-REV	MCI	Diesel	14	Fixed Route	RFTA
	443	2015	1	0	BUS-REV	MCI	CNG	14	Fixed Route	RFTA
	444-449	2016	6	0	BUS-REV	MCI	CNG	14	Fixed Route	RFTA
	450	2017	1	0	BUS-REV	MCI	CNG	14	Fixed Route	RFTA
	451	2018	1	0	BUS-REV	MCI	CNG	14	Fixed Route	RFTA
	452-457	2021	5	1	BUS-REV	MCI	CNG	14	Fixed Route	RFTA
40' Bus	101-110	2019	10	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	RFTA
	111-125	2021	15	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	RFTA
	126-139	2023	14	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	RFTA
	546-556	2007	10	0	BUS-REV	NEWFLYER	Diesel	14	Fixed Route	RFTA
	631-638	2019	4	0	BUS-REV	NEWFLYER	BEB	14	Fixed Route	RFTA
		2019	4	0	BUS-REV	NEWFLYER	BEB	14	Fixed Route	COA
	701-704	2013	4	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RFTA
	721-738	2013	17	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RFTA
	739-740	2018	2	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RFTA
	741-750	2023	10	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RFTA
	791	2010	1	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	RGS
35' Bus	281	2012	1	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	COA
	282-285	2017	4	0	BUS-REV	GILLIG	Diesel	14	Fixed Route	COA
30' Bus	792	2019	1	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RGS
	793	2020	1	0	BUS-REV	GILLIG	CNG	14	Fixed Route	RGS
Cutaway	G08	2007	0	1	TRAVELER	FORD	Unleaded	10	Demand Response	Garfield Co.
	G11-G12	2009	1	1	TRAVELER	FORD	Unleaded	10	Demand Response	Garfield Co.
	G14-G15	2015	2	1	TRAVELER	FORD	CNG	10	Demand Response	Garfield Co.
	G16-G17	2018	2	0	TRAVELER	FORD	Unleaded	10	Demand Response	Garfield Co.
	G18-G19	2021	2	0	TRAVELER	FORD	Unleaded	10	Demand Response	Garfield Co.
	G20	2023	1	0	TRAVELER	FORD	Unleaded	10	Demand Response	Garfield Co.
	S29	2011	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	RFTA
	S19-S21	2014	3	0	VEH-REV	FORD	Unleaded	10	Fixed Route	COA
	S22	2015	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	COA
	W01	2015	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	RFTA
	R24	2016	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	RFTA
	S25	2019	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	COA
	S26-S28	2019	3	0	VEH-REV	FORD	Unleaded	10	Fixed Route	COA
	S30	2019	1	0	VEH-REV	FORD	Unleaded	10	Fixed Route	RFTA
Totals	TOTAL Fleet		134	12						
	RFTA Fleet		106	9						
	COA Fleet		17	0						
	Garfield County Fleet		8	3						
	RGS Fleet		3	0						
	Totals		268	24						
			292							

Figure 3 shows that more than 50 of RFTA's vehicles are in operation for the majority of the service day (8:00am-6:00pm) with a peak usage at 4pm of 71 vehicles. RFTA's large service area and high frequency of service in the winter peak season necessitate high utilization of the fleet. This could present a challenge for ZEB implementation because vehicles might not have time for mid-day charging or refueling.

Figure 3: Hourly weekday winter peak vehicle requirements (fixed route)

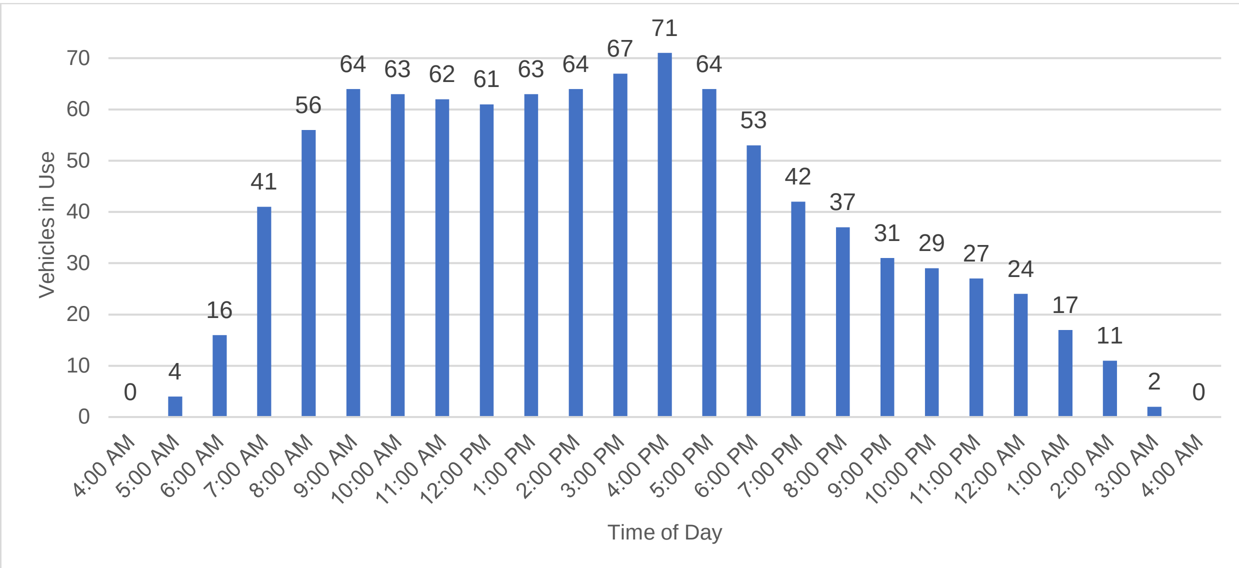
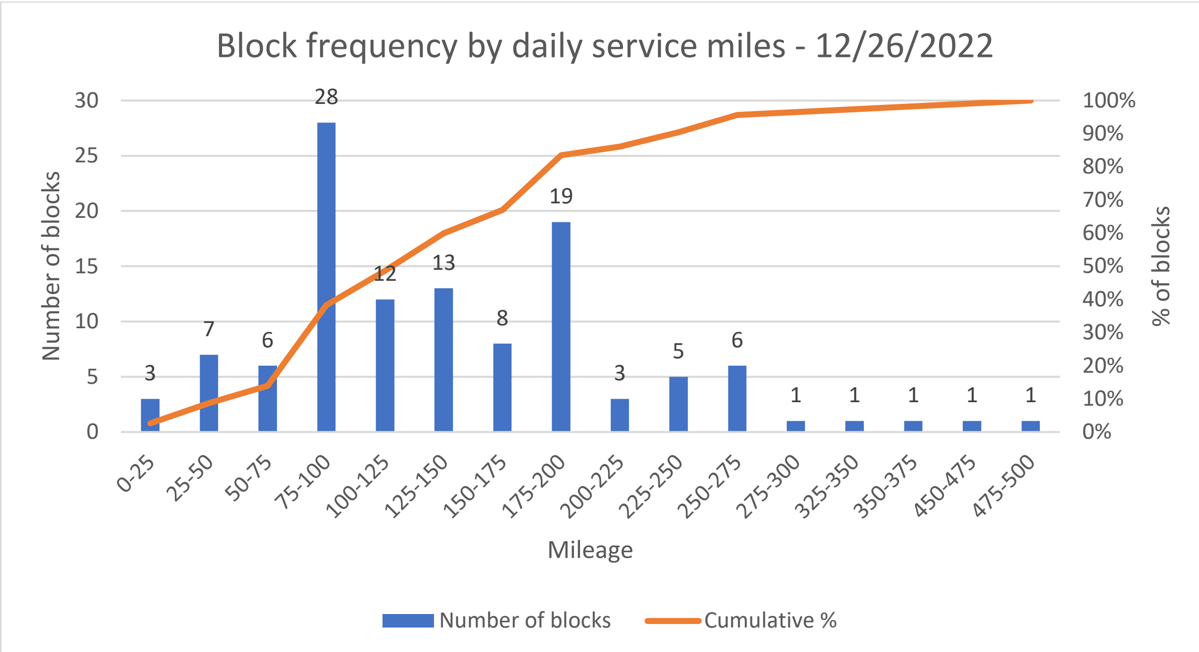


Figure 4 shows that vehicles also travel long distances to provide service to RFTA customers throughout the day. This figure shows the distribution of blocks by total mileage. For example, three blocks traveled between zero and 25 miles, seven blocks traveled between 25 and 50 miles, and so on.

Only 67% of the blocks are less than 175 miles, 10% of the blocks are over 225 miles. Blocks with mileage below 25 miles were strategic back-up trips and manual trips. A total of 85 vehicles covered 121 blocks with an average mileage per block of 148 miles. When blocks are combined at the vehicle level, average daily vehicle mileage observed was 205 miles. RFTA vehicles traveled a total of 16,587 miles on the sampled day with distances ranging from a minimum of 44 miles to 495 miles[3]. The limited range of ZEBs may prove challenging to implement on a 1:1 vehicle replacement basis without on-route / opportunity charging, midday charging, reblocking, or some other strategies to help make ZEBs more feasible in this service area.

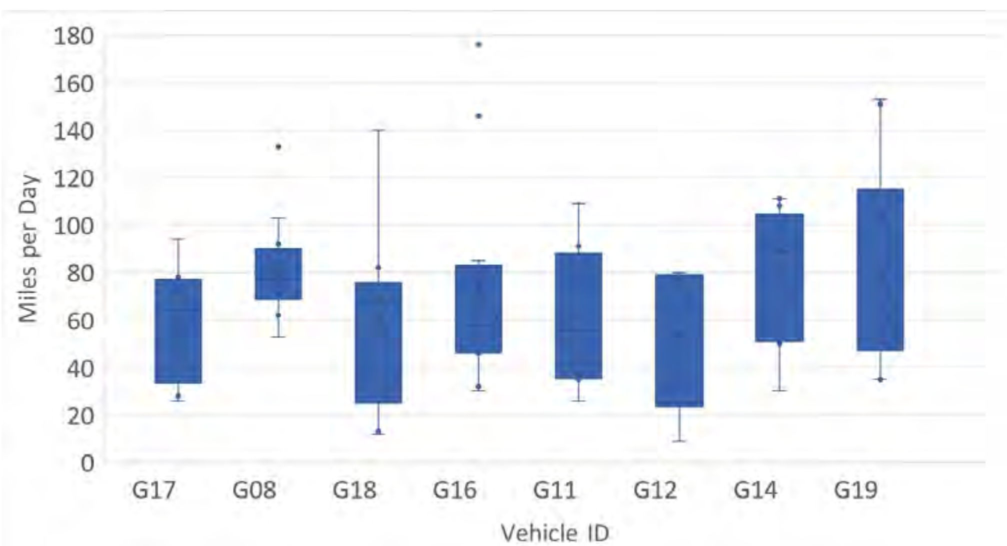
[3] Long block mileages are a result of service modifications where a small subset of blocks is longer than RFTA's historic normal. These blocks require 45-ft diesel MCIs to complete, and it is likely that this trend will continue for RFTA as it is efficient from a scheduling and operating standpoint.

Figure 4: Fixed route block frequency by daily service miles (12/26/2022)



The box and whisker plot in Figure 5 shows the variety of DAR vehicle mileages. A total of 943 DAR runs were analyzed for December 2022 with an average distance of 73 miles and a median distance of 66 miles. However, the longest distance traveled in one day by one vehicle is 176 miles. Some vehicles traveled distances that are close to and above the average current operational range of ZEV cutaways presenting potential range-related issues with ZEV implementation for demand response service.

Figure 5: Daily mileage for DAR vehicles (12/5/2022-12/31/2022)



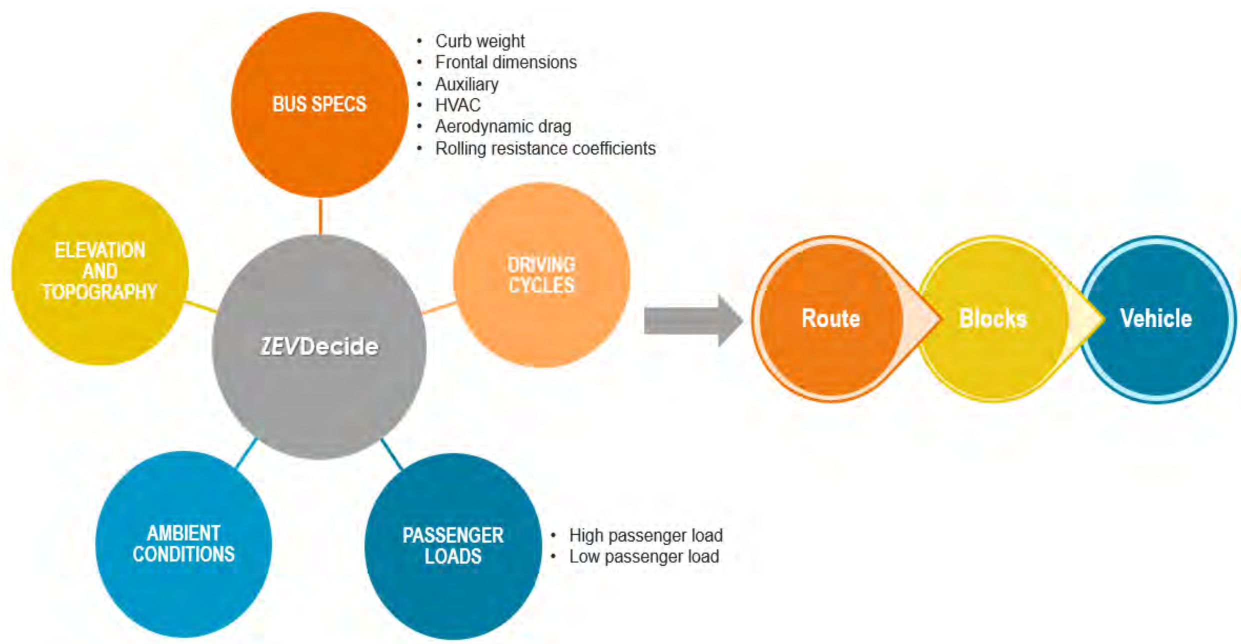
4.0 REVENUE FLEET MODELING

This section provides an overview of the power and energy modeling methodology and presents the results of the modeling to understand the feasibility of transitioning RFTA's operations to different ZE alternatives. Based on the modeling outcomes, we present a discussion of the different ZE fleet solutions and the pros and cons of different fleet compositions that were analyzed.

4.1 FLEET AND POWER MODELING OVERVIEW

ZEVDecide, Stantec's fleet modeling tool, was used to determine a feasible ZEV composition for RFTA's fleet. Figure 6 provides a schematic overview of the modeling process. The predictive ZEV performance modeling depends on several inputs, such as actual passenger loads, driving dynamics, topography, vehicle specifications, and ambient conditions subject to the environment in which the agency operates.

Figure 6: ZEVDecide modeling overview



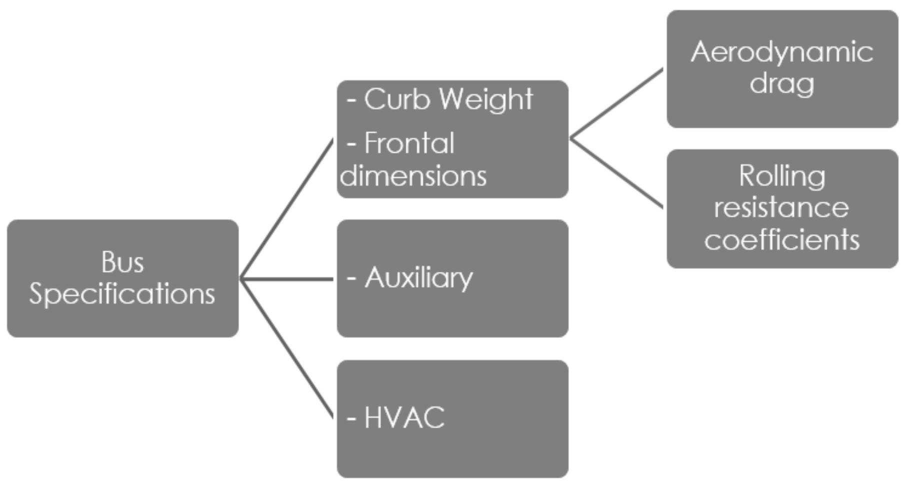
4.1.1 Modeling Inputs

ZEVDecide's modeling process predicts ZEV drivetrain power requirements specific to given acceleration profiles. The following inputs are included in the model to determine feasibility of different ZEV technologies under RFTA's operating conditions.

Bus/vehicle specifications: the bus specification inputs used in the modeling are shown in Figure 7. For RFTA, the key bus specifications used in the modeling process for each service type are shown in Table 3. Both BEBs and FCEBs were modeled for fixed-route services.

RFTA operates a mix of vehicle sizes. Cutaways, 30-ft, 40-ft, and 45-ft vehicles were modeled as fixed-route service at the block level with the vehicle type typically used to service that block. All demand response services were modeled with cutaways. For the modelling of the BEB-only and mixed fleet scenarios we assumed that all ZEV cutaways, 30-ft buses, 40-ft buses, and 45-ft buses will have on-route charging capability.

Figure 7: Schematic of the inputs for bus specifications



In current operations, 40-ft buses and 45-ft buses are often used interchangeably. The vehicle size assignments by block from the dates 12/14/2022 and 12/26/2022 were used to model a realistic typical distribution of those vehicle sizes and the blocks they service. Thus, the modeled energy requirements and operating range estimates reflect a snapshot of those actual service days.

Table 3: Vehicle specifications for energy modeling

Technology Type	Vehicle size	Battery (kWh) or tank (kg)
BEB	45-ft	544 kWh
	40-ft	525 kWh
	35-ft	450kWh
	30-ft	350 kWh
	Cutaway	120 kWh
FCEB	45-ft	50 kg

Technology Type	Vehicle size	Battery (kWh) or tank (kg)
	40-ft	50 kg
	35-ft	37.5 kg
	30-ft	37.5 kg
	Cutaway	13.5 kg

Representative driving cycles: also called acceleration profiles or duty cycles, representative driving cycles are speed versus time profiles that are used to simulate vehicle performance and energy use. Cycles were assigned to all routes based on RFTA's operations and observed driving conditions and are derived from a customized process that overlays GTFS data and general traffic conditions for the service region from Google API. The complete assignment of driving cycles to all routes is presented as an appendix in the energy modeling report. For demand response services, the model used the average driving speeds for each individual run instead of assigning representative driving cycles.

Passenger loads: to examine the weight associated impacts of passenger loads experienced by RFTA's fleet, assumptions for 75% and 90% passenger load for each route are modeled. For demand response services, an average of four passengers onboard was assumed.

Ambient temperature: Stantec developed a correlation between ambient temperature and power requirements from the HVAC system. The power requirement was set based on a winter average of 47°F[4].

Topography and elevation: given that portions of RFTA's service area are impacted by elevation and topography, it is important to account for the impacts of terrain and elevation on the energy efficiency of ZEBs. Each route alignment was imported into Google Earth to create an elevation profile to understand the total elevation gains/losses seen for each route in the system (see example in Figure 8).

Figure 8: Elevation profile example (Route 1)

Source: Google Earth

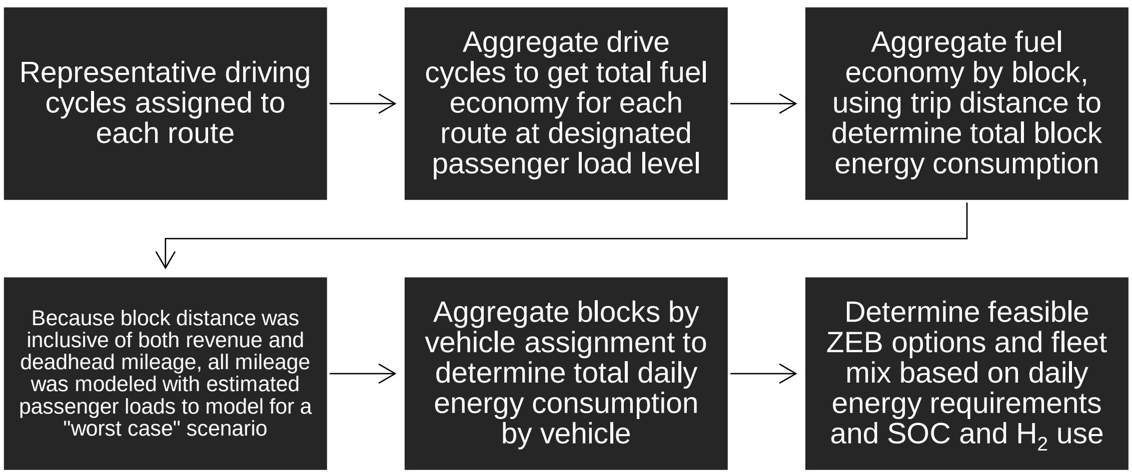
[4] US Climate Data https://www.usclimatedata.com/climate/anaheim/california/united-states/usca0027

The average and maximum grades for each route were determined using these elevation profiles, which were used as the inputs in the topography analysis. Modeling for demand response services did not directly consider topography. Instead, the model used driving speed information for all modeled runs to predict the fuel economy.

4.1.2 Modeling Process

Using the inputs above, predictive energy and power modeling was completed for fixed-route and demand response services. The energy modeling process for fixed-routes first aggregates results at the route level, then at the block level, and is then aggregated at the vehicle assignment level to determine total daily energy consumption per vehicle. This process is described in Figure 9 for fixed routes and Figure 10 for demand response service.

Figure 9: ZEVDecide energy modeling process, fixed routes

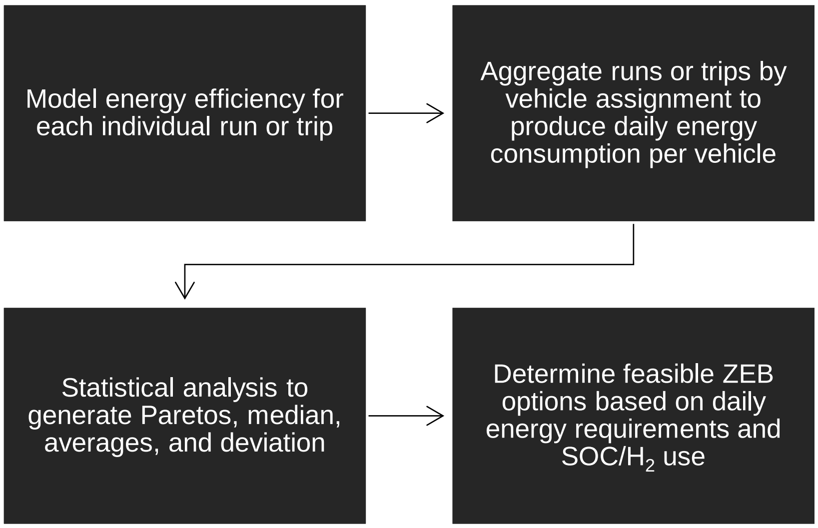


Modeling Results provide insight into:

- Fuel economy and energy requirements
- Operating range
- The feasibility of a BEB to complete its assigned service by estimating the state of charge (SOC); the vehicle assignment can be successfully completed with a BEB if it can complete its scheduled service with at least 20% battery SOC remaining

As mentioned above, modeling for demand response services included all individual runs and vehicle assignments between December 5th, 2022, and December 31st, 2022 (110 runs). The energy requirement for each individual trip was aggregated at the vehicle level to calculate the total energy consumed by each vehicle per weekday. A statistical analysis was conducted on the entire dataset to determine the average fuel efficiency and daily energy use per vehicle to evaluate success levels. This process is shown in Figure 10.

Figure 10: ZEVDecide energy modeling process, demand response



Like the fixed-route modeling, the results of the modeling for demand response service provide insights into:

- Average fuel economy
- Probability of energy requirements
- Probability of operating range
- The feasibility of different ZEB technologies

For battery electric (BE) cutaways, success is determined through SOC; the vehicle assignment can be successfully completed when the BE vehicle can complete its scheduled service with at least 20% battery SOC. For hydrogen cutaways, if a vehicle consumes less than 95% of its tank capacity, the vehicle assignment is counted as successful.

4.1.3 Modeling Results

Typical RFTA operations rely on manual dispatch vehicle assignment and individual vehicles can be assigned to multiple blocks daily. Block mileage is constant by schedule type weekday/weekend, winter/summer season. Dispatchers manually assign vehicles to multiple blocks daily and those arbitrary assignments lead to varied individual vehicle mileage day to day. BEB block-level and vehicle-level modeling results for fixed-route services are shown in the following figures. The criterion to deem if a block can be successfully served by a BEB is if the SOC of the battery is above 20% after completing all the trips in a block. A block is deemed unsuccessful if the battery SOC drops below 20% after completing the block. These results show that under high and low passenger loads, 78 to 85% of blocks can be successfully electrified with BEBs, while 93 to 94% of blocks can be successfully completed using FCEBs. Table 4 summarizes the average BEB fuel efficiency for each vehicle type, and

Table 5 provides the average fuel efficiency of FCEBs.

Figure 11: Fixed-route FCEB and BEB block success rates

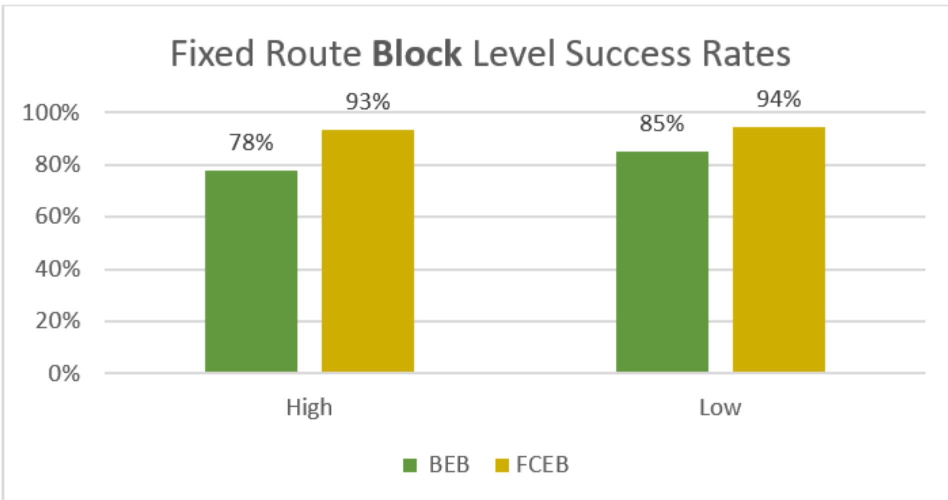


Table 4: Average fuel efficiency for fixed route BEB modeling results

Vehicle type	Avg Fuel Efficiency (kWh/mi)	Est. Max Range (mi) using ambient temperature 47 degrees F
45’	2.0-2.12	205-207
40’	2.06-2.24	188-204
35’	2.03-2.43	148-177
30’	1.79-1.94	144-156
Cutaway	1.93-2.01	46-50

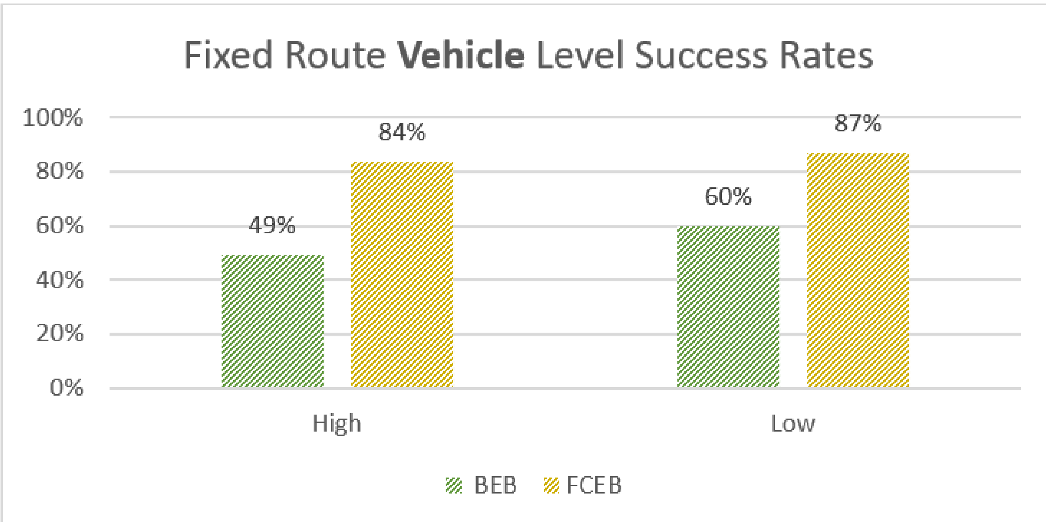
Table 5: Average fuel efficiency for fixed route FCEB modeling results

Vehicle type	Avg Fuel Efficiency (mi/kg)	Est. Max Range (mi) using ambient temperature 47 degrees F
45’	7.09-7.69	337-365
40’	6.88-7.46	327-354
35’	6.41-6.95	228-248
30’	7.71-8.37	275-298

Cutaway	7.53-8.17	93-105

The criterion to deem if a block can be successfully served by a FCEB is if the tank has 5% or more fuel remaining after completing all the trips in a block. A block is deemed unsuccessful if the fuel remaining in the tank drops below 5% after completing the block. Next, fixed route service was modeled with FCEBs and BEBs at the vehicle level. These results are shown in Figure 12 which shows that at the vehicle level, under high and low passenger loads, only 49 to 60% of current vehicle assignments can be successfully electrified with BEBs, while 84 to 87% of vehicle assignments can be successfully completed using FCEBs.

Figure 12: Fixed-route FCEB and BEB vehicle success rates



The electrification success was also evaluated for demand response services. Modeling was based on a sample size of 79 runs completed in December of 2022. Table 6 summarizes the average fuel efficiency and range for the BE cutaways for Demand Response service under RFTA's operating conditions.

Table 6: Average fuel efficiency for Demand Response cutaway modeling results

Vehicle type	Average fuel efficiency (kWh/mi)	Est. max range (mi) **using ambient temperature 47 degrees F**
BE cutaway	1.27	85

Figure 13 shows the distribution of SOC per demand response vehicle; as mentioned above, any blocks with a SOC of 20% or above (y-axis) can be successfully electrified. In total, 62% of demand response vehicle assignments can be successfully electrified with electric cutaways.

Figure 13: SOC distribution of daily Demand Response service – BE cutaways

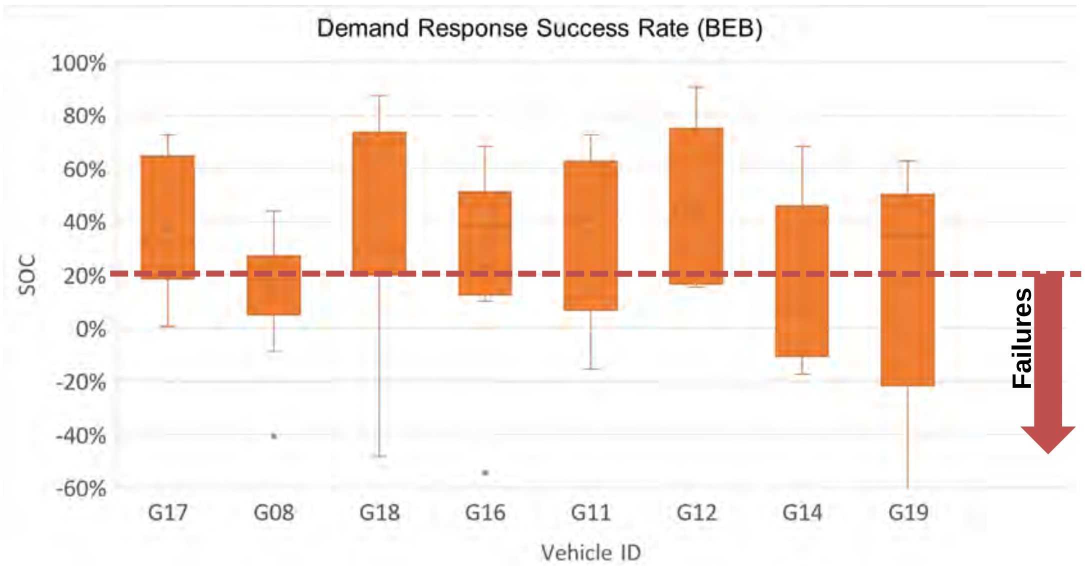
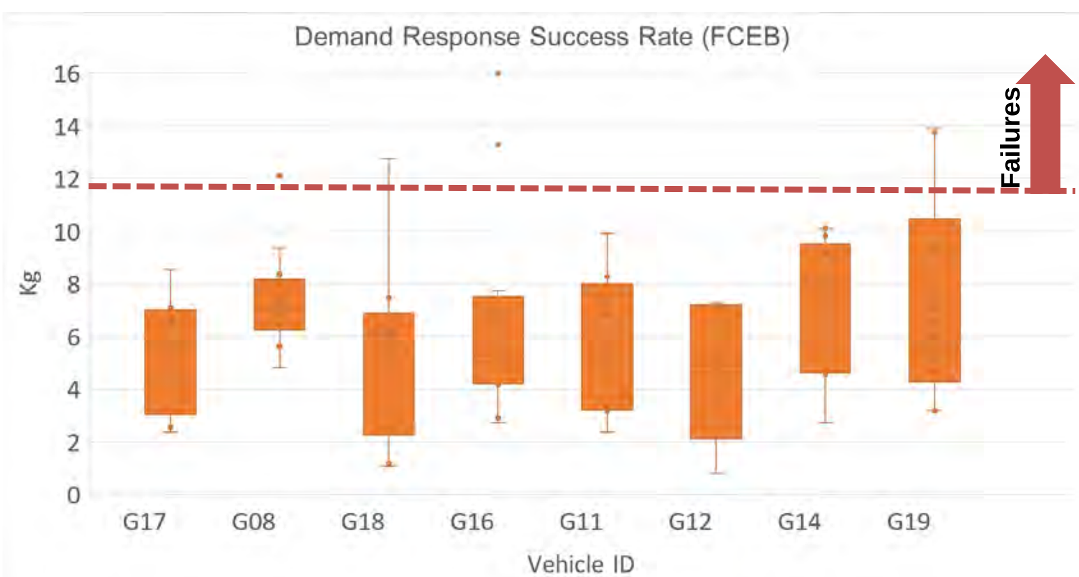


Figure 14 shows that 95% of DAR vehicles can be successfully transitioned to hydrogen fuel with cutaways that have 13-kg tanks, as all documented daily hydrogen uses are below 12 kg/vehicle.

Figure 14: Demand Response FCE Cutaways vehicle success rate



The daily mileage for hydrogen cutaways operating demand response is a maximum 141 miles with an average fuel efficiency of 11 mi/kg. Table 7 summarizes the average fuel efficiency and range for the FCE cutaways under RFTA's operating conditions.

Table 7: Average fuel efficiency for Demand Response modeling results

Vehicle type	Average fuel efficiency (mi/kg)	Est. max range (mi) using ambient temperature 47 degrees F
FCE Cutaways	11	141

It is important to note that no Altoona testing has been completed for hydrogen cutaways and not enough public data is available to validate expected hydrogen efficiency.

4.1.4 Proposed Operational Modifications for ZEB Fleet Scenarios

4.1.4.1 100% BEB Fleet

Given that not all blocks or vehicle assignments as currently designed will be able to be operated by BEBs, Stantec worked with RFTA staff to identify the best solution to help transition the failing blocks to electric vehicles. Table 8 below shows the failing blocks, vehicle type, and pull-out/pull-in time associated with the block, as well as the proposed strategy to make it a successful block run by electric vehicles, which includes on-route charging. While 45-ft electric coaches currently don't have on-route charging capability (July 2024), it's assumed this type of vehicle will be procured last to allow for technology improvements and on-route charging feasibility. To account for the operational modifications that will be required to operate the BEB blocks, charging infrastructure at Rubey Park and the West Glenwood Springs Park and Ride are considered in the financial assessment.

Table 8: 100% BEB Fleet Strategy

BEB Failing Blocks	Vehicle type	Pull out	Pull in	Proposed Strategy for 100% BEB Operations
BG-CM	35'	6:05 AM	2:28 AM	On-route charging at Rubey Park
CL	35'	6:30 AM	2:17 AM	On-route charging at Rubey Park
BG-CM	40'	6:07 AM	12:38 AM	On-route charging at Rubey Park
SM	40'	5:03 AM	4:46 PM	On-route charging at Rubey Park
SM	40'	6:16 AM	6:04 PM	On-route charging at Rubey Park
BRT-HGB	40'	7:00 AM	4:56 PM	On-route charging at Rubey Park
BRT-HGB	40'	1:00 PM	10:06 PM	On-route charging at Rubey Park
L-BRT	40'	2:15 PM	1:17 AM	On-route charging at Rubey Park
BRT-HGB	40'	3:30 PM	12:37 AM	On-route charging at Rubey Park
BRT-HGB	40'	4:30 PM	1:36 AM	On-route charging at Rubey Park
BRT-HGB	40'	4:30 PM	12:35 AM	On-route charging at Rubey Park

BEB Failing Blocks	Vehicle type	Pull out	Pull in	Proposed Strategy for 100% BEB Operations
HGB-L-BRT	40’	4:45 PM	1:47 AM	On-route charging at Rubey Park
L	45’	7:03 AM	11:47 PM	On-route charging at Rubey Park and Glenwood
L	45’	7:03 AM	11:47 PM	On-route charging at Rubey Park and Glenwood
BRT-HGB	45’	4:30 AM	1:36 PM	On-route charging at Rubey Park and Glenwood
HGB-BRT	45’	5:15 AM	4:36 PM	On-route charging at Rubey Park and Glenwood
BRT-HGB	45’	5:30 AM	11:36 PM	On-route charging at Rubey Park and Glenwood
HGB-BRT	45’	6:00 AM	7:21 PM	On-route charging at Rubey Park and Glenwood
BRT-HGB	45’	6:35 AM	12:36 AM	On-route charging at Rubey Park and Glenwood
BRT-HGB	45’	8:00 AM	5:16 PM	On-route charging at Rubey Park and Glenwood
HGB-BRT	45’	3:45 PM	1:06 AM	On-route charging at Rubey Park and Glenwood
MV	Cutaway	6:15 AM	2:10 AM	**ASPEN**: bigger vehicles to charge at Rubey Park
GS	Cutaway	8:03 AM	5:18 PM	**ASPEN**: bigger vehicles to charge at Rubey Park
GS	Cutaway	8:05 AM	5:21 PM	**ASPEN**: bigger vehicles to charge at Rubey Park
XT	Cutaway	7:30 AM	11:13 PM	**ASPEN**: bigger vehicles to charge at Rubey Park
WC	Cutaway	4:30 PM	1:01 AM	Reblock, likely an additional cutaway

4.1.4.2 100% FCEBs Fleet

The blocks below are expected to fail under a hydrogen fleet transition. To have the failing blocks operational with hydrogen vehicles, Table 9 below shows the assumed strategy, which includes mid-day refueling at their origin maintenance facility and delaying purchase of small cutaway hydrogen vehicles until the tank capacity reaches at least a 20kg/tank.

Table 9: 100% FCEB Fleet Strategy

FCEB Failing Blocks	Vehicle type	Pull out	Pull in	Proposed Strategy for 100% FCEB Operations
BG-CM	35’	6:05 AM	2:28 AM	Mid-day refill at AMF
L	45’	7:03 AM	11:47 PM	Mid-day refill at GMF
BRT-HGB	45’	5:30 AM	11:36 PM	Mid-day refill at GMF
BRT-HGB	45’	6:35 AM	12:36 AM	Mid-day refill at GMF
MV	Cutaway	6:15 AM	2:10 AM	**ASPEN**: Delay purchase to have bigger H2 tanks
XT	Cutaway	7:30 AM	11:13 PM	**ASPEN**: Delay purchase to have bigger H2 tanks
WC	Cutaway	4:30 PM	1:01 AM	Delay purchase to have bigger H2 tanks

4.1.4.3 Mixed Fleet

To consider a mixed fleet, it was assumed that the GMF will be transitioned to hydrogen fueling and vehicles housed at GMF will be transitioned to FCEBs at their planned retirement age. The AMF will transition into a BEB hub, and all vehicles housed at AMF will be transitioned to BEBs. Redundancy of fueling and maintenance options at GMF will exist with eight BEB charging plugs planned for the new bus storage building in 2024. Under the mixed scenario AMF is not planned to accommodate hydrogen vehicle's fueling and maintenance.

This strategy allows for all 45-ft coaches to operate with hydrogen and have longer mileage covering the BRT and Local Valley Trips. It is estimated that four 45ft FCEBs will need midday refueling to successfully complete service. Additionally, only a portion of the vehicles that need to have on-route charging at Rubey Park will need that accommodation under the mixed fleet. FCEBs housed at GMF will make up to 56% of the fleet and BEBs housed in AMF will make up to 44% of the fleet. Table 10 below shows the strategy for the failing blocks under a mixed fleet technology scenario.

Table 10: Mixed Fleet Strategy

BEB/FCEB Failing Blocks	Vehicle type	Pull out	Pull in	Proposed Strategy for 100% Mixed ZEB Fleet
BG-CM	35'	6:05 AM	2:28 AM	On-route charging at Rubey Park
CL	35'	6:30 AM	2:17 AM	On-route charging at Rubey Park
BG-CM	40'	6:07 AM	12:38 AM	On-route charging at Rubey Park
BRT-HGB	40'	3:30 PM	12:37 AM	On-route charging at Rubey Park
BRT-HGB	40'	4:30 PM	12:35 AM	On-route charging at Rubey Park
L	45'	7:03 AM	11:47 PM	Mid-day refill at GMF
BRT-HGB	45'	5:30 AM	11:36 PM	Mid-day refill at GMF
BRT-HGB	45'	6:35 AM	12:36 AM	Mid-day refill at GMF
MV	Cutaway	6:15 AM	2:10 AM	COA: Reblock, likely increase in daily active cutaways and decrease of spare ratio
GS	Cutaway	8:03 AM	5:18 PM	COA: Reblock, likely increase in daily active cutaways and decrease of spare ratio
GS	Cutaway	8:05 AM	5:21 PM	COA: Reblock, likely increase in daily active cutaways and decrease of spare ratio
XT	Cutaway	7:30 AM	11:13 PM	COA: Reblock, likely increase in daily active cutaways and decrease of spare ratio
WC	Cutaway	4:30 PM	1:01 AM	Reblock, likely an additional cutaway

4.2 MODELING SUMMARY

In summary, the modeling results have the following major implications:

A. To have an operational BEB-only fleet, it's assumed that RFTA's fixed-route services can accommodate the following:

   - Blocks as currently operated can be completed successfully with the availability of on-route charging at Rubey Park and West Glenwood Springs Park and Ride lot.
   - The current flexibility to assign vehicles to more than one block in a day on an arbitrary basis will be limited in a BEB-only case. The vehicle assignment process will need to transition to pre-scheduled vehicle assignments that account for the available vehicle charge after the first block is completed. The vehicle assignment will need to be driven by the goal to minimize peak period charging and to account for extended periods needed to achieve full charge. To do so, RFTA will need to implement a smart charging system that aligns with an agency-wide systems integration.

B. With hydrogen, the majority of RFTA's blocks can be completed successfully, but reblocking for less than 7% of the operated blocks would be required. The current flexibility to assign vehicles to more than one block in a day on an arbitrary basis will not be as limited as in the BEB case since FCEB vehicles can be refueled at times comparable to fossil fuel vehicles.

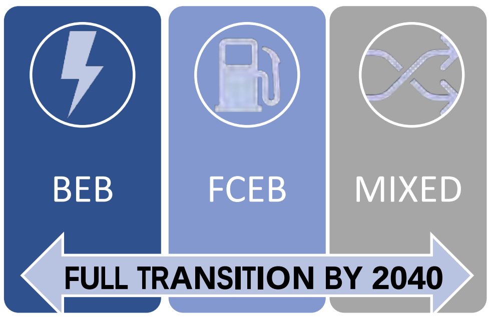
C. Demand response services were mostly successful when modeled with BE cutaways (69% of modeled runs are successful). For FCEB cutaways, 96% of modeled runs were successful, though the market for these vehicles is less mature. Hydrogen cutaways are not currently available on the market (July 2024) and the hydrogen vans that exist are not yet Altoona-tested (if switching to smaller vehicles were to be an option).

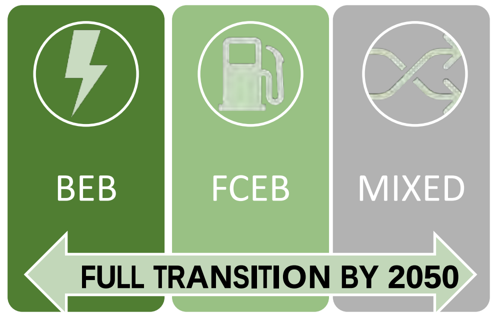
Following the modeling results, Stantec met with RFTA staff to workshop the feasibility of the different solutions. Initial discussions included potential conversions of existing fleet subsets (For example, 45-ft buses to 40-ft buses or some cutaways to 30-ft buses). The outcome was that under both the BEB and FCEB scenarios, preferred vehicle types will mimic RFTA's current vehicle size composition with a preference to keep the fleet diverse in size and maintain responsiveness to the varied demand levels by route. Therefore, Stantec and RFTA have reached specific assumptions for each failing block, which assume on-route charging, midday refueling of hydrogen, and delaying the procurement of cutaways and 45-ft buses to account for technology improvements.

Based on the modeling results and outlined assumptions in this section, RFTA has three technology options to convert their services to zero-emission 1) a BEB-only fleet, 2) a FCEB-only fleet and 3) a mixed fleet of BEBs and FCEBs. To select the best fleet option and pace of transition Stantec and RFTA staff carried out a multi-criteria trade-off analysis as the next step of the project to determine the best fit for RFTA.

5.0 FLEET PROCUREMENT OPTIONS BY TIMELINE AND FUEL TYPE

Full transition by 2040 and 2050 were analyzed, resulting in six fleet scenarios. This section of the report presents the year-by-year procurement strategy for each of the six ZEB procurement scenarios.





The first step was to understand the Base Case, or business as usual scenario, if RFTA were to continue with its current fleet, which aims to maintain a 1/3, 1/3, 1/3 technology mix of CNG, diesel, and BEB. Figure 15 displays a graph with the proportion of the fleet by fuel type and ownership over time for the Base Case. BEB purchases continue through 2029 when the BEB share reaches 29% and remains constant for all future analysis-years thereafter.

Figure 15: Base Case – Fleet Composition

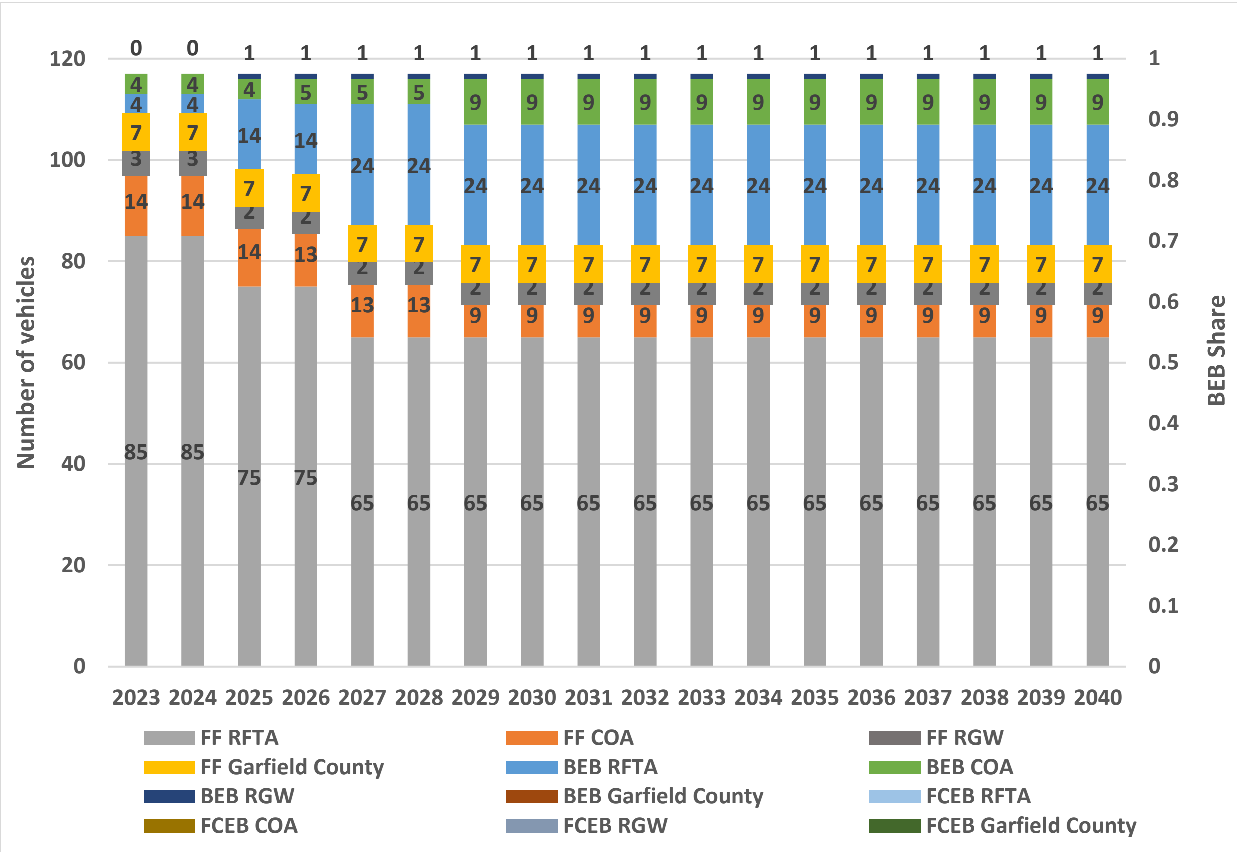
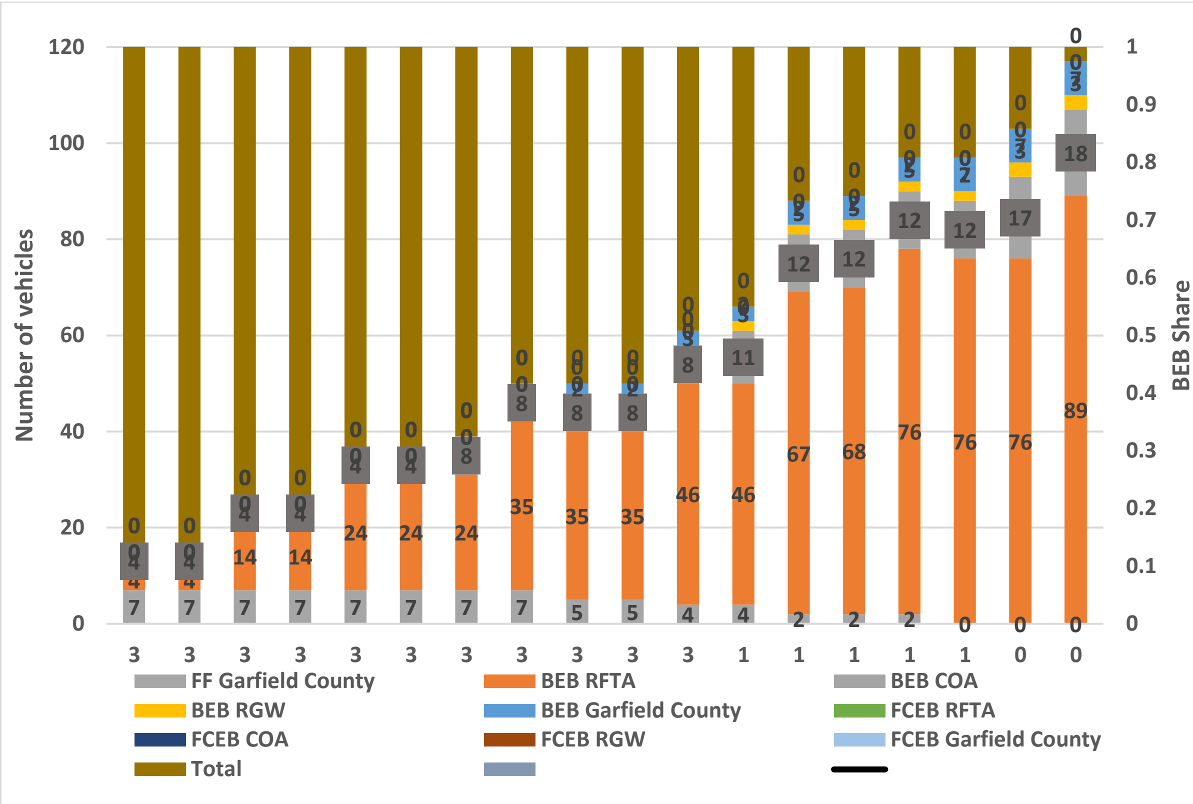


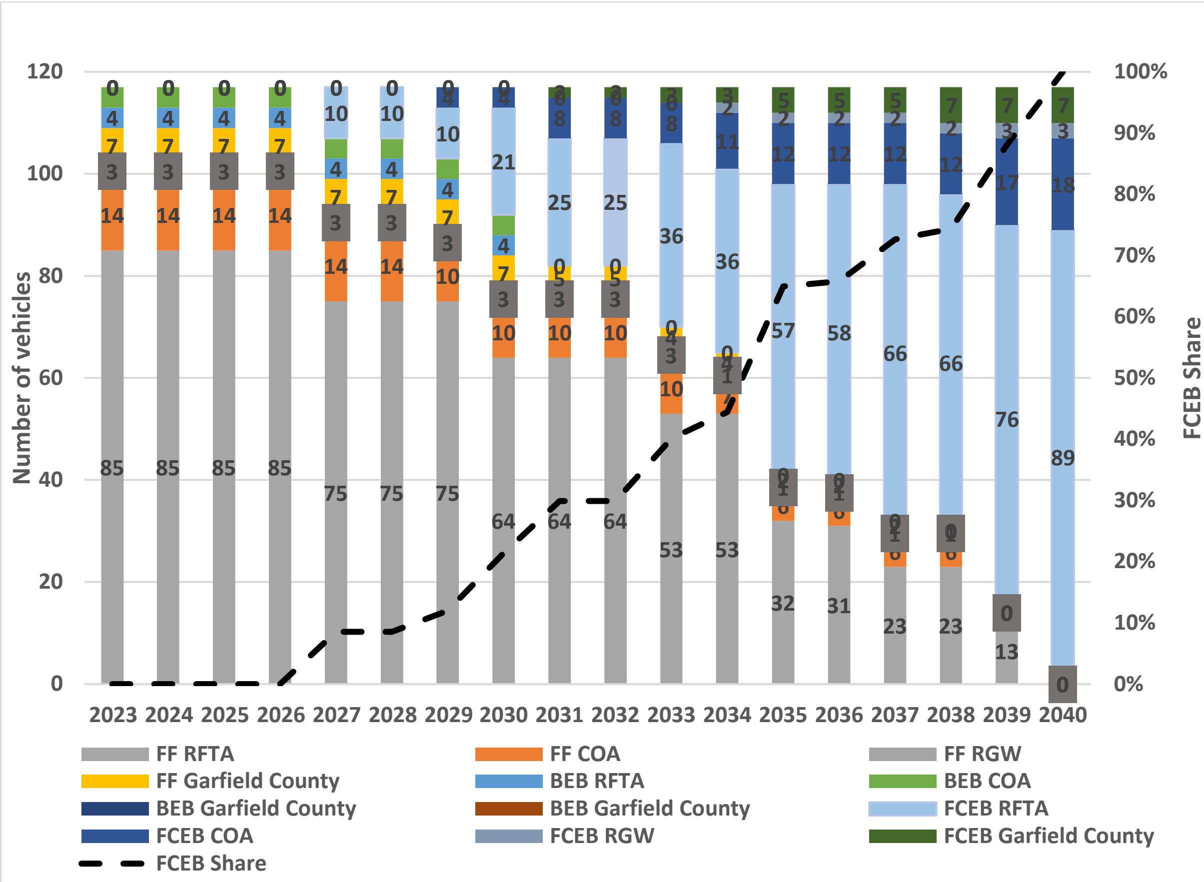
Figure 16 displays the same graph with the transition from carbon-emitting vehicles to BEB-only fleet under the accelerated 2040 timeline. The purchases of BEBs after 2032 accelerates until the fleet reaches a 100% BEB share (full transition) in 2040.

Figure 16: BEB Case Full Adoption by 2040 – Fleet Composition



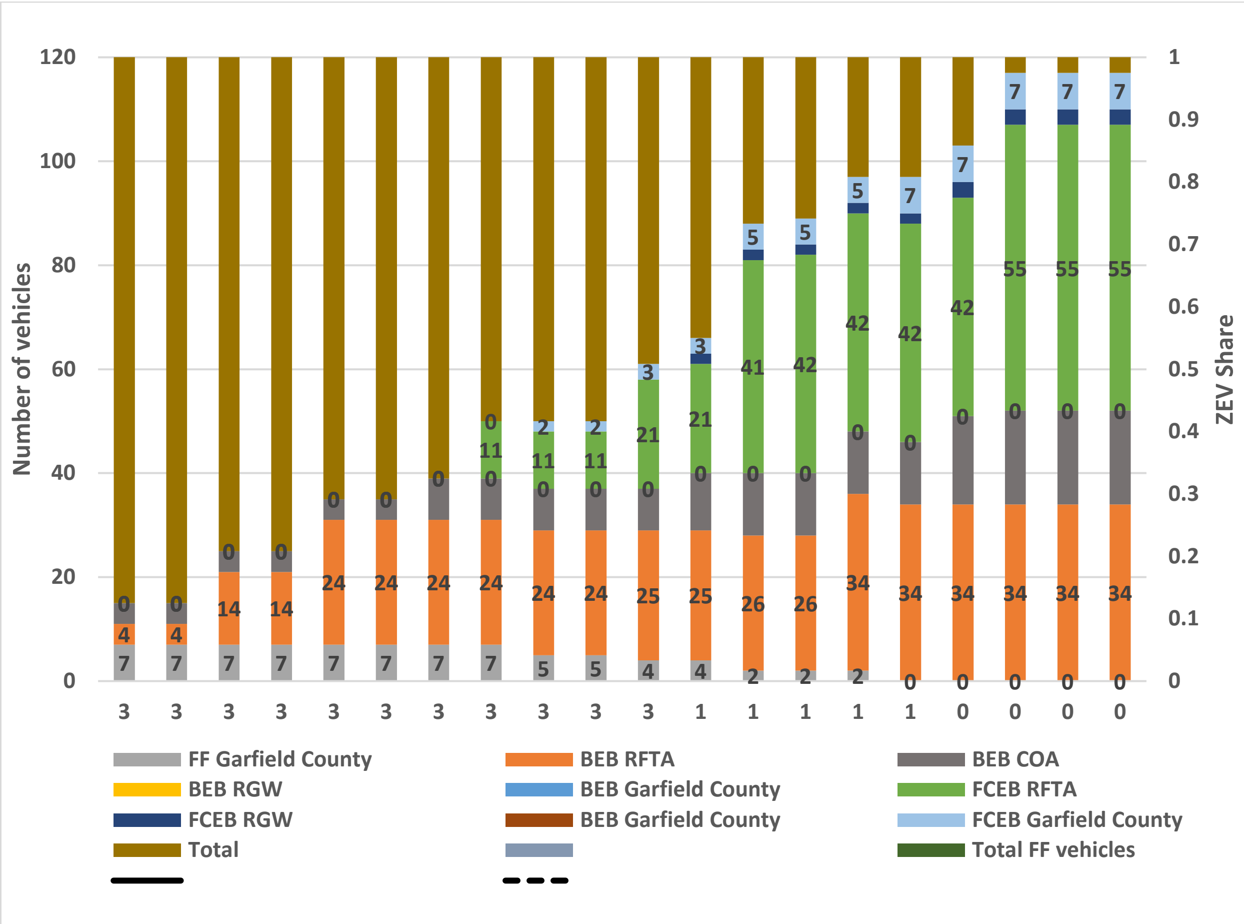
The FCEB Case fleet transition for the accelerated 2040 timeline is shown in Figure 17. The purchase of FCEBs starts in 2027 with the purchase of ten 40-ft RFTA FCEBs and accelerates until the fleet reaches a 100% BEB share (full transition) in 2040. Under this case it is assumed that the current eight BEB vehicles in the fleet will be replaced at their replacement date with FCEB vehicles. Due to the limited available FCE cutaway options on the current market (July 2024), cutaway acquisition should be delayed in the accelerated timeline to achieve a 100% transition by 2040. Therefore, the first cutaway acquisitions would occur in 2031 and 2033.

Figure 17: FCEB Case Full Adoption by 2040 – Fleet Composition



The Mixed Case with full adoption by 2040 is illustrated in Figure 18. The purchases of BEBs mostly follows the scheduled Base Case acquisitions through 2032 when the BEB share will have reached 27% of the fleet. FCEB purchases start in 2029 and ramp up quicker than BEB purchases, as FCEB infrastructure gets built out at the GMF. In 2040, FCEBs housed at the GMF will represent 56% of the fleet and BEBs housed at the AMF will represent 44% of the fleet.

Figure 18: Mixed Case Full Adoption by 2040 – Fleet Composition



The BEB Case Full Adoption by 2050 has a slower pace of BEB acquisition compared to the accelerated timeline BEB Case. Figure 19 displays a graph with the proportion of the fleet by fuel type and ownership over time. The purchase of BEBs mostly follows the Base Case and reaches a 27% share of the fleet in 2032 then builds up to 50% of the fleet in 2039-2040. Then the pace accelerates until the fleet reaches a 100% BEB share (full transition) in 2050.

Figure 19: BEB Case Full Adoption by 2050 – Fleet Composition

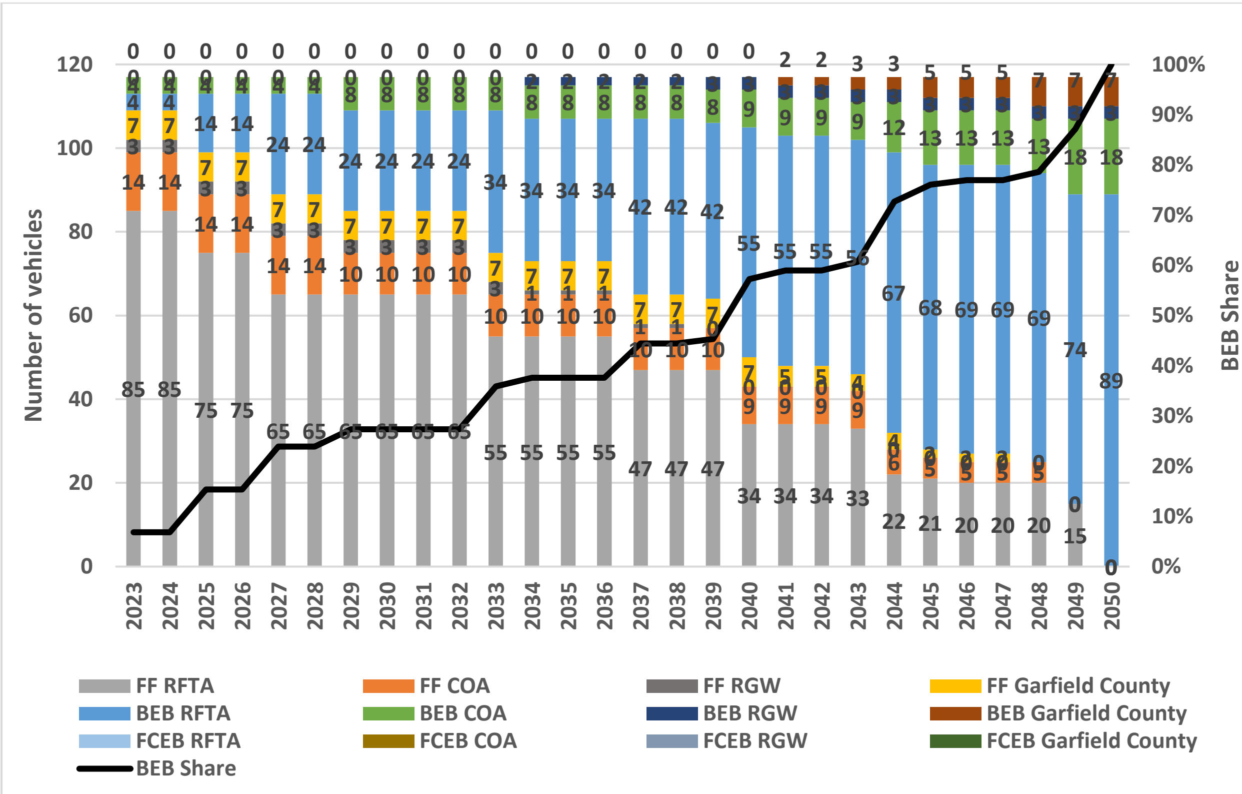


Figure 20 displays the pace of acquisition and fleet conversion under the FCEB Case with full adoption by 2050, both the GMF and AMF are assumed to build out hydrogen fueling infrastructure under this case. The purchases of FCEBs start in 2029 with the purchase of ten 40-ft RFTA FCEBs and accelerates until the fleet reaches a 50% FCEB share in 2040-2041 and (full transition) in 2050. Under this case it is assumed that the current eight BEBs in the fleet will be replaced at their retirement date with FCEBs. Due to the limited available FCE cutaway option on the current market, cutaway acquisition is delayed until 2041.

Figure 20: FCEB Case Full Adoption by 2050 – Fleet Composition

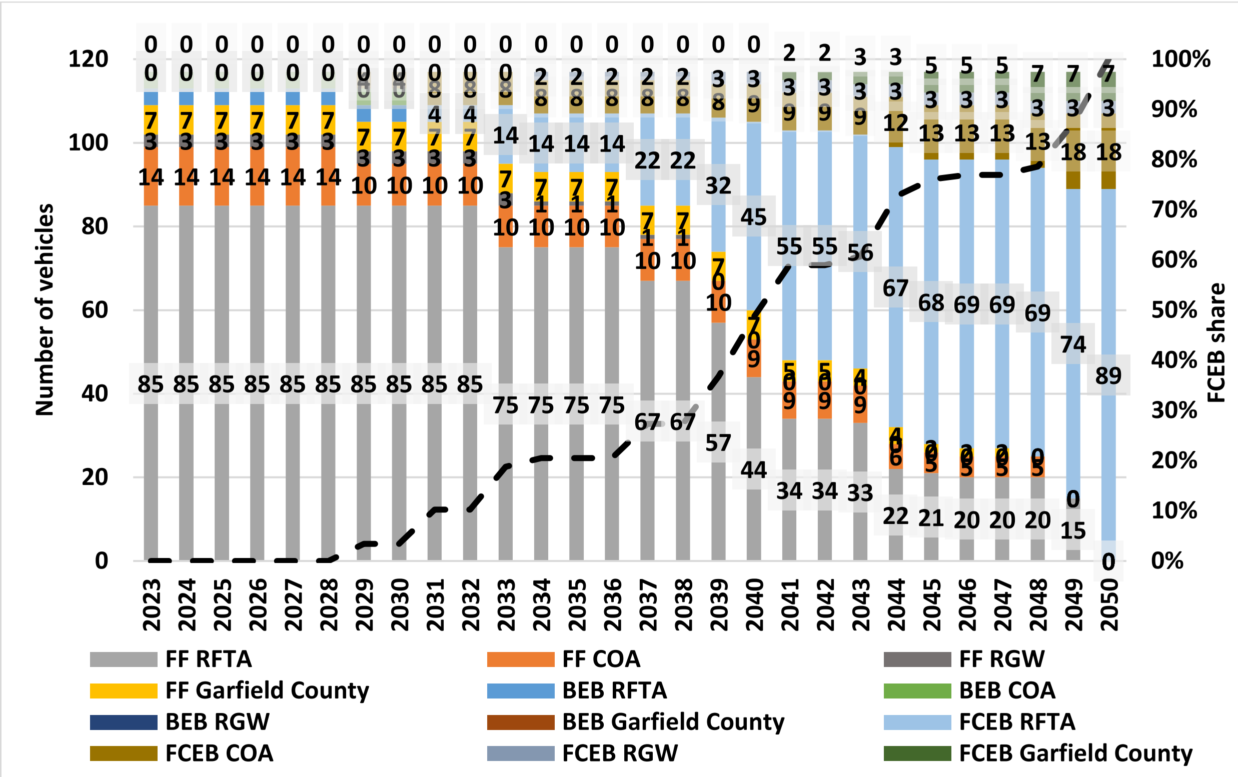
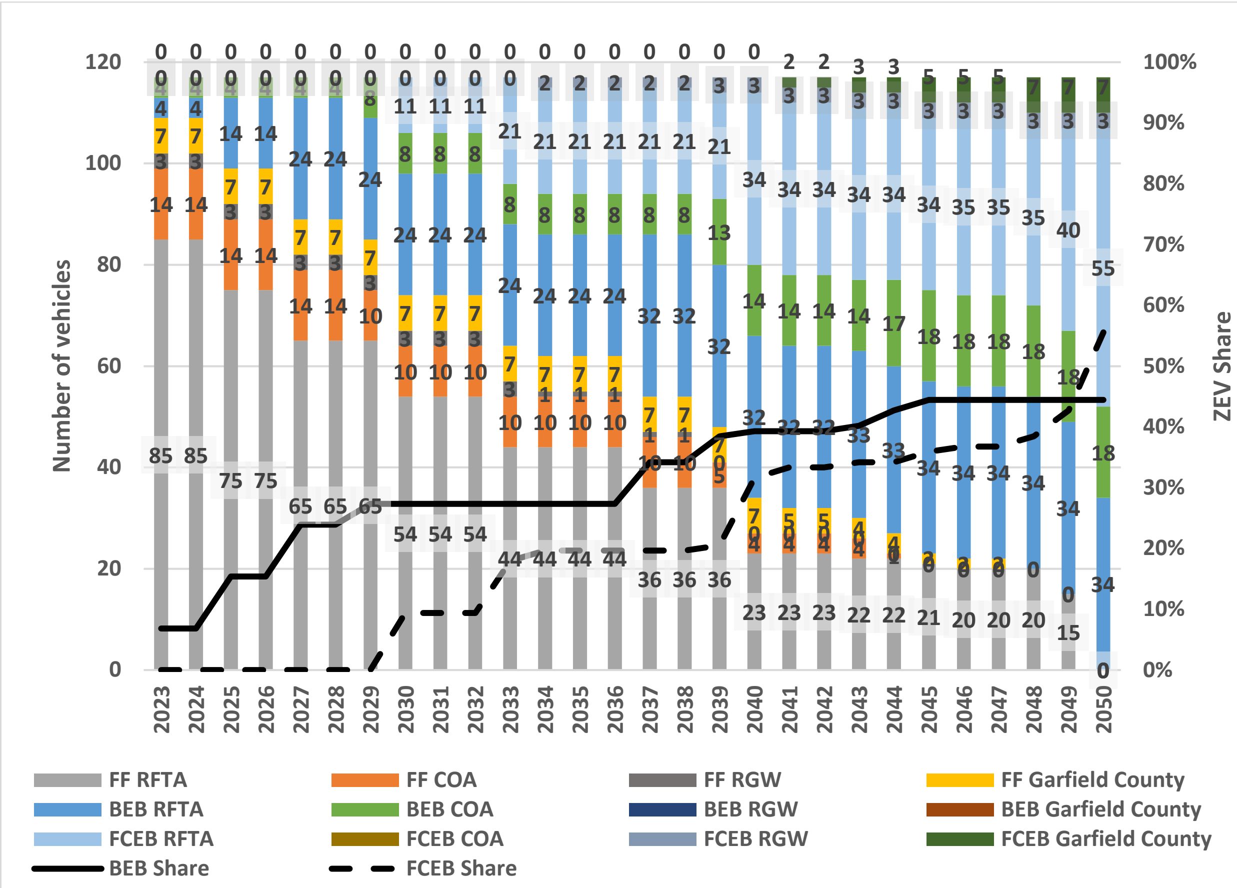


Figure 21 displays a graph with the proportion of the fleet by fuel type and ownership over time as the transition from carbon-emitting vehicles to a Mixed Case with both FCEBs and BEBs proceeds through full adoption in 2050. The purchase of BEBs mostly follows the scheduled Base Case acquisitions through 2037. FCEB purchases start in 2030 and later catch up with BEB purchases, as FCEB infrastructure gets build out at GMF. In 2050 FCEBs housed at GMF will make up to 56% of the fleet and BEBs housed in AMF will make about 44% of the fleet.

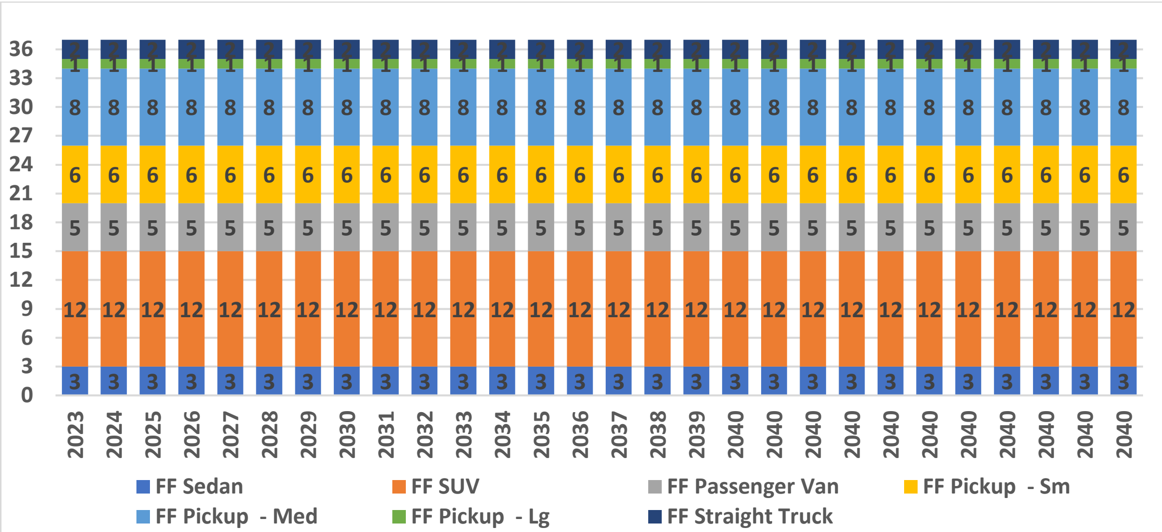
Figure 21: Mixed Case Full Adoption by 2050 – Fleet Composition



5.1 SERVICE VEHICLE PROCUREMENT OPTIONS BY FUEL TYPE FOR 2050 TIMELINE

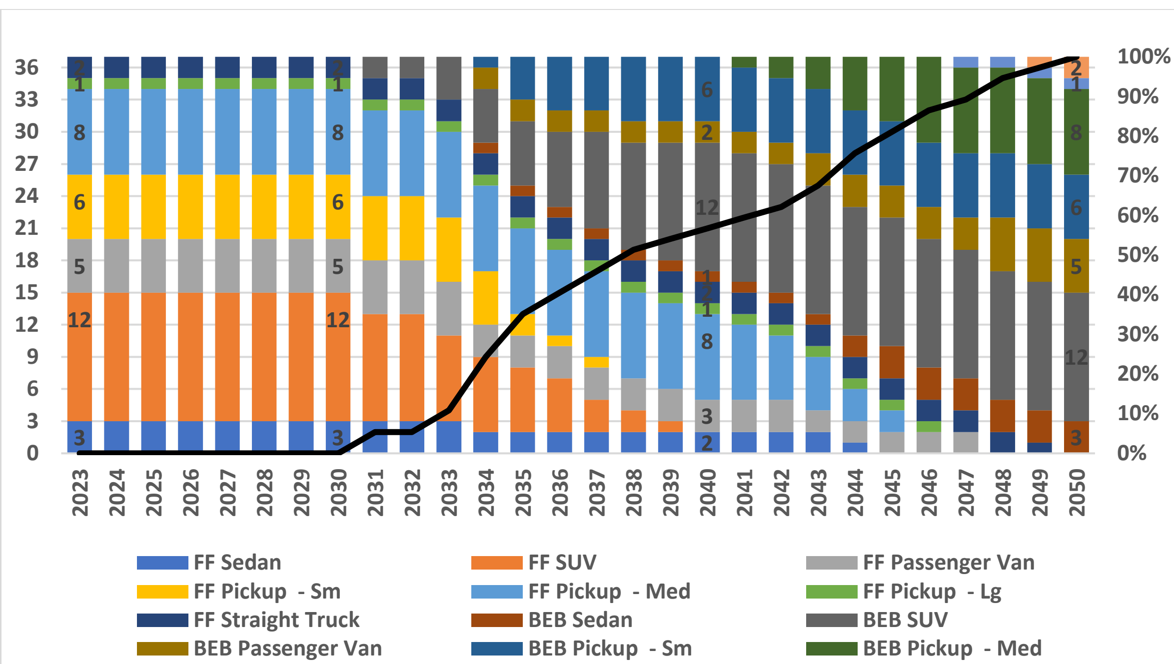
In addition to the procurement strategy for the revenue fleet, year-by-year procurement strategies for two ZE service vehicle procurement scenarios were developed. The first step was to understand the Base Case, or business as usual scenario, if RFTA were to continue with its current service fleet replacement plan. Most of the service vehicles are gasoline powered, except for a few diesel trucks and hybrid-electric vehicles. Figure 22 displays a graph with the proportion of the fleet by fuel type and vehicle type over time for the Base Case. As of late 2023, RFTA operations were supported by thirty-seven active service vehicles and an additional ten to twelve vehicles in Active Prep and Active Surplus status.

Figure 22: Service Fleet Base Case - Fleet Composition



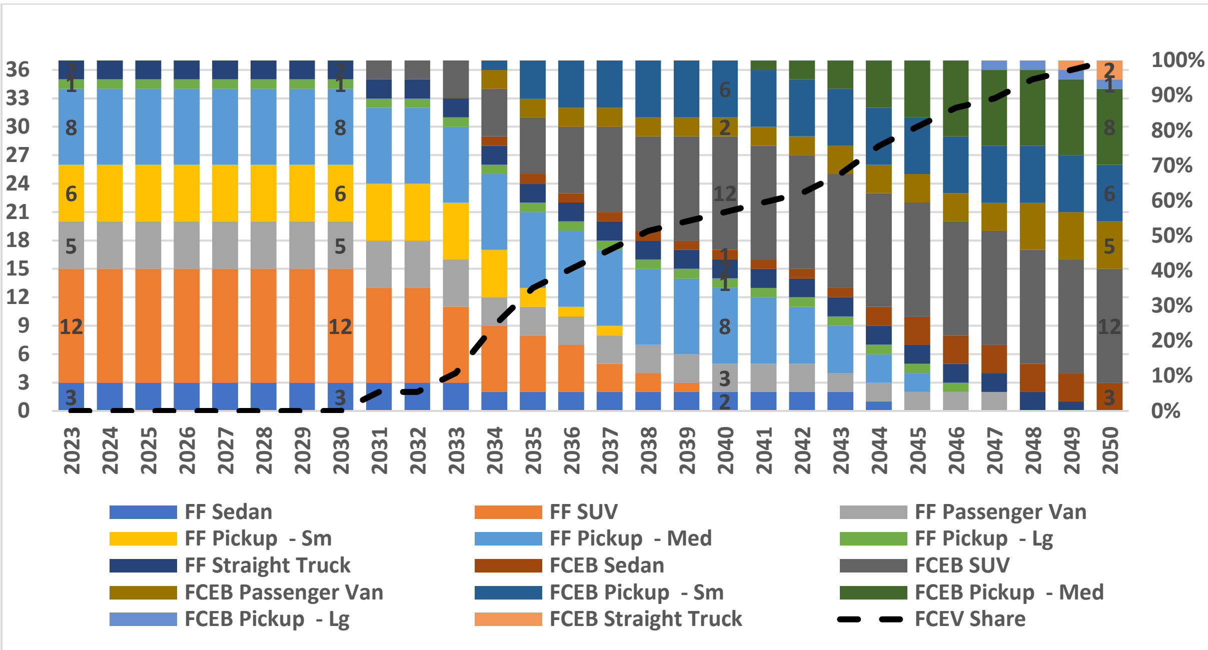
The proposed fleet composition for the BE Service Fleet Case Full Adoption by 2050 is shown in Figure 23. The graph displays the proportion of the fleet by vehicle type and fuel type over time. The purchase plan for service vehicles follows the Base Case through 2030, when the first purchases of BE SUVs and sedans start. Next passenger vans and small pickups are phased in and last are the medium and large pickups and straight truck. The share of the BE service vehicles in 2038 builds up to 51% and a 100% ZEV share (full transition) is reached in 2050.

Figure 23: BE Service Fleet Case 2050 Timeline - Fleet Composition



The proposed fleet composition for the FCE Service Fleet Case Full Adoption by 2050 is shown in Figure 24. The purchase of service vehicles follows the Base Case through 2030, when the first purchases of FCE SUVs and sedans occur. Like the ZEV Case, passenger vans and small pickups are phased in and the purchases of FCE medium and large pickups and straight truck are delayed until later in the timeline, when more original equipment manufacturer (OEM) options will be available on the market. The FCEV Case mirrors the phasing of the ZEV case with the share of ZEV service fleet in 2038 at 51% and in 2050 at 100% ZEV share (full transition).

Figure 24: FCE Service Fleet Case 2050 Timeline - Fleet Composition



5.2 MULTI CRITERIA EVALUATION

This section of the report documents the evaluation process and evaluation criteria developed by Stantec and RFTA staff for the purposes of assessing the different alternatives for transitioning RFTA's fleet and non-revenue service vehicles to light-duty battery electric vehicles (BEVs), hydrogen fuel cell electric vehicles (FCEVs), or a mixed fleet of both BEVs and FCEVs.

A predictive power and energy modeling exercise was completed to understand how different ZEV technologies can feasibly operate RFTA's services. Based on the results of the modeling, six alternatives have been developed to help RFTA achieve a ZEV fleet transition, listed in Table 11 below. While all six alternatives are feasible, there are several important quantitative and qualitative considerations that need to be assessed to determine which alternative is the best fit for RFTA. This section outlines the evaluation criteria methodology and process to evaluate and score the six ZEV alternatives.

Table 11: Alternatives for ZEV fleet transition

Alternative	Timeline for Full ZEB Fleet	Fleet Make up	Refueling Strategy for Revenue Fleet	Refueling Strategy for Non-Revenue Fleet
1	2040	BEV	On Route Charging + Reblocking	Limited mileage + midday charging
2	2040	FCEV	Midday Refueling	Midday Refueling
3	2040	Mixed	Aspen Maintenance Facility = BEB, Glenwood Maintenance Facility = FCEB	Based on overnight location
4	2050	BEV	On Route Charging + Reblocking	Limited mileage + midday charging
5	2050	FCEV	Midday Refueling	Midday Refueling
6	2050	Mixed	Aspen Maintenance Facility = BEB, Glenwood Maintenance Facility = FCEB	Based on overnight location

The evaluation process follows the Analytic Hierarchy Process (AHP). When using AHP a comparison is first carried out to prioritize the evaluation criteria (i.e., the weights of the varied criteria are established), and then typically a scale is used to score the alternatives under each criterion.

Early engagement of RFTA's staff included an online survey and in-person workshop conducted in June 2023. In that phase, seven criteria were discussed and weighted by participants. Description of the criteria is provided in Section 5.3 of this report. Summaries of the survey produced initial weights or priorities for the set of seven criteria selected for the screening and they are listed in Section 5.4 of this report.

A final evaluation workshop was held with RFTA staff participation, during which Stantec presented a proposed score for each evaluation criteria and scenario until scoring consensus was achieved. In preparation for this step, Stantec developed quantitative and qualitative scores for each criterion based on the findings of the energy modeling, financial modeling, technology-specific considerations, and discussions with RFTA regarding the level of operational changes needed under each alternative.

5.3 CRITERIA DESCRIPTION

Early engagement of RFTA's staff included an online survey and in-person workshop conducted in June 2023. The following seven criteria were discussed and weighted by participants. In this section, the descriptions of the criteria are also expanded to describe how the scores for the six alternatives were evaluated under each criterion. The scores for all criteria were between 0-100, with some of those scores developed based on a qualitative scale developed from the modeling effort and total cost of ownership. The score of one hundred indicates the highest positive impact and score of zero indicates the worst possible impact.

Evaluation criteria 1: Scheduling and Planning. This criterion considers range limitations, fleet variants, and other characteristics of the fleet technology type that could impact the blocking of RFTA's services. For example, blocks will have to be designed under a limited mileage depending on the expected vehicle's range (if on-route charging is not available). Additionally, even when utilizing on-route charging, the layovers will have to be designed with enough time to ensure vehicles will have sufficient time to connect to a charger, charge, dismount, and continue service, potentially impacting the total time for completing a service route.

This is a quantitative criteria and alternatives were evaluated by listing the number of new blocks or changes to existing blocks that are needed to accommodate ZEB operations and on-route charging or midday refueling. For example, if only 60% of the blocks can be completed without any operational modification or on-route charging for BEBs, then that scenario resulted in a score of 60 for the Scheduling and Planning criteria.

A big concern relates to how 45-ft motor coaches are usually not equipped with on-route charging equipment because these taller buses hinder roof-mounted pantograph charge bars, which would limit the length of blocks assigned to this type of vehicle.

Evaluation criteria 2: Dispatch Flexibility. This criterion considers the degree of complexity and flexibility provided by the fleet's technology to be assigned to service. For example, vehicles with limited ranges (i.e. BEBs) would need to be assigned to the correct blocks, limiting the flexibility in dispatching electric vehicles to longer blocks.

This is a qualitative criteria and alternatives were evaluated by assessing the reduction or increase of dispatching flexibility - which buses can perform specific blocks, and to what degree dispatching will be limited due to requiring specific vehicle types on specific blocks.

Evaluation criteria 3: Training Diversification. This criterion considers the scale and complexity that might be required to have an agency-wide ZEV workforce training for mixed ZEV technologies. For example, comprehensive training for only BEB or only FCEB is less complex than training courses for both technologies.

This is a qualitative criterion that will evaluate if the ZEB alternative introduces a new type of fuel and fueling infrastructure that requires training of staff.

Evaluation criteria 4: Technology Availability/OEMs/Procurement. This criterion considers how complex procurement will be under each fleet concept and how currently available vehicles under each technology option will impact the feasibility of transitioning. For example, for some vehicle types, there are fewer OEMs and fewer vendor options than for others. Furthermore, 45-ft hydrogen coaches are not currently available (July 2024), and it is uncertain when that sector of the market will mature, posing risks to the implementation of hydrogen scenarios.

This is a qualitative criteria and alternatives will be evaluated by assessing the number of OEMs that can provide the vehicle types matching RFTA's existing fleet and planned fleet make up. For example, if no OEM currently produces the specific vehicle needed, then the score will be lower. Alternatives with a later ZEB transition timeline assume that advancements in technology will continue at its current pace and that more ZEB options and OEMs will be available.

This criterion also assesses the complexity of having a diversity of manufacturers for maintenance purposes. Or, going from two brands to four will require an increase in the spare parts and equipment that are recommended to keep in stock for maintenance purposes, such as windows, doors, etc.

Evaluation criteria 5: Fueling/charging Infrastructure Interoperability. This criterion considers the extent to which vehicles can be refueled or recharged at either facility. This is a qualitative criterion that will include physical constraints at the facilities and operational impacts. For example, the time it takes to depot or on-route charge a BEB, versus the time it takes to refuel a FCEB, poses risk for a vehicle running out of fuel at a facility without specific fueling capabilities. Cost impacts related to the fueling/charging infrastructure are considered in the cost of ownership category.

Evaluation criteria 6: Cost of Ownership. This criterion considers high-level capital cost estimates (e.g., vehicle purchases and charging/fueling infrastructure, associated electrical upgrades, fire and gas detection systems, ventilation systems and facility retrofits, etc.) and operating cost estimates (e.g., maintenance and fuel use) of each scenario for preliminary comparative purposes. The operational cost also captures the increase in needed staff to manage operational modifications due to reblocking (when applicable), or mid-day refueling, as well as any increase in fleet size and related operations resulting from transitioning to each ZEB fleet type. The useful life of bus and facility equipment and their replacement costs are also considered.

This is a quantitative criterion, and the alternatives are evaluated by their net present value (NPV) in 2023 dollars, under a total cost of ownership approach (reflecting capital and operational costs).

Evaluation criteria 7: Resiliency and Redundancy. This criterion evaluates operational continuity during unexpected circumstances like power shutdowns or equipment failures. This criterion also considers the reliability and flexibility of each scenario under emergency circumstances, such as evacuation plans during natural disasters.

This is a qualitative criterion and costs for additional equipment such as CNG or diesel generators for BEB charging infrastructure or FCEB fueling are assessed here, as well as under the Cost of Ownership criterion. Generator type and cost will vary depending on fleet charging/fueling type and type of emergency operations required. A critical consideration for the hydrogen scenarios is that hydrogen stations are designed with redundant critical equipment (e.g., additional pumps and compressors) that allow continuous operations in case of equipment failure. Additionally, and related to the hydrogen supply, a hydrogen supply vendor contract should include contingency of supply in case of events that could interrupt normal supply channels.

Two additional criteria were added as the project progressed and further discussions were held with the RFTA staff and internal stakeholders.

Evaluation criteria 8: Environmental Considerations. This criterion considers tailpipe greenhouse gas emissions (GHGs) and other harmful emissions as well as upstream GHGs emissions related to energy/fuel production.

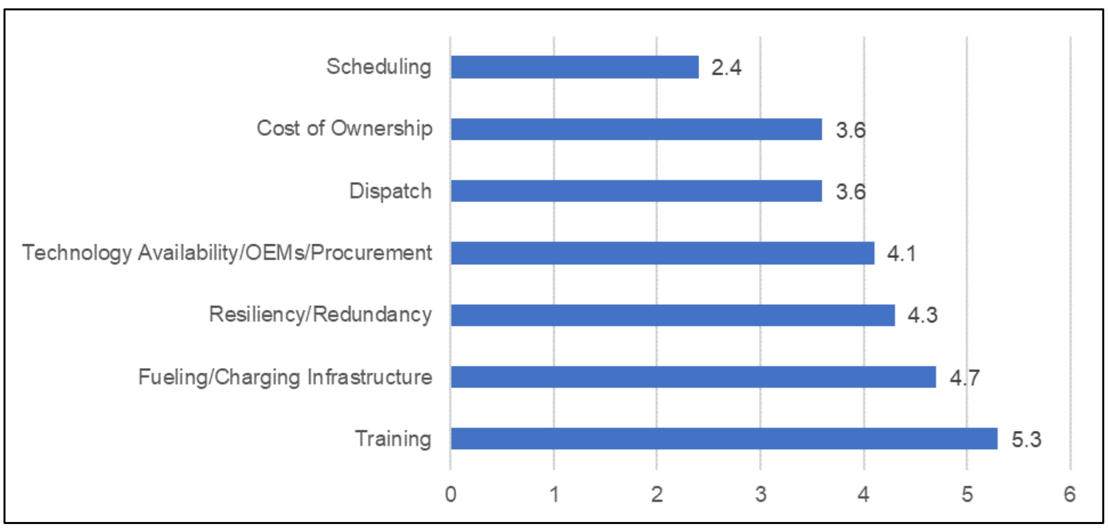
This is a quantitative metric based on the estimates for GHG reduction by metric tons of Co2 equivalent and GHG footprint across the timeline of transition for each alternative.

Evaluation criteria 9: Rider Experience. This qualitative criterion considers rider comfort/discomfort for each scenario. For example, riders have expressed preference for riding larger coaches for commuter trips with long duration instead of the low floor 40-ft buses Given the limited availability of 45-ft ZEB coaches for the purposes of the six-scenario analysis, any scenario in 2040 assumed that 45-ft battery electric coaches don't have the option of on-route charging. Any failing block will therefore need to be reblocked, causing an increase in operational costs to swap vehicles and potentially increase the fleet size. For any scenario in 2050, it was assumed that 45-ft battery electric coaches do have the capacity to have on-route charging, therefore allowing a 1 to 1 replacement. For the hydrogen scenarios, it was assumed that 45-ft hydrogen coaches are commercially available both in 2040 and in the 2050 timeline. Another consideration is how ZEB technologies can provide quieter bus operations, which increases rider comfort and is less disruptive to the local community compared to diesel and CNG options.

5.4 CRITERIA WEIGHT ASSIGNMENT

From the survey and in-person workshop conducted in June 2023, a list of criteria sorted (or scored) was developed based on the priority assigned by each RFTA staff member. Figure 25 shows the criteria sorted by the revealed preferences from the survey results. On a scale of 0 to 6 each criterion was ranked. The lower the number, the higher the importance of the criteria. For example, Scheduling was scored as highly important by getting closer to the number 1 priority, and training was the least critical, comparatively. Recognizing that Rider Experience and Environmental Considerations were not yet identified in the original survey, Stantec added the two criteria and assigned them a weight; Rider Experience a 5 and Environmental Considerations a 6.

Figure 25: List of criteria sorted by priority as a result of the initial survey



Once all the criteria were ranked based on preference, the results were normalized along a scale with weights from 0 to 10. First, the scores were converted by subtracting the assigned weight of the criteria from 10. For example, Scheduling with a weight of 2.4 from the survey becomes 7.6 (10-2.4 = 7.6) on a 0 to 10 scale.

The next step was to calculate the normalized weight based on the relative weight of a criterion in terms of the sum of the weights. For example, the normalized weight provided to Scheduling is calculated as 7.6/(7.6+6.4+6.4+5.9+5.7+5.3+5+4.7+4) = 0.15. Table 12 shows the criteria and their normalized weights used in the evaluation matrix.

Table 12: Normalization of weights

Criteria	Weight from Survey	Weight on a 10 scale	Normalized Weights
Scheduling	2.40	7.60	0.15
Cost of Ownership	3.60	6.40	0.13
Dispatch	3.60	6.40	0.13
Technology Availability/ OEM/Procurement	4.10	5.90	0.12
Resiliency/Redundancy	4.30	5.70	0.11
Fueling/ Charging Infrastructure	4.70	5.30	0.10
Rider Experience	5.00	5.00	0.10
Training	5.30	4.70	0.09
Environmental Considerations	6.00	4.00	0.08

6.0 MAINTENANCE FACILITY INFRASTRUCTURE MODIFICATIONS

This section outlines the proposed facility modifications for both BEB and FCEB implementation in RFTA's bus operations and maintenance facilities at GMF and AMF. Master plans have been developed proposing the addition of new charging stations in the bus storage facilities and hydrogen fueling dispensers with new hydrogen equipment in the yards of the facilities. The preliminary analysis suggests that both facilities have sufficient space opportunity for either new hydrogen fueling equipment or charging stations. However, some constraints have been identified that need further investigation during the preliminary design stages. Some elements that might need to be future-proofed were identified in the GMF multi-phase construction project.

As of July 2024, the remodeled GMF facility, and the corresponding maintenance and operations systems, functionally support additional BEB charging, or new hydrogen fueling infrastructure. Additionally, the GMF has been a CNG fueling hub, allowing for straightforward safety modifications for future hydrogen operations.

The AMF currently houses and maintains only diesel and gasoline vehicles. The facility does not meet fire protection, ventilation, and gas detection standards for CNG vehicles storage and maintenance. The lack of these systems and the age of the building limit the feasibility of hydrogen infrastructure upgrades. The compact site also has sufficient but limited options for adding hydrogen fueling and storage infrastructure.

Under the BEB scenarios that anticipate new outdoor Level 2 depot chargers, maintenance cycles and support vehicle parking may be disrupted, as a result of space limitations.

Due to the compact nature of the services facilities and the need to maintain operations, phasing of all construction will need to be carefully planned. RFTA will need to work closely with the designers, engineers, and contractors to implement the proposed modifications to the facilities. Since the construction impacts to daily operations will be temporary in nature, permanent displacement of any function at the facilities is not anticipated.

In summary, significant constraints were identified at the AMF property that could create noteworthy cost increases to the implementation of the proposed hydrogen fueling improvements, such as the following:

- Lack of ventilation suitable for hazardous exhaust, event exhaust fans and combustible gas detection within the building. An upgrade for the HVAC system will be needed to accommodate CNG and FCEB storage and maintenance inside the facility.
- Multiple unprotected wall openings and air-intakes and waste oil tanks are located within the 75-ft offset distance from the proposed liquid hydrogen storage nozzle. Further evaluation of needed modifications to those building elements would be required to ensure code compliance.
- For the maintenance area, a combustible gas detection system is recommended.

The costs to address these constraints are not included in the current cost estimates and would require additional engineering review and analysis.

6.1 PROPOSED BEB CHARGING FACILITY MODIFICATIONS

The following summarizes the proposed improvements for new BEB charging systems and associated infrastructure at the GMF and AMF.

6.1.1 BEB Charging at GMF

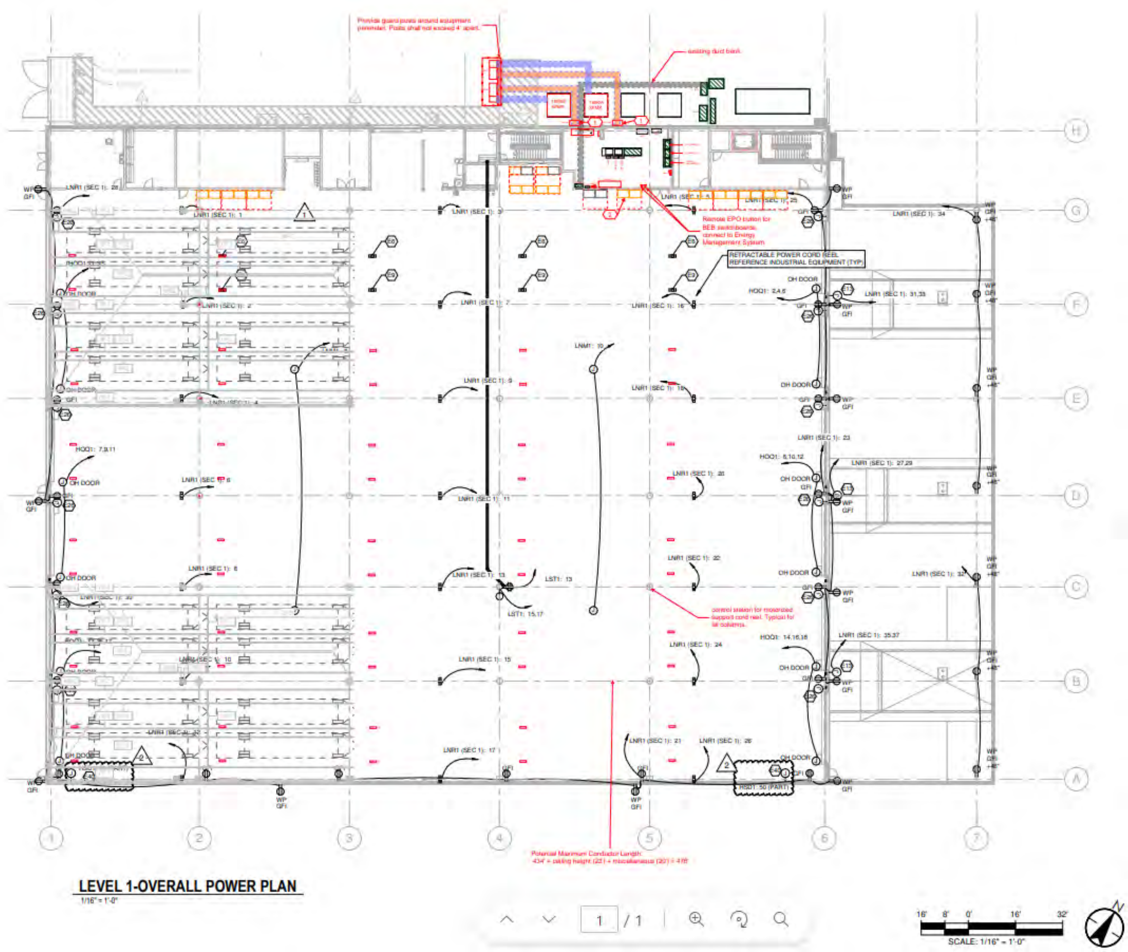
BEB charging at the GMF is planned for the new bus storage building, projected to be completed in the fall of 2024. The current project includes provisions for four dual 150kW BEB chargers with eight plugs.

The following summarizes anticipated future improvements for a 100% BEB fleet transition. (see Figure 26):

- 60 new charging plug-in stations (Overhead Depot Charge Boxes) rated at a minimum of 150 kW.
- 30 new chargers at a minimum of 150 kW each
- New switchgear for the 60 charging stations along with power main feeder and sub-feeders.
- Two new 1,500kVA utility transformers.
- Two new MW diesel-fired generators to support 60 charging stations
  - New generators will be exterior mounted
  - New by-pass isolation ATS (automatic transfer switch) between generators and switchgear.
- Equipment pads and associated bollard protection around all new chargers, generators, and electrical equipment.
- Pavement/base replacement/repair for trenching associated with electrical distribution to chargers and equipment.

The site plan in Figure 26, and Appendix A, presents a conceptual solution for the charging infrastructure described in this section. The site plan forms the basis of a high-level cost estimate for recommended modifications. Assuming 2023-2024 construction costs, the un-escalated capital investment would be approximately $17.7M for charging infrastructure. See Appendix B for more detailed cost estimates.

Figure 26: GMF Conceptual Master Plan BEB Infrastructure



LEGENDS

- 24'W x 8"H duct bank from utility transformer to SES. Drop to 5' below grade to avoid existing duct bank.
- 24'W x 8"H duct bank from SES to switchboard. Drop to 5' below grade to avoid existing duct.
- Two BEB Power Cabinets in a row with 48" clearance in front.
- Overhead Depot Charge Box.

6.1.2 BEB Charging at AMF

Additional BEB charging infrastructure is proposed for the existing AMF bus storage building. As of July 2024, there are four dual chargers (eight plugs) and eight dedicated interior parking spaces. An additional 32 parking spaces are needed to support future charging infrastructure.

The following summarizes the proposed improvements for the new BEB charging stations and associated infrastructure (see Appendix A and

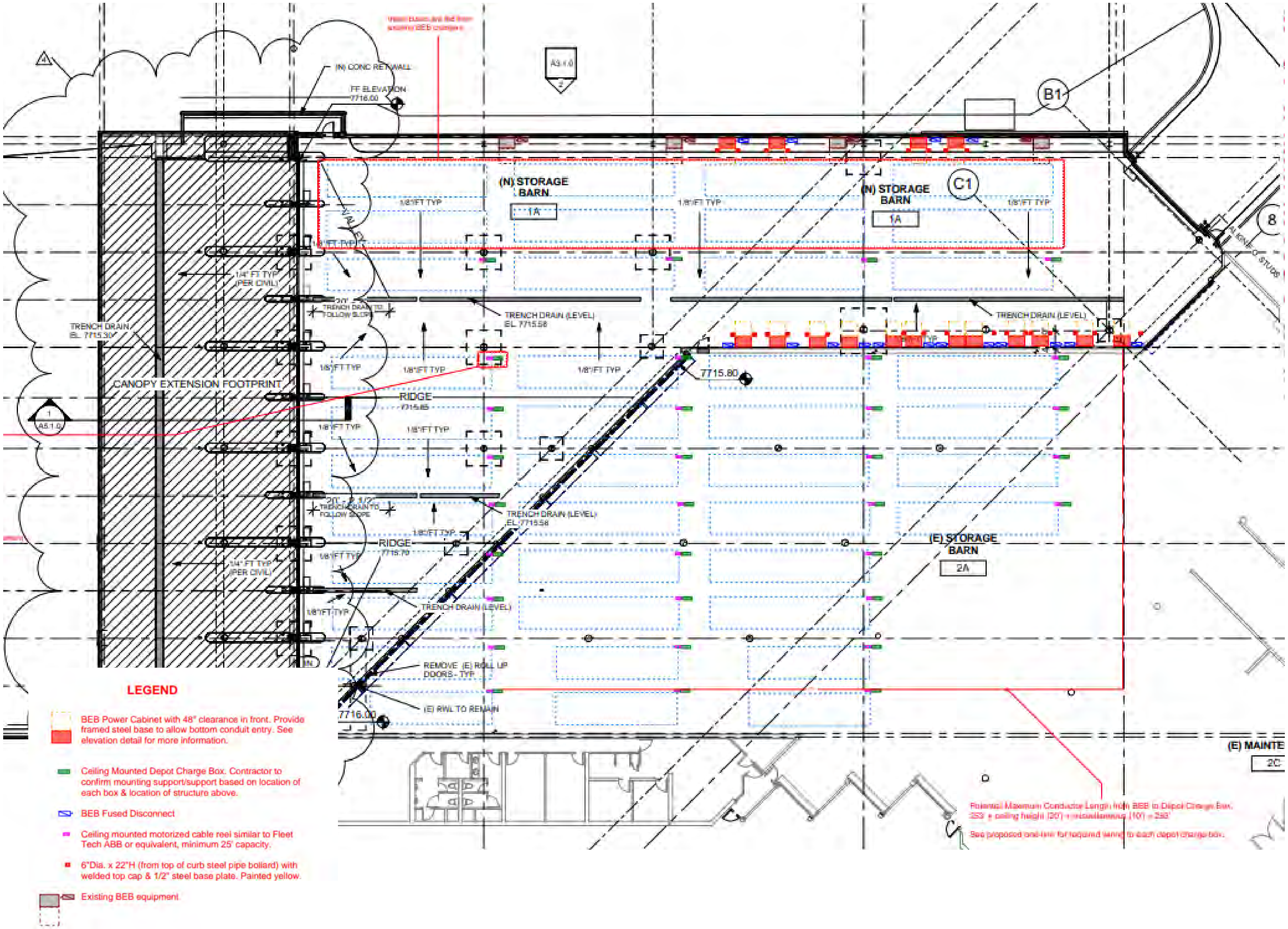
Figure 27).

- 32 new charging plugs
- 16 new charging cabinets, each at 150kW.
- New switchgear for the 32 charging stations along with power main feeder and sub-feeders.
- Two new 1,500kVA utility transformers.
- Two new MW diesel-fired generators as back-up for 32 charging stations
    - New generators will be exterior mounted.
    - New ATS (automatic transfer switch) between generators and switchgear.
- Equipment pads and associated bollard protection around all new chargers, generators, and electrical equipment.
- Pavement/base replacement/repair for trenching associated with electrical distribution to chargers and equipment.

The site plan in

Figure 27, and Appendix A, presents a conceptual site layout for the charging infrastructure described in this section. The site plan forms the basis of aa high-level cost estimate for recommended modifications. Assuming 2023-2024 construction costs, the un-escalated capital investment would be approximately $13.9M for charging infrastructure. See Appendix B for more detailed cost estimates.

Figure 27: AMF Conceptual Master Plan BEB Infrastructure



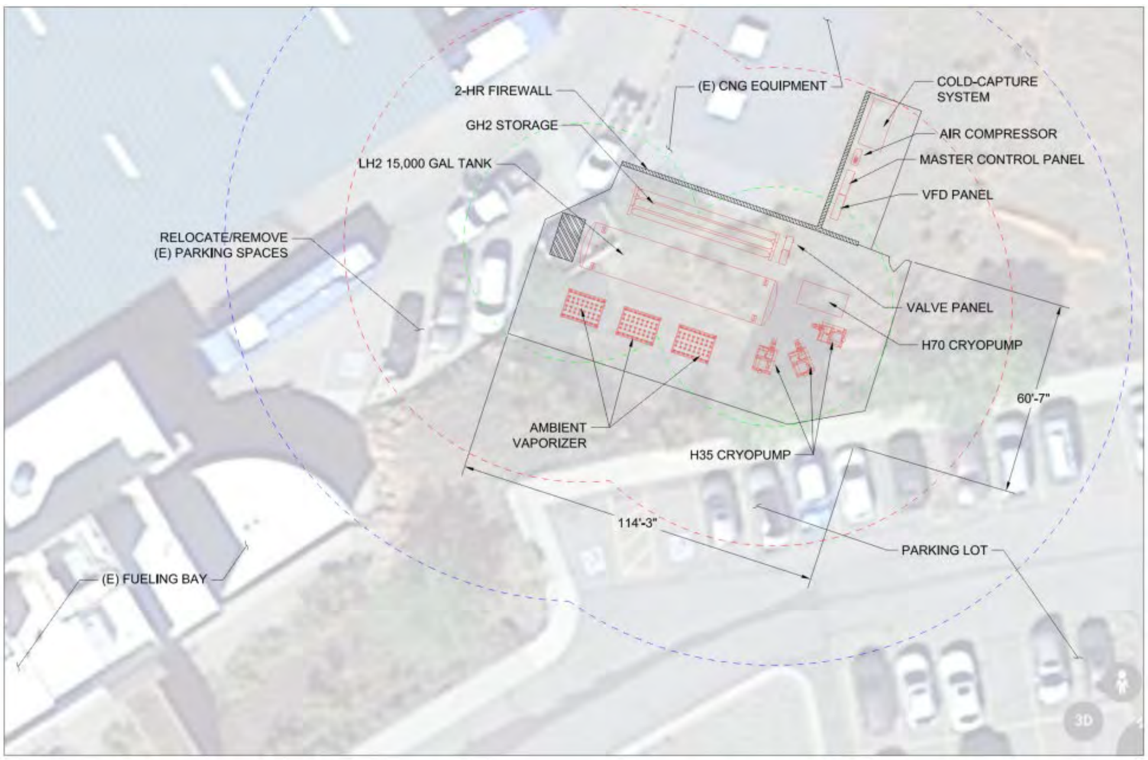
6.2 PROPOSED HYDROGEN FUELING FACILITY MODIFICATIONS

The following summarizes the proposed improvements for new hydrogen fueling systems and associated infrastructure at the GMF and the AMF.

6.2.1 Hydrogen Fueling at GMF

As of July 2024, the GMF is undergoing multi-phase redevelopment and the first BEB charging infrastructure is projected to be installed in late 2024. Previous construction plans already contemplated future hydrogen storage and refueling in conjunction with the RFTA-owned CNG compressor and refueling station.

Figure 28: GMF ZEB Site Conceptual Master Plan



The following summarizes the proposed improvements for the new hydrogen fueling systems and associated infrastructure at the GMF (see Figure 28 above, and Appendix A):

- A new hydrogen fueling system designed to dispense 1,900 kg of hydrogen per day. The assumed fleet size consists of: (52) 40-foot buses with an average fuel amount dispensed of 35.92 kg/bus, (1) 35-foot bus with an average fuel amount dispensed of 14 kg/bus, and (5) cutaways with an average dispensed amount of 7 kg/vehicle. Quantities of each component are one unless noted otherwise (see Figure 28 for details).
  - 15,000 gallon liquified hydrogen tank

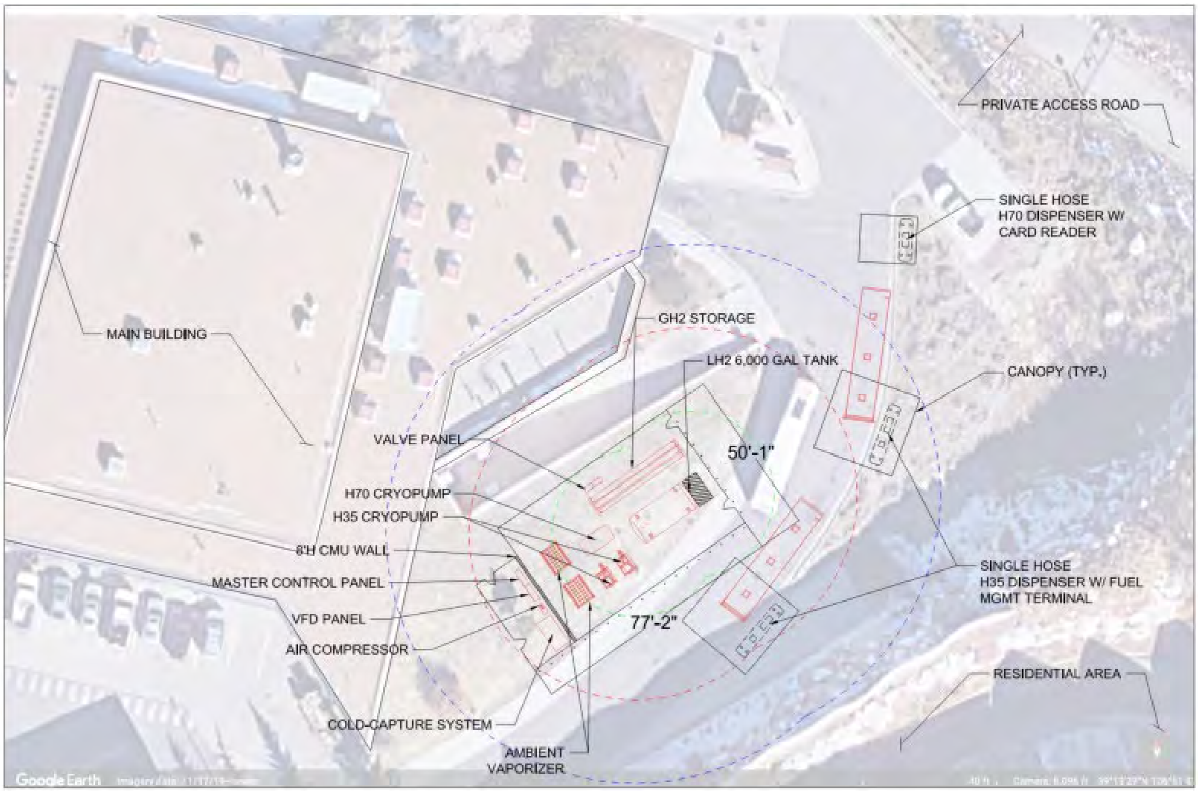
    - Reciprocating LH2 pump for H35 fueling (qty.: 3)
    - High pressure LH2 pump for H70 fueling
    - Hydrogen ambient vaporizer (qty.: 3)
    - Fluid heat exchanger H35/H70 (qty.: 3)
    - GH2 priority valve panel
    - High-pressure GH2 storage vessel for H35/H70 fuel (qty.: 12)
    - Thermal management system – chiller (qty.: 1)
    - GH2 H35 dispenser (qty.: 2)
    - GH2 H70 dispenser
    - Cold-capture system for precooling dispensed hydrogen
    - Air compressor system
    - Main electrical service panelboard (existing)
    - VFD panels for pump motor (qty.: 4)
    - System control panel
- New hydrogen equipment yard site improvements:
    - Perimeter security fencing surrounding hydrogen storage and equipment yard. Fencing to include lockable vehicle and pedestrian access gates.
    - 10-foot tall, 2-hour rated CMU site wall separating the adjacent CNG equipment yard electrical equipment to the west.
    - Bollards along the vehicle traffic facing sides of the yard.
    - Equipment pads/foundations as required and pavement between all portions of the equipment yard to allow for access and maintenance activities.
- Modifications to the Fuel Building's service lanes includes new equipment pads for GH2 dispensers and new bollards.
- Electrical system improvements and modifications:
    - A new panelboard to provide power connection to the new hydrogen equipment.
    - Connection of new panelboard to existing electrical switchgear at the east end of the CNG equipment yard. Power supply for hydrogen fueling equipment will be backed-up by the new generator per notes in section above.
    - Associated equipment pads, fencing and bollards.
- Pavement replacement/repair for trenching associated with electrical distribution, piping to the new hydrogen dispensers, etc.
- New site lighting and security cameras in the hydrogen equipment yard as required.
- Gas detection system modifications at Fuel Building and Maintenance Building, see narrative below.

The site plan in Figure 28 presents the details for the charging infrastructure described in this section for the hydrogen station. The site plan forms the basis of aa high-level cost estimate for recommended modifications., If the hydrogen station were to be built in 2023/2024, the un-escalated capital investment would be $10.6M See Appendix B for more detailed cost estimates.

6.2.2 Hydrogen Fueling at AMF

The AMF currently houses and maintains only diesel and gasoline vehicles. The lack of ventilation and fire protection systems that would be required to make this facility suitable for CNG and the age of the building contribute to higher anticipated capital cost improvements at the facility. The compact site has limited options for adding hydrogen fueling and storage infrastructure.

Figure 29: AMF ZEB Site Conceptual Master Plan



The following summarizes the proposed improvements for the new hydrogen fueling systems and associated infrastructure at the AMF and highlights constraints that need to be addressed in the design phase (see Figure 29 above):

- A new hydrogen fueling system designed to dispense 950 kg of hydrogen per day. The assumed fleet size consists of: (31) 40-foot buses with an average fuel amount dispensed of 24.33 kg/bus, (3) 35-foot buses with an average fuel amount dispensed of 36.57 kg/bus, and (8) cutaways with an average dispensed amount of 11.57 kg/vehicle. Quantities of each component are one unless noted otherwise (see Figure 29 for details).
    - 6,000 gallon liquified hydrogen tank
    - Reciprocating LH2 pump for H35 fueling (qty.: 2)
    - High pressure LH2 pump for H70 fueling

  - Hydrogen ambient vaporizer (qty.: 2)
  - Fluid heat exchanger H35/H70
  - GH2 priority valve panel
  - High-pressure GH2 storage vessel for H35/H70 fuel (qty.: 12)
  - Cold-capture system for precooling dispensed hydrogen
  - GH2 H35 dispenser (qty.: 2)
  - GH2 H70 dispenser
  - Air compressor system
  - Main electrical service panelboard (existing)
  - VFD panel for pump motors (qty.: 3)
  - System control panel
- New hydrogen equipment yard site improvements:
  - Perimeter security fencing surrounding hydrogen storage and equipment yard. Fencing to include lockable vehicle and pedestrian access gates.
  - 10-ft tall, 2-hour rated CMU site wall separating the electrical equipment to the west.
  - Bollards along the vehicle traffic facing sides of the yard.
  - Equipment pads/foundations as required and pavement between all portions of the equipment yard to allow for access and maintenance activities.
- Modifications to the facility plan include new equipment pads for GH2 dispensers and new bollards.
- Risk-mitigation implementation due to siting:
  - Due to the nearby administration building, north of the proposed hydrogen storage and equipment yard, it was identified that building openings and roof air-intakes fall within the setback distances defined by code. Active risk-mitigation methods must be implemented and approved by the AHJ (Authority Having Jurisdiction). These may include:
    - Modifications to existing air-intake ducting
    - Gas detection
    - Relocation of building openings
    - Hydrogen leak-diffusion modeling
- Electrical system improvements and modifications:
  - A new panelboard to provide power connection to the new hydrogen equipment.
  - Connection of new panelboard to any existing electrical switchgear. The power supply for hydrogen fueling equipment will be backed-up by a new generator.
  - Associated equipment pads, fencing and bollards.
- Pavement replacement/repair for trenching associated with electrical distribution, piping to the new hydrogen dispensers, etc.
- New site lighting and security cameras in the hydrogen equipment yard as required.

- Gas detection system modifications at Fuel Building and Maintenance Building.

The site plan in Figure 29, and Appendix A, presents the details for the charging infrastructure described in this section for the hydrogen station. The site plan forms the basis of a high-level cost estimate for recommended modifications. Assuming 2023-2024 construction costs, the un-escalated capital investment would be $11.4M See Appendix B for more detailed cost estimates.

6.2.1 Fire Protection Considerations

With the implementation of FCEBs, fire protection and life-safety concerns can be significant. The primary code dictating the implementation of hydrogen fueling systems is the National Fire Protection Association (NFPA) 2 – Hydrogen Technologies Code. Because the GMF was designed to support CNG vehicles, many of the requirements for hydrogen fueling can already be met with little to no changes to that facility. However, the existing constraints and lack of accommodation for CNG vehicles at the AMF dictates constraints and potential high costs for retrofitting the AMF with CNG or hydrogen equipment.

The need for enhanced fire protection systems has not been specifically assessed as a part of this study and should be discussed with the local fire marshal and the local building officials to ensure all stakeholders in the approval process understand the proposed systems. Fire truck access to the site and hydrant access is already well defined but will need to be reviewed and approved by the pertinent authorities having jurisdiction (AHJs) prior to implementation of any facility improvements.

In summary, it is assumed that no fire protection system modifications are required at the GMF for FCEB implementation, and further analysis may be required.

The hydrogen equipment compounds as considered for the hydrogen and mixed-fleet cases were sited based on NFPA 2 - 2023, which is the latest edition as of July 2024. Nearby exposures were evaluated to ensure setback distances are met, and passive and active means of risk-mitigation are accounted for in the preliminary design to enhance safety.

7.0 FUEL DEMAND AND SUPPLY

One key aspect of the ZEB transition planning is assessing the fueling or charging needs of RFTA's fleet to help inform the:

- Infrastructure and equipment right-sizing,
- Facility power needs, and
- Design constraints and opportunities.

7.1 ELECTRICITY DEMAND AND SUPPLY

Based on the ZEB modeling and service plan, Stantec tested different charging specifications and configurations to best evaluate how RFTA could optimally recharge its revenue fleet. Stantec used its depot emulation tool to simulate how, based on pull-out and pull-in schedules and different charger characteristics, RFTA can recharge its fleet and estimate the maximum power that would be needed.

Four locations for charging were considered: the two depots (GMF and AMF) and two on-route charging locations (Rubey Park and West Glenwood Springs Park and Ride). The utility providers by location and the rates considered are listed in Figure 30 below.

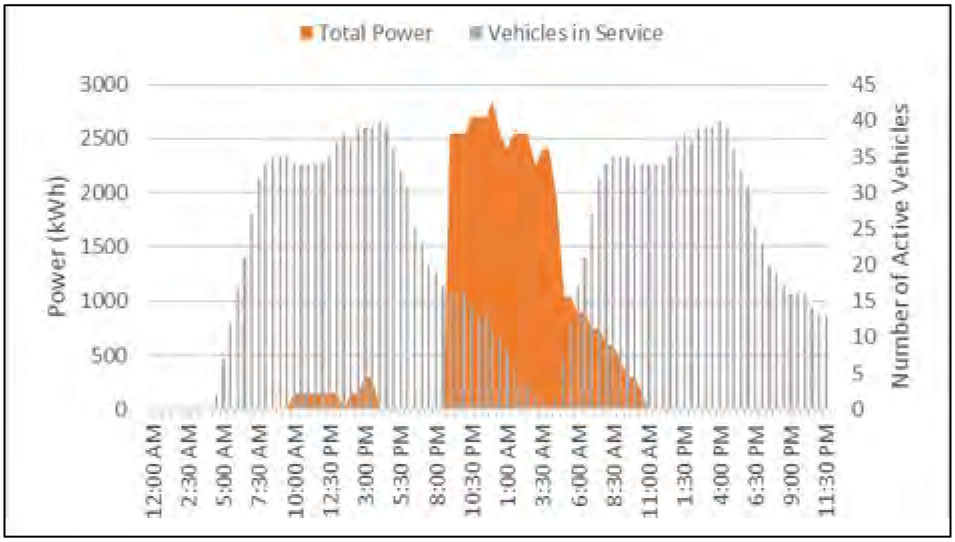
Figure 30. Utility Rates by Facility

Utility	Facility	Consumer Availability/ Service Charge	Current Tariff ($2023)	Other	Notes
Holy Cross Energy (HCE)	AMF	$12	0.24[$/kWh] -peak period 0.06[$/kWh] -off-peak period	PCA: 4.08% WE CARE rider: 2%	Rate Code: 56; General Services - Time of Day (optional)
The Aspen Electric Department	Rubey Park Transit Center	$1,076	0.06[$/kWh] up to 23,200 kWh 0.08[$/kWh] b/w 23,200 kWh - 110,500kWh	20.82 $/kW	Has demand fees. Large commercial customer assume 1800 AMP.
City of Glenwood Springs Electric System	GMF	$60	0.1127[$/kWh]	na	Flat fee, no peak or demand fees.
City of Glenwood Springs Electric System	West Glenwood Park and Ride	$60	0.1127[$/kWh]	na	Flat fee, no peak or demand fees.

The power demand and charging profile presented in Figure 31 includes the charging requirements for the active revenue vehicles housed at GMF. It was assumed that 44 vehicles were in service daily. The model also avoided charging between the 4 PM and 9 PM peak utility period. While the current City of Glenwood Springs Electric System does not have peak hour demand charges, these may be adopted in the future.

Based on the full implementation of the service plan for the BEB 2050 Case, the GMF will require a maximum power capacity of 2,850 kW during the overnight, off-peak, charging window (Figure 31). This information will be important for RFTA to use as part of its continued discussions with City of Glenwood Springs Electric System. The analyzed scenario assumed 150kW chargers with a 1:2 connection.

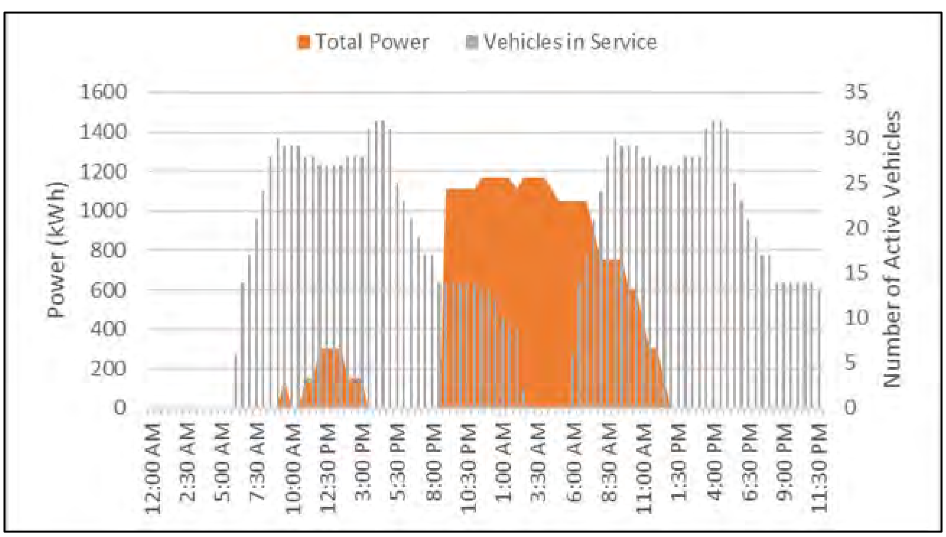
Figure 31. Charging Profile at GMF



The power demand and charging profile presented in Figure 32 includes the charging requirements for the active revenue vehicles housed at AMF. It was assumed that 35 buses and 5 cutaways were in service daily. The model also avoided charging within the 4PM to 9PM peak charging period to honor the Holy Cross Electric time of use tariff that was established for RFTA in 2019.

Based on the full implementation of the service plan for the BEB 2050 Case with all BEBs in revenue service, the AMF will require a maximum power capacity of 1,170 kW that would be realized during the overnight charging window (Figure 32). This information will be important for RFTA to use as part of its continued discussions with Holy Cross Energy. The analyzed scenario assumed 150kW chargers with a 1:2 connection for buses and cutaways.

Figure 32. Charging Profile at AMF



The analysis assumed that 13 blocks will use on-route charging at the Rubey Park Transit center in the City of Aspen. These blocks serve City of Aspen Burlingame, Castle Maroon and Cemetery Lane routes, as well as RFTA regional Local Valley VelociRFTA BRT routes. Vehicles on those routes typically have layovers ranging from 5 minutes to 30 minutes at Rubey Park, which allows replenishing up to 22.5-121.5 kWh per charging session. The on-route chargers at Rubey Park are assumed to be 450 kW chargers[5].

The analysis assumes that a schedule will be created that optimizes the charging order and priority so that vehicles charge only when needed and as much as needed. Space constraints at the Rubey Park Transit Center exist and will increase as the share of BEB's increases and on-route charging frequency increases. Future operations under a BEB Case or Mixed Case are expected to incorporate real time tracking of SOC and optimized and scheduled vehicle assignments through a new dispatch process. Having real-time SOC and scheduled vehicle assignment in turn will provide the inputs needed for efficient scheduling of on-route charging operations.

Eight long distance blocks within the Grand Hogback, Local Valley and VelociRFTA BRT routes were modeled to need on-route charging for operational success. These blocks will likely on-route charge at the West Glenwood Springs Park and Ride. The layover time, on average, is between 25-75 minutes and allows replenishing between 32-105 kWh per charging session. The future on-route chargers at West Glenwood Springs Park and Ride are also assumed to be 450 kW chargers.

7.2 HYDROGEN FUEL DEMAND AND SUPPLY

7.2.1 Hydrogen Demand

The estimated daily hydrogen demand assumes the maximum hydrogen utilization, which is an FCEB-only scenario for each facility, as well as the best method of supplying hydrogen to the facility. Table 13 and Table 14 summarize estimated hydrogen demand by facility. This is comprised exclusively of RFTA's transit fleet and assumes no shared fueling with peer fleets or the public.

Table 13: Daily hydrogen demand at GMF

Description	Vehicles	Units
Total Hydrogen demand per day (for all vehicles)		1,900 kg/day
Total number of active 45- and 40-ft buses (50kg tanks)	52 active buses	35.92 kg/bus
Total number of active 35-ft buses (37.5kg tanks)	1 active buses	14 kg/bus
Total number of cutaways (13.5kg tanks)	5 active cutaways	7 kg/bus

[5] Vehicles can receive up to 300kW max unless otherwise specified during procurement even if chargers have capacity of 450 kW.

Table 14: Daily hydrogen demand at AMF

Description	Vehicles	Units
Total Hydrogen demand per day (for all vehicles)		950 kg/day
Total number of active 45- and 40-ft buses (50kg tanks)	31 active buses	24.33 kg/bus
Total number of active 35-ft buses (37.5kg tanks)	3 active buses	36.57 kg/bus
Total number of cutaways (13.5kg tanks)	8 active cutaways	11.57 kg/bus

Due to site space constraints, the only method of supplying hydrogen at the facilities that was considered was trucked-in liquified hydrogen, since onsite production requires significant space that is not available. For the purposes of this plan, the analysis, recommendations, and strategies for the hydrogen-fueled and mixed fleet scenarios assume that RFTA will deploy equipment necessary for on-site storage of liquified hydrogen, conversion to high-pressure gaseous hydrogen, and dispensing of gaseous hydrogen to FCEBs and hydrogen cutaways.

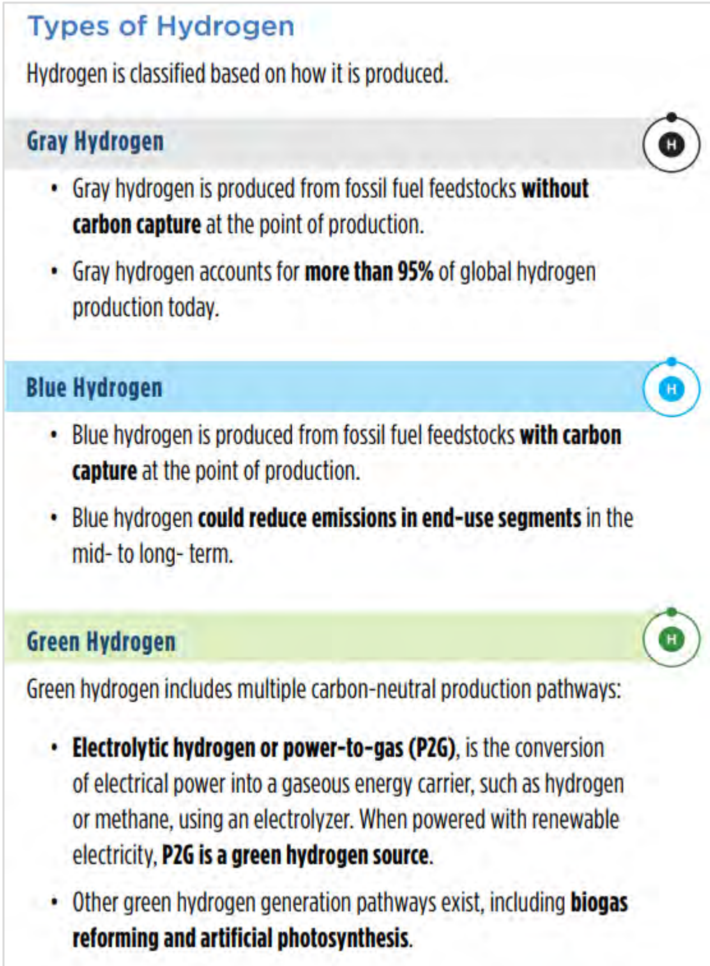
7.2.2 Hydrogen Supply

There are three classifications of hydrogen based on how it is produced, each with different carbon intensity levels. Figure 33 provides an overview of the different hydrogen classifications based on the generation source. Gray, blue, and green hydrogen have different levels of carbon emissions, with green being ideal because it is carbon neutral and preferred by the State of Colorado to meet climate action goals.

Today, 37%-44% of hydrogen used in transportation is renewable, but 95% of all hydrogen produced in the United States is made by industrial-scale natural gas (NG) reformation (gray hydrogen). This process is called fossil fuel reforming or steam methane reforming (SMR). The process takes natural gas and high-pressure steam to generate a product stream of carbon dioxide (CO_2) and hydrogen (H_2). Greenhouse gas emissions can be avoided completely if the CO_2 produced in SMR is captured and stored (blue hydrogen), which is a process known as carbon capture and storage (CCS).

In the short-term, RFTA will likely truck-in liquified hydrogen from facilities in Nevada or California. As of July 2024, LH2 is available from the recently commissioned Air Liquide facility in North Las Vegas, NV, which produces 20 MT per day.

Figure 33: Types of hydrogen based on generation source[6]



Types of Hydrogen

Hydrogen is classified based on how it is produced.

Gray Hydrogen

- Gray hydrogen is produced from fossil fuel feedstocks **without carbon capture** at the point of production.
- Gray hydrogen accounts for **more than 95%** of global hydrogen production today.

Blue Hydrogen

- Blue hydrogen is produced from fossil fuel feedstocks **with carbon capture** at the point of production.
- Blue hydrogen **could reduce emissions in end-use segments** in the mid- to long- term.

Green Hydrogen

Green hydrogen includes multiple carbon-neutral production pathways:

- **Electrolytic hydrogen or power-to-gas (P2G)**, is the conversion of electrical power into a gaseous energy carrier, such as hydrogen or methane, using an electrolyzer. When powered with renewable electricity, **P2G is a green hydrogen source**.
- Other green hydrogen generation pathways exist, including **biogas reforming and artificial photosynthesis**.

As sustainable renewable energy generation advances in the United States, it is anticipated that low- to zero-carbon hydrogen production will become available locally in the state of Colorado.

Neighboring Hydrogen Hubs such as The Pacific Northwest Hydrogen Association (Washington, Oregon, and Montana) and the California Hydrogen Hub were selected in 2023 to receive up to $1 billion each in federal funding from the U.S. Department of Energy (DOE) for four defined development phases spanning nine years, with $20 million allocated for Phase 1.

Within the state of Colorado, the Colorado State University (CSU) leads efforts in hydrogen refueling station development. In January 2024 CSU in partnership with New Day Hydrogen, became the recipient of a $8.9 million grant[7] from the U.S. Department of Transportation under the Charging and Fueling Infrastructure Program, FY 2022-2023. The program is set to develop hydrogen refueling infrastructure along the I-25

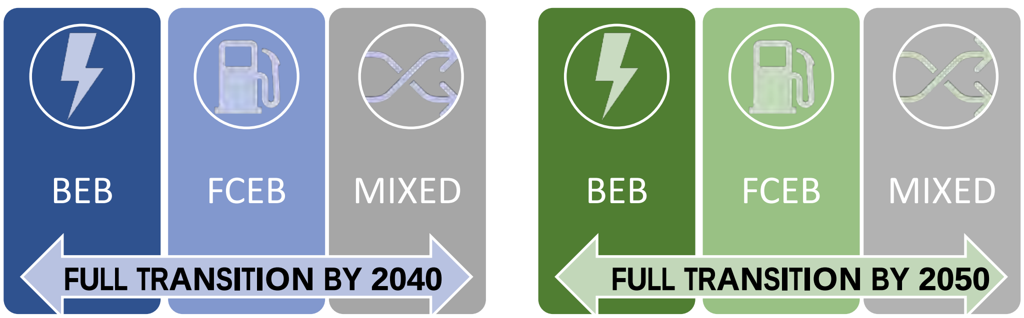
[6] https://www.energy.ca.gov/sites/default/files/2021-06/CEC_Hydrogen_Fact_Sheet_June_2021_ADA.pdf
[7] DOT awards $8.9M for hydrogen fueling stations project (colostate.edu)

corridor, with stations in Fort Collins, Denver, and Pueblo. These stations will serve medium- and heavy-duty fleet vehicles initially and light-duty passenger vehicles in the future. CSU will be responsible for managing the overall program as well as creating a workforce development component with partners at the Southern Colorado Institute of Transportation Technology at CSU Pueblo that addresses the local transportation impacts and environmental justice elements.

8.0 FINANCIAL EVALUATION AND IMPACTS

The financial evaluation for RFTA's ZEB transition consisted of modeling a Base Case and ZEB Cases grouped into a 2040 Full Adoption Timeline and a 2050 Full Adoption Timeline. There are three technology options considered under each timeline: 100% BEB, 100% FCEB, and a mixed fleet of both ZEB technologies.

Figure 34: ZEB Cases by Timeline



The Base Case is the 'business as usual' scenario and assumes the continued use of the current RFTA fleet as well as all planned BEB purchases through 2032. The ZEB Cases assume the fleet is transitioned to 100% ZE vehicles. The fixed-route and demand response fleet were analyzed in the same process for all six cases.

The financial modeling process is comprised of several steps. First, Stantec worked with RFTA to collect all relevant financial data. The data, coupled with industry research, was used to determine the model inputs. After the model inputs were complete, costs were projected year by year for the full analysis timeline 2023 through 2050 using a 3% inflation rate, energy price trends[8], battery price trends, and vehicle price trends where applicable. The financial modeling is expressed in year of expenditure. All scenarios considered under both timelines, the 2040 Full Adoption Timeline and the 2050 Full Adoption Timeline, are evaluated for the full analysis period 2023-2050 to allow for a fair comparison of the total costs of ownership between the two different timelines.

It is important to understand the inherent limitations of the financial modeling due to assumptions about costs, service levels, operations, asset life cycles, and other factors that are difficult to predict. Additionally,

[8] U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

it is important to note the categories modeled are focused on the impacts of a change in propulsion type. They do not account for service delivery costs (such as driver salaries) as these costs would be comparable in all cases. This cost analysis is aimed to be a comparison between the different scenarios and not a detailed capital and operational forecast for RFTA.

The main assumptions/inputs for the cost modeling are:

- Financial modeling is expressed in year of expenditure.
- Discount Rate was assumed at 0%
- The fleet replacement and procurement plan was based on RFTA's Fleet Management Plan and was vetted with RFTA staff regarding useful life and fleet size. Active fleet size of 117 vehicles was reflected in the fleet phasing assuming no fleet expansions or reductions in the period 2023-2050.
- Acquisition costs, fuel costs, maintenance costs and refurbishment costs were separated by fleet ownership.

Infrastructure costs were not separated by ownership and placed in their own category; the appropriate shared costs can be assigned to other stakeholders by RFTA in the future. The following sections present the input assumptions and the financial evaluation for each of RFTA's services separated by ownership.

8.1 FINANCIAL ANALYSIS ASSUMPTIONS

This section describes the major assumptions for the financial analysis of the revenue fleet alternatives. More details about the assumptions and the individual input values for the Base Case and the ZEB Cases can be found in Appendix C: Financial Modeling Inputs and Assumptions.

8.1.1 Fleet Acquisition

Fleet acquisition includes the purchase price of a vehicle inclusive of options, taxes, and extended warranty. The purchase price of the vehicles varies by vehicle length, fuel type and vehicle type. All the purchase costs for CNG, diesel, and 40-ft BEBs are in real 2023 dollars and were adjusted based on procurement costs and trends RFTA received. Based on RFTA's fleet inventory data with the corresponding procurement prices, and per RFTA's request, all prices from 2021 were adjusted with a 12% increase rate to 2022$, and then an increase rate of 20% was applied from prices 2022 to the standard 2023 baseline.

For FCEB purchase prices, Stantec conducted industry research and leveraged RFTA's BEB procurement targets to determine appropriate costs. In general, FCEBs are 15-20% more expensive than BEBs. Some of the ZEB vehicles modeled, for example 45-ft FCEBs, do not have commercially available options currently on the market (July 2024). The cost for those vehicles were developed based on the costs for the closest in size FCEB vehicles available on the market and the expected price differential to account for a larger/smaller vehicle.

Stantec applied a trend for the cost projection of all bus types based on market trends and experts' predictions. See Figure 38 in Appendix C for more details.

8.1.2 Fleet Refurbishment

Fleet refurbishment includes mid-life rehabilitation, defined as any heavy mid-life work needed to achieve the vehicle's useful life benchmark. Stantec used engine refurbishment costs and transmission refurbishment costs as part of the mid-life refurbishment. These costs vary by vehicle length, vehicle type and fuel. The cost estimates were developed from RFTA's internal tracking reports of engine and transmission expenses at the bus level from 2014 through 2023. These historical costs were brought to 2023$ using a 3% inflation rate. Cutaways (fossil fuel, BE, and FCE) were assumed to have no refurbishment costs due to their shorter useful life.

For BEBs a refurbishment cost of $416/kWh (2023$) tied to the battery size was used as a baseline. The future year costs for BEB refurbishments include price projection trends from the Bloomberg NEF 2021 Report (See Figure 64 in Appendix C: Financial Modeling Inputs and Assumptions), which projects a steady cost reduction over the years for the $/kWh price. For FCEBs a flat cost of $30,000 (2023$) per bus for fuel cell replacement was assumed based on information from Ballard. The future year costs for both fossil fuel and BEB vehicle refurbishments include a 3% inflation factor.

8.1.3 Infrastructure and Facility Modifications

The following cost estimates are based on a conceptual level of analysis without a detailed project description or design. Some estimates may change as the project moves forward. This cost category refers to infrastructure modification costs such as equipment installation (chargers and hydrogen fueling stations), testing, civil and electrical work, and contractor labor fees and escalation factors. It also includes a backup generator for hydrogen fueling equipment and BEB chargers. The costs for BE and FCEB charging and fueling equipment were escalated at 3% per year to project future costs in year of expenditure. All construction and labor items have an allowance for escalation (to midpoint construction) applied at 8% per year, since labor cost increases year to year are expected to stay high for the analysis period.

8.1.3.1 BEB Charging Infrastructure

Infrastructure modifications are assumed to be executed at both the AMF and GMF facilities. As of July 2024, the AMF has and existing four dual depot chargers (eight total plugs). With the rate of BEB fleet adoption listed in Section 5 for the BEB Case under the accelerated 2040 timeline and the 2050 timeline, the current assumption is that up to 46 BEB vehicles will be operating from AMF and 44 plugs/chargers will be available for those vehicles. That allows for some redundancy as some spare vehicles do not need overnight charging. The specific timeline for when those chargers will come online at the facility will be dependent on the specific procurement timeline (2040 vs 2050). Additionally, a heavy capital improvement year has been assigned to each timeline for the installation of a new transformer, conduit, backup generator, required retrofit at the maintenance bays, and any related mechanical and civic work required for the expansion beyond the current available capacity at the AMF.

The GMF facility is currently undergoing a multi-phase, multi-year renovation and expansion project. As part of those improvements, four dual-depot chargers (eight plugs) are planned for installation in late 2024. The first expansion of BEB charging infrastructure at the GMF is planned past 2024 for both the 2040 and 2050 timeline. Similarly, a heavy capital improvement year has been assigned to each timeline for the installation of a new transformer, conduit, and backup generator. However, it’s assumed that minimal retrofitting will be required at the parking and the maintenance areas since the GMF is designed as a 100% ZEV Support Facility. The current assumption is that up to 71 active BEB vehicles will be operating from GMF, and 68 chargers will be available, assuming that not all spare vehicles will require overnight charging.

On-route charging infrastructure will ramp up at the on-route charging locations as the BEB share increases and the route coverage includes more longer-range blocks. The first on-route pantograph charger in Colorado was installed at the end of 2023 at the Rubey Park Transit Center in downtown Aspen. The City has permitting for two additional on-route chargers that will be added according to the specific needs of each procurement timeline (2040 vs 2050). At the West Glenwood Springs Park and Ride, new charging infrastructure is also anticipated for up to 3 on-route chargers.

It's important to note that up to 40 pedestal chargers were assumed for the Base Case scenario, since it’s assumed that additional charging infrastructure will be needed to support the 1/3 of the fleet that will be BEBs.

For the BEB-only scenario, modifications were assumed as described above for the AMF, GMF, Rubey Park and at West Glenwood Springs Park and Ride. However, for the Mixed-fleet scenario, the electrical modifications are only anticipated for the AMF and Rubey Park, since the GMF will only have hydrogen infrastructure and no on-route charging at West Glenwood Springs Park and Ride will be required.

8.1.3.2 Hydrogen Infrastructure for FCEBs

The FCEB infrastructure modifications assume the construction of hydrogen fueling infrastructure, including hydrogen dispensers at both the AMF and GMF facilities. The GMF facility is assumed to have a high-capital investment year prior to the first delivery of FCEB vehicles according to each timeline. The infrastructure upgrades will include maintenance infrastructure upgrades, a generator, gas detection equipment, a hydrogen equipment plant, and a fueling island. A second phase will add redundancy equipment (a second compressor, evaporator, etc.). No major mechanical modifications are expected at the GMF in neither the parking nor maintenance area, since it’s assumed that current retrofits will make such areas code compliant related to ventilation and gas detection systems. The upgrades at the AMF will mirror the scale and timeline at the GMF. However, the AMF is anticipated to have higher retrofit costs to accommodate the required ventilation upgrades, safety features around the hydrogen plan, and gas detection systems. More details about the required upgrades and equipment are described in Section 6.2. Lastly, the Mixed-fleet scenario assumed that hydrogen infrastructure will only occur at GMF.

8.1.3.3 Vehicle Useful Life

The assumption for useful life by vehicle type was based on RFTA’s goals for fleet replacements by type, which aligns with the Federal Transit Administration’s (FTA) recommended useful life metrics. For fossil fuel buses a useful life of 14 years is used and for cutaways the useful life is 10 years. For the ZE buses and cutaways the same useful life was assumed. Some vehicles with retirement dates planned prior to 2031 in the RFTA fleet management plan will have different retirement ages (higher or lower age at retirement) than the assumed target useful life. The financial model kept those assumptions from the fleet management plan. Retirements of vehicles past 2031 follow the target useful life assumptions.

8.1.3.4 Operating Costs

Operating costs include fuel costs for the revenue vehicles. Fuel costs for existing traditional fuel vehicles are estimates from 2024 RFTA budget costs and vary by fuel type (CNG, diesel, and gasoline). For BEBs, electricity costs vary by location, AMF, GMF, Rubey Park or West Glenwood Springs Park and Ride, and by utility provider, Holy Cross Electric, City of Aspen, and City of Glenwood Springs. Stantec and it's subconsultant FHU conducted targeted outreach to each of the utility providers to understand the present and future cost of electricity for an electric fleet. While the engagement resulted in the current rates of electricity for each facility, and a desire for regional collaboration, no specific guidance was provided for future electricity costs. RFTA staff will need to continue these regional utility discussions.

The electricity tariff for each site was used in combination with the projected daily energy consumption and projected charging profile (an hour-by-hour forecast of power consumption). While the current assumption is that most sites will be able to avoid charging at peak-hours, thus avoiding any existing or future demand charges, BEB depot charging at the AMF is guided by a specific time-of-use tariff that HCE established specifically for RFTA in 2019. Specific market trends were used to project the future cost of electricity and trends for other fossil fuels using projected data from the U.S. Energy Information Administration (EIA) (see Figure 65 in Appendix C: Financial Modeling Inputs and Assumptions).

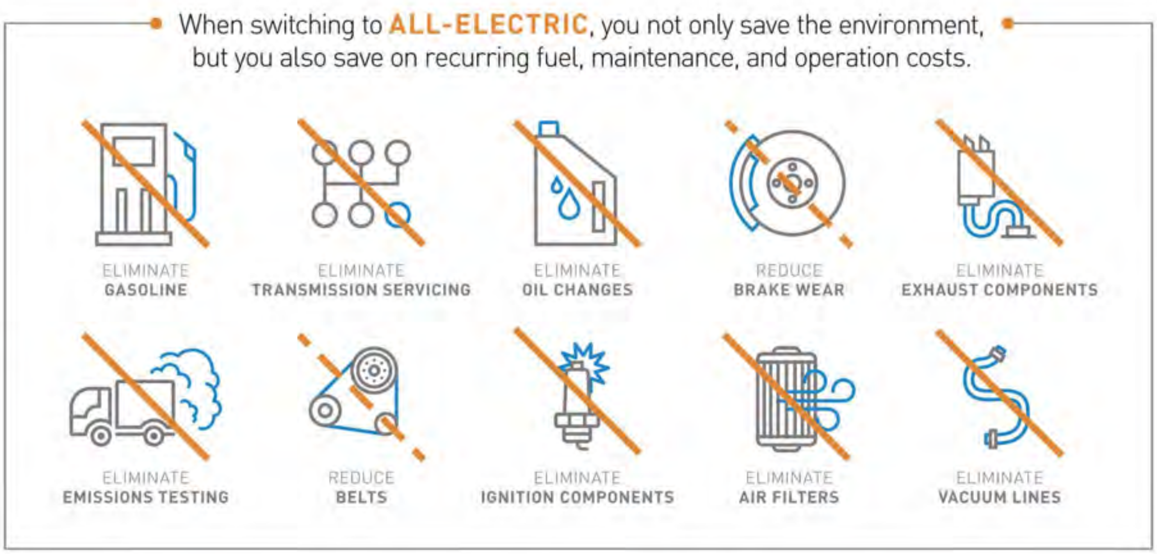
For FCEBs, hydrogen costs are based on data from two California FCEB transit operations (starting at $8/kg) and assume a green tax. The Bloomberg NEF 2021 report had a similar trend for green hydrogen cost projections.

The future year costs for both fossil fuels, electricity and hydrogen were projected by overlaying the fuel specific price trend and a 3% inflation rate.

8.1.3.5 Maintenance Costs

Maintenance costs per mile inclusive of labor and parts for scheduled and unscheduled maintenance are included in these costs. Maintenance costs vary by vehicle type, fuel type, and vehicle mileage and are estimated from the 2022 Vehicle Maintenance data shared by RFTA. Maintenance costs exclude the fuel costs. For BEBs and FCEBs, Stantec's assumption is that the maintenance costs will be 10% less than those for fossil-fuel buses. This assumption has been validated by other transit agencies, since maintaining ZEBs involves fewer mechanical components and fewer oils, lubricants, etc. (see figure below for reference).

Figure 35: ZEB Maintenance Savings



Weighted averages for RFTA's historical maintenance costs for existing CNG and diesel buses (by size 40ft, 45ft etc.) were summarized and a 10% reduction was applied to calculate the expected BEB/FCEB maintenance costs. It's important to note that current mileage varies greatly by vehicle size and fuel type, however, in the future, it's expected that the utilization mileage will be equally distributed by vehicle size. Therefore, the maintenance costs were equalized by vehicle size to project the maintenance cost of BEBs and FCEBs. Over the years, a 3% inflation rate was applied to account for the increase in labor and cost of parts.

Lastly, the maintenance costs for BEBs currently considers the cost of diesel fuel to power the external heaters that are supporting the current BEBs operated by RFTA and COA. This cost was assumed constant and a permanent component of the maintenance cost of BEBs. The reality is that BEBs would be expected to have a lower maintenance cost than FCEBs, however, the expected reduction for the BEBs is equivalent to the added cost of the fuel to support the external heaters. Therefore, the maintenance cost of BEBs and FCEBs is currently assumed to be the same.

The observed maintenance costs for the eight 40-ft pilot BEBs that started operating in 2019 are $1.5-1.69$/mi.

All new 40-ft BEBs added to the RFTA fleet will operate as substitutes for retired CNG and diesel buses, which historically incur higher maintenance and operating costs. As a result of future on-route charging to extend daily range, maintenance costs of $0.77/mi were calculated for any new 40-ft BEBs based on RFTA's historical maintenance costs for existing 40ft buses. Coupled with the aforementioned 10% reduction in maintenance costs for BEBs, anticipated costs decreased from $1.69/mi to $0.77/mi for future BEBs operating under similar service conditions.

8.1.3.6 Fuel Efficiency

Fuel efficiency takes into consideration the energy consumption of each vehicle type on a per mile basis. It is represented as miles/gallon, miles/DGE, mi/kWh, or mi/kg based on fuel type. These estimates are calculated from the fleet usage by fuel type data shared by RFTA. For BEBs and FCEBs efficiency estimates are derived from Stantec Modeling. Table 15 lists the efficiencies per mile for 40ft buses and uses fuel costs in 2023 dollars to calculate corresponding $/mi statistics by fuel type. These costs are for operations only and do not include maintenance and refurbishment costs or future fuel cost trends.

Table 15: Fuel Efficiency and Costs per Mile in 2023$ dollars by Fuel Type for 40ft Bus

Efficiency by Fuel Type

Fuel Type	Efficiency	Metric
Diesel	5.97	mi/diesel gallon
CNG	5.37	mi/ diesel gallon equivalent
Electricity	0.48	mi/kWh
Hydrogen	6.89	mi/kg

Fuel per Mile

Fuel Type	Fuel per Mile	Metric
Diesel	0.17	diesel gallon/mi
CNG	0.19	diesel gallon equivalent/mi
Electricity	2.08	kWh/mi
Hydrogen	0.15	kg/mi

Costs by Fuel Type

Fuel Type	Costs (2023$)	Metric
Diesel	3.05	$/diesel gallon
CNG	1.95	$/diesel gallon equivalent
Electricity	0.11	$/kWh
Hydrogen	8.00	$/kg

Cost per Mile

Fuel Type	Cost per Mile	Metric
Diesel	0.51	$/mi
CNG	0.36	$/mi
Electricity	0.23	$/mi
Hydrogen	1.16	$/mi

8.1.3.7 Vehicle Utilization

This refers to the average yearly mileage of the vehicles. The level of utilization is based on the 2022 fleet mileage with details by vehicle number and vehicle fuel type as provided by RFTA. For the financial modeling, Stantec used weighted averages of miles traveled by fleet ownership for all fuel types under a specific vehicle length. Meaning, while there is currently a significant utilization gap between CNG and diesel buses, the gap is eliminated under the future operations of BEBs and FCEBs. Existing electric vehicles were assumed to continue to be used at their current average mileage, but any new BEB vehicles are set to be utilized at a higher rate matching the weighted average mileage observed for the existing fossil fuel vehicles by vehicle size. On-route charging will allow for BEBs to operate at comparative mileages as current fossil vehicles. For the ZEB Cases, annual total mileage is assumed to remain constant to help with comparison across different ZEB Cases and the Base Case (business as usual).

8.2 REVENUE FLEET FINANCIAL ANALYSIS RESULTS

Stantec utilized an Excel-based model to process all the above-described inputs and to calculate the Total Cost of Ownership of each scenario. This section lists the results from the financial analysis for each ZEB case in comparison with the Base Case.

8.2.1 Base Case

Stantec developed the forecast for the Base Case (business-as-usual), assuming that the existing fleet of diesel and BEBs would be maintained and replaced through 2050, with an additional 34 BEBs procured between 2023 and 2033 as part of the RFTA's Destination 2040 Plan. Those new BEBs will be mostly 40-ft RFTA-owned vehicles but also include City of Aspen 35- and 40-ft buses and one RGS-owned 40-ft bus. Those purchases will bring RFTA's total operated fleet to 29% BEB in 2032. It should be noted that this Base Case would be non-compliant with the RFTA's Climate Action Plan and the State's goal to transition the state transit fleet to 100% ZEB by 2050. Under this Base Case RFTA operations would still deploy fossil fuel vehicles for two-thirds of the fleet between 2033 and 2050. The Base Case is used only for comparative purposes to determine the financial impacts of a ZEB rollout.

The Base Case fleet consists of 117 active vehicles, of which 98 are heavy-duty buses (30-ft-45-ft buses) and 19 are cutaways and it remains constant in size over time. The size of the fleet is based on the number of active vehicles as of September 2023 and, in addition to RFTA-owned vehicles, the fleet also includes vehicles with COA, Glenwood Springs, and Garfield County ownership.

This model is inclusive of all scheduled fleet replacements required during the 2050 analysis horizon. For example, diesel or CNG vehicles procured in 2030 with a 14-year useful life would be replaced in 2044. Below are additional details about the inputs that are specific to the base case.

Vehicle Utilization: Weighted average mileage per year for 45-ft buses is estimated to be 63,664 miles as per RFTA's 2022 annual maintenance data (based on mileage of CNG and diesel buses with the corresponding total share of each fuel type). The 40-ft buses operate an average 47,922 miles per year and the 30-35-ft buses operate up to 39,000 miles per year. The mileages for each vehicle length are derived from the weighted average of total of miles per fuel type divided by the total number of vehicles for each fuel type.

Fleet Acquisition: Capital expenses modeled consist of fleet acquisition based on the Base Case replacement plan for inputs related to replacement quantities and estimated purchase costs. See Section 5.0 Fleet Procurement Options by Timeline and Fuel Type for details on the acquisition timeline and Appendix C: Financial Modeling Inputs and Assumptions for more information on the purchase prices.

Midlife refurbishments for the heavy-duty buses (30-ft-45-ft buses) in the fleet are assumed for all propulsion types. Engine and transmission work were included for CNG buses and diesel buses. Estimates for those costs come from RFTA's historical maintenance data from 2014 to mid-2023 and were combined to estimate a midlife refurbishment cost. RFTA currently does not have a scheduled midlife refurbishment program, but it is considering transitioning to one that will include engine and transmission work for all heavy-duty buses at year seven of operations (mid-useful life).

8.2.2 Full Adoption by 2040

The first group of alternative cases falls under the accelerated timeline to achieve a 100% ZEB transition by 2040 but is analyzed on a timeline between 2023 and 2050. The accelerated timeline allows RFTA to achieve greater reductions in GHG emissions earlier and to have cumulatively higher GHG emission reductions over the analysis period through 2050 when compared to a later adoption timeline.

Under the accelerated timeline there may be more funding sources available for early adopters of ZEB technologies. RFTA's planning and finance staff have a successful track record of securing funding for innovative initiatives in the past and would have to actively continue to seek and win such grants.

One disadvantage of the accelerated timeline is that is has a shorter period to plan and implement infrastructure improvements. Additionally, some ZEB types might have limited availability on the market within the accelerated timeline. For example, the market still has few alternatives for BEB cutaways with larger battery sizes and extended ranges, and there are limited implementations of 45-ft BE coaches with on-route charging capability. Furthermore, procuring ZEBs and related infrastructure early on also translates into higher replacement costs after the useful life of such vehicles and equipment is met.

8.2.2.1 BEB Case Full Adoption by 2040

The BEB Case foresees the transition to 100% BEB revenue vehicle operations by 2040 in a more accelerated pace than envisioned in RFTA's Climate Action Plan and the State's goal to transition the state transit fleet to 100% ZEB by 2050. The transition follows the fleet replacement schedule presented previously in Section 5.0. The assumed lifecycle for the BEBs is 14 years in accordance with the discussions with RFTA staff and industry standards.

RFTA's fleet currently includes 45-ft buses with both diesel and CNG fuel that cover block assignments of up to 500 miles, with about 11 blocks covering distances of 250-500 miles. In the BEB Case modeling, it was assumed that 45-ft BEBs will cover those longer blocks with on-route charging at West Glenwood Springs Park and Ride. Since 45-ft buses with on-route charging capability are currently not available, the fleet replacement plan for the BEB Case with an accelerated 2040 timeline assumed those purchases would be delayed until 2030. Similarly, cutaways have limited ranges and battery size in current market offerings and their purchases were delayed until 2031-2033, to allow a better match with RFTA's needs. The successful rollout of the BEB-only Case will depend on expanding the availability of on-route charging at the Rubey Park Transit Center in Aspen and implementing on-route charging at West Glenwood Springs Park and Ride. Existing blocks that depend on on-route charging include blocks for the Local Valley, the VelociRFTA BRT, and some COA routes. Inputs for the BEB Case are the same as the Base Case except where noted.

Infrastructure Modifications are assumed to be installed at both the AMF and GMF facilities. Currently the AMF has four (4) dual depot chargers (8 plugs).With the rate of BEB fleet adoption listed in Section 4.0 for the BEB Case under the accelerated 2040 timeline, eight new plugs will need to be installed at the AMF in 2025 reaching the current capacity of the electric infrastructure at the facility. Additional investment for a new transformer, conduit, backup generator and chargers will be needed in 2027, and that will bring the total chargers at the AMF to 20 plugs. Additional chargers will be installed in 2029 (12 plugs), 2033 (10 plugs) and 2037(10 plugs) as the use of diesel buses decreases and the share of BEBs at the AMF increases to 100%. The current assumption is that up to 46 BEBs will be operating from the AMF in 2040 and 44 plugs will be available for those vehicles. That allows for some redundancy as spare vehicles do not need overnight charging.

The GMF facility is currently undergoing improvements and, as part of those improvements, four (4) dual depot chargers (8 plugs). The first expansion of BEB charging infrastructure at the GMF is planned for 2028 and it will include a new transformer, conduit, backup generator and 6 chargers with 12 plugs. Additional chargers with dual plugs will be installed in the GMF in 2031 (13 plugs), 2033 (23 plugs) and 2036 (12 plugs) as the use of diesel and CNG buses decreases and the share of BEBs at the GMF increases to 100%. The current assumption is that up to 71 active BEBs will be operating from the GMF in 2040 and 68 chargers will be available for those vehicles, with up to three spare vehicles not needing overnight charging. The infrastructure modifications assumed do not reflect the capital cost of charging infrastructure that is already existing at the AMF (eight plugs) and planned at the GMF through 2025. Additionally, minimal mechanical and civic modifications are expected at the GMF since the current retrofit is accounting for required upgrades to support ZEBs at the facility.

On-route charging infrastructure will ramp up at the on-route charging locations as the BEB share increases and route coverage includes longer-range blocks. Rubey Park currently has one on-route charger and capacity for two additional chargers that are assumed to be added in 2030 and 2036 for the BEB 2040 Case. In this analysis the costs assumed for the additional chargers account only for equipment and installation and it was assumed that no additional electrical upgrades will be needed. At West Glenwood Springs Park and Ride, new charging infrastructure is planned for 2029 that will include two chargers. With the expected electrical upgrades and equipment installation in 2034, an additional charger will be installed.

Operating Cost: For the BEB Case, electricity rates were calculated based on current rates from the three providers (City of Aspen Electric Department, City of Glenwood Springs Electric System and Holy Cross Electric Association, Inc.), using demand estimates for the full BEB fleet to account for off-peak/peak period rates, maximum power surcharges and other subscription and monthly charges.

The current provider electricity rates are assumed to be applicable as base costs for the analysis period, inflation and electricity price trends have also been applied to that base cost. It is assumed that no major increases in the rates or changes in the rate structure and surcharges will occur outside of the anticipated inflation and price trend changes. Electricity cost changes can be tested further in the financial model sensitivities. All power modeling at the facilities assumed that charging in peak hours will be avoided. To achieve consistent off-peak charging in day-to-day operations, smart charging and dispatch software will need to be implemented. Costs for that software and implementation are not currently included in the total cost estimates.

Specifically, it is expected that RFTA will charge the buses at the AMF under the “Time of Day (Optional)” rate, which has preferential rates of 0.06 [$/kWh] for off-peak hours (peak is from 4:00 PM to 9:00 PM) and a $12 monthly customer charge as well as variable PCA and We CARE Rider charges that add up to approximately a 6% monthly charge. The City of Glenwood Springs Electric System is the provider for electricity for the GMF and the West Glenwood Springs Park and Ride. It is assumed that the current energy rate at $0.1127kWh and $60 service charge per meter for large commercial and industrial accounts will continue to be applicable as a base cost for the analysis period. At Rubey Park, the assumption is the City of Aspen Electric Department provider will continue to charge RFTA operations as a Large Commercial customer. The cost for Large Commercial customers includes a tiered rate of $0.06 per kWh (up to 23,200 kWh) and $0.08 per kWh (above 23,200 kWh); a customer availability charge of $1,076, and demand charge on customer peak kW expected to be $20.82 per kW for RFTA's operations and maximum power demand at Rubey Park. The levels of GHG emission reductions in the BEB Case will depend on the share of renewable electricity sources used by RFTA's electricity providers.

A summary of the financial model findings for the BEB Case assuming full adoption of ZEBs by 2040 is listed below. Total nominal costs for the analysis period 2023 through 2050 are shown in Table 16. Costs are separated by capital costs and operating costs. Capital costs include fleet acquisition, refurbishment, and any infrastructure related costs. Operating costs are fuel costs and fleet maintenance costs. Total costs in the BEB Case are 14% or $83M more compared to the Base Case. There are notable savings in Fleet maintenance and Fuel costs in the BEB Case. However, the higher costs of acquisition and additional improvements to infrastructure make the BEB total costs higher than the total costs under the Base Case.

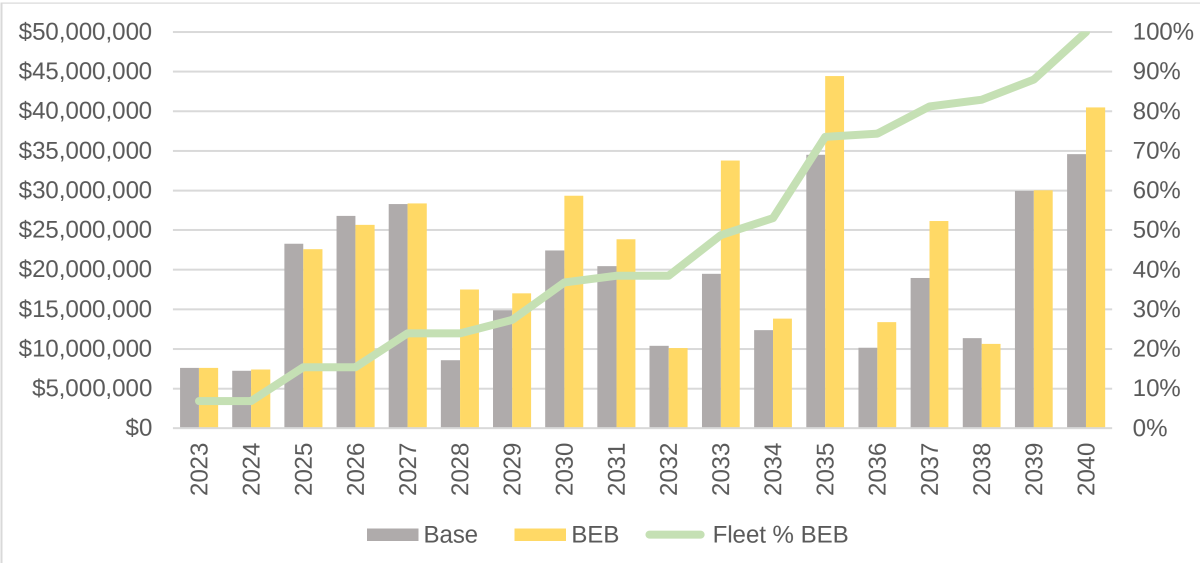
Table 16: BEB Case Full Adoption by 2040 Total Cost of Ownership (analysis period 2023-2050)

	Accelerated Timeline - 2040 Scenario			
Cost Components	**Base Case**	**BEB Case**	**Savings**	**Cost difference (BEB - Base)**
Fleet Acquisition	$ 270,473,175	$ 348,987,421	$ (78,514,246)	$ 78,514,246
Fleet Refurbishment	$ 16,250,101	$ 16,606,069	$ (355,967)	$ 355,967
Fleet Maintenance	$ 207,577,553	$ 195,297,206	$ 12,280,347	$ (12,280,347)
Fuel/Electricity	$ 72,778,743	$ 55,874,428	$ 16,904,316	$ (16,904,316)
Infrastructure	$ 22,888,623	$ 55,988,069	$ (33,099,446)	$ 33,099,446
Total	*$ 589,968,196*	*$ 672,753,192*	*$ (82,784,997)*	$ 82,784,997

In the Base Case, 46% of the costs are related to fleet acquisition. In the BEB Case, 52% of the total costs are related to acquisition – a 29% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while maintenance is only 29% of the total costs in the BEB Case – a 6% decrease when compared to the Base Case. In the Base Case, 12% of the total costs are related to fuel costs; In the BEB Case only 8% of the total costs are related to electricity – a 23% decrease compared to the Base Case. In the Base Case 2.8% of the total costs are related to refurbishment costs; In the BEB Case only 2.5% of total costs are related to refurbishment costs – a 2.2% decrease when compared to the Base Case. In the Base Case 3.9% of the total costs are related to Infrastructure while they are 8.3% of total costs in the BEB Case – a 145% increase when compared to the Base Case.

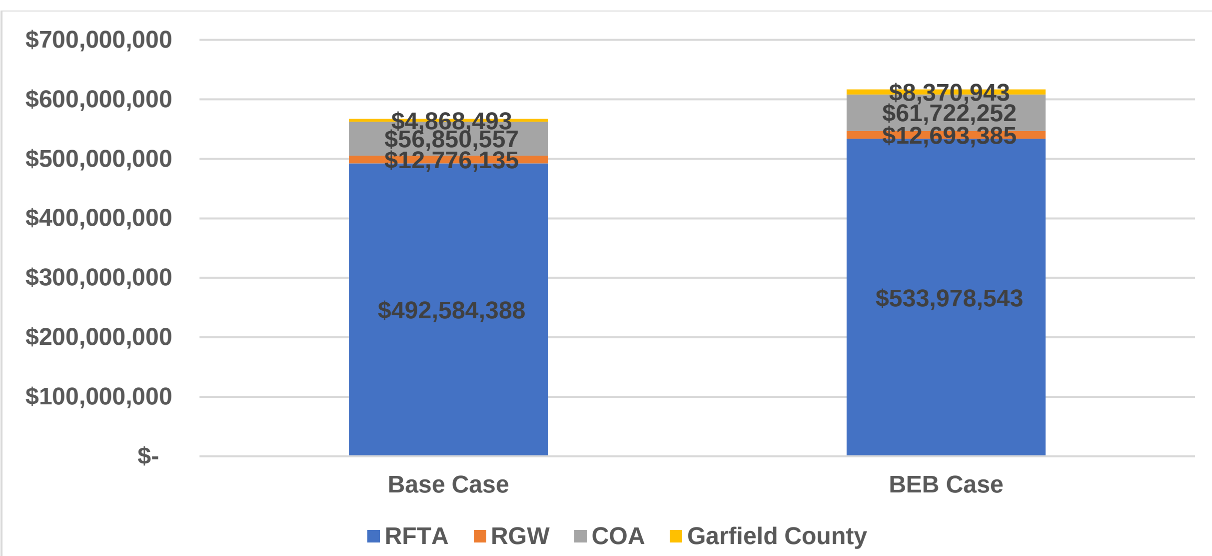
Annual cost comparisons between the Base Case and the BEB Case are shown in Figure 36 all costs are listed in the year of expenditure $ value. Annual costs for both cases are similar through 2027, as new BEBs are procured and the percentage of the fleet that is BEBs increases, costs for the BEB Case becomes higher than the Base Case. Spikes in annual costs in the BEB Case are correlated to new BEB bus procurements or infrastructure updates to facilities. As shown in the figure, a 100% BEB fleet is achieved in the year 2040.

Figure 36: Annual Cost Comparison Base Case vs BEB Case Full Adoption by 2040



Total cost of ownership by RFTA, Glenwood Springs, COA and Garfield County are shown in Figure 37. As shown in the figure, most costs are associated with RFTA, followed by COA, Glenwood Springs, and Garfield County. The costs have increased proportionally for each ownership entity and the total cost is 9% or $49.7M more than the Base Case. Even though there are savings in maintenance costs and fuel costs, higher costs of acquisition make the BEB Case costs increase significantly compared to the Base Case for all entities. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 37: BEB Case Full Adoption by 2040 - Total Cost of Ownership by Entity (excluding infrastructure costs)



8.2.2.2 FCEB Case Full Adoption by 2040

The FCEB Case assumes 100% FCEB revenue vehicle operations by 2040 in a more accelerated pace than envisioned in RFTA's Climate Action Plan and Colorado State policy but analyzed on a 2023-2050 timeline. The transition follows the fleet replacement schedule presented previously in Section 5.0 FCEB current and future tank size and ranges are a better match as a one to one preplacement for the long distances covered by RFTA's 45-ft fossil fuel buses with the current operational schedule. There are currently limited market offerings for FCE cutaways, and their purchases were delayed until 2033 to allow a better match with RFTA's needs. The successful rollout of the FCEB-only Case depends on establishing long-term favorable contracts with green hydrogen suppliers. Inputs for the FCEB Case are the same as the Base Case except where noted.

Vehicle maintenance costs for FCEBs like BEBs is assumed to have a 10% reduction in costs compared to the fossil fuel fleet current RFTA maintenance costs, the savings assumption is based on literature from comparative FCEB and fossil fuel bus operations for two California transit agencies. The findings in these reports demonstrated that on a per mile basis, vehicle maintenance costs were comparable between fossil fuel buses and FCEBs.[9] The lack of data on maintenance costs, particularly for costs outside of any OEM warranty, makes maintenance costs difficult to forecast. Mid-life refurbishment costs of a flat $30,000 (2023$s) per vehicle were assumed for FCEBs at year 7 of operations. In this case, costs account for fuel cell refurbishment.

CALSTART reports there being 211 FCEBs in operation in the US at the end of 2022 – a 64% increase from the year prior.[10] While most of those are in California, states like Ohio, Arizona, and Maryland are procuring and operating FCEBS as well. Growth in FCEB operations is expected across the country in the coming years, and most of this growth is likely to take place in California with a projected 2,000 units in operation by 2040.[11]

Fuel Efficiency: fuel efficiency of FCEB vehicles from Stantec modeling were used in the financial model. Based on the size of the vehicle and the mileage the fuel economy ranges between 6.89 to 8.37 miles per kilogram for buses. For FCE cutaways 8.33 miles per kilogram is the assumed fuel economy.

Operating Cost: fuel costs were based on industry reports that indicate that the price per kg of hydrogen will decrease in the future as the supply chain matures along with investments from private and public actors (from $8 per kg in year 2023 to $6 per kg in 2029, to $4 per kg in year 2033). The cost assumption is for the cost of the commodity as delivered liquid hydrogen.

Infrastructure Modifications: The FCEB infrastructure modifications assume the construction of hydrogen fueling infrastructure including hydrogen dispensers at both the AMF and GMF facilities. The GMF facility is assumed to have a $7M investment in 2026 just prior to the first delivery of ten 40-ft FCEB vehicles in

[10] https://calstart.org/wp-content/uploads/2023/02/Zeroing-in-on-ZEBs-February-2023_Final.pdf; page 5, Table 1.
[11] https://www.nrel.gov/docs/fy21osti/75583.pdf; page 5, Figure 1.

2027. The infrastructure upgrades will include maintenance infrastructure upgrades, a generator, hydrogen equipment plant, and fueling island. A second phase in 2032 will add redundancy equipment (a second compressor, evaporator, etc.) expected to cost $4.8M. No major mechanical modifications are expected at the GMF in either the parking or maintenance area, since it's assumed that current retrofits will make such areas code compliant related to ventilation and gas detection systems. The upgrades at the AMF will mirror the scale and timeline at the GMF but will occur two years later in 2028 and 2034. However, the AMF is anticipated to have higher retrofit costs to accommodate the required ventilation upgrades, safety features around the hydrogen plant, and gas detection systems.

The levels of GHG emission reductions will depend on the share of renewable electricity sources used by RFTA's hydrogen supplier.

A summary of the financial model findings for the FCEB Case, assuming full adoption of ZEBs by 2040, is listed below. Total nominal costs for the analysis period 2023 through 2050 are shown in Table 17. Total costs for the FCEB Case are 20% or $119.9M more compared to the Base Case. There are notable savings in fleet maintenance and some savings in fleet refurbishment costs in the FCEB Case. Higher costs of acquisition, higher fuel costs and additional improvements to infrastructure make the FCEB total costs higher than the Base Case.

Table 17: FCEB Case Full Adoption by 2040 Total Cost of Ownership (analysis period 2023-2050)

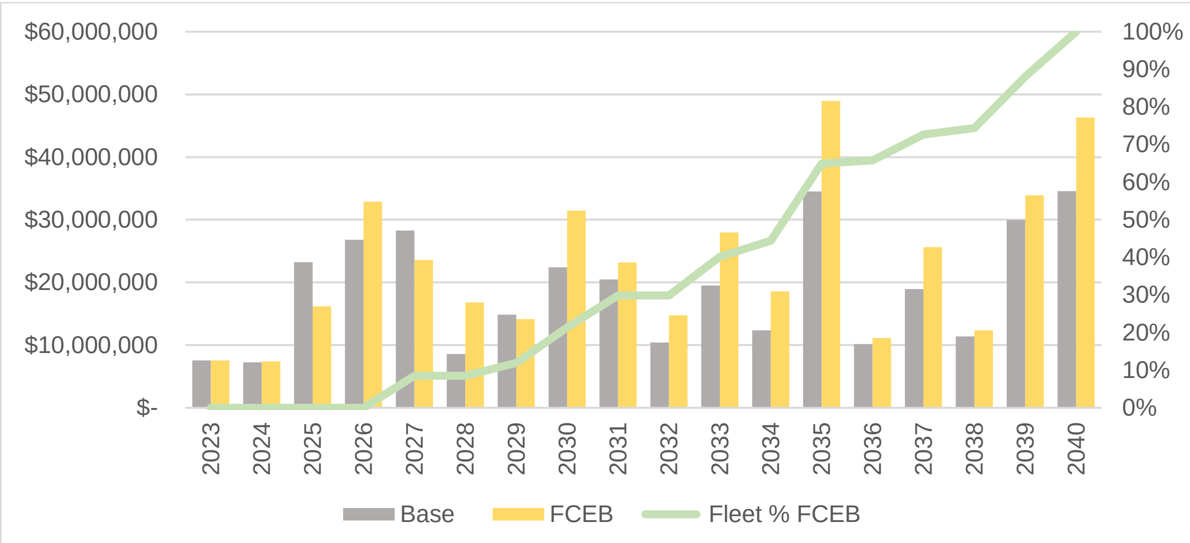
	Accelerated Timeline - 2040 Scenario			
Cost Components	**Base Case**	**FCEB Case**	**Savings**	**Cost difference (FCEB - Base)**
Fleet Acquisition	$ 270,473,175	$ 364,619,449	$ (94,146,274)	$ 94,146,274
Fleet Refurbishment	$ 16,250,101	$ 11,089,810	$ 5,160,291	$ (5,160,291)
Fleet Maintenance	$ 207,577,553	$ 197,140,467	$ 10,437,086	$ (10,437,086)
Fuel/Electricity	$ 72,778,743	$ 98,095,599	$ (25,316,856)	$ 25,316,856
Infrastructure	$ 22,888,623	$ 38,845,777	$ (15,957,154)	$ 15,957,154
Total	*$ 589,968,196*	*$ 709,791,102*	*$ (119,822,907)*	$ 119,822,907

In the Base Case, 46% of the costs are related to fleet acquisition. In the FCEB Case, 51% of the total costs are related to acquisition – a 35% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while they are only 28% of the total costs in the FCEB Case – a 5% decrease when compared to the Base Case. In the Base Case, 12% of the total costs are related to fuel costs; In the FCEB Case 14% of the total costs are related to hydrogen – a 35% increase compared to the Base Case. In the Base Case 2.8% of the total costs are related to refurbishment costs; In the FCEB Case only 1.6% of total costs are related to refurbishment costs – a 32% decrease when compared to the Base Case. In the Base Case 3.9% of the total costs are related to infrastructure while they are 5.5% of total costs in the FCEB Case – a 70% increase when compared to the Base Case.

Annual cost comparisons between the Base Case and the FCEB Case are shown in Figure 38. Annual costs for both Cases are similar through 2024. As new FCEB infrastructure gets built and new FCEBs are procured, the costs for the FCEB Case become higher than the Base Case. Spikes in annual costs in the

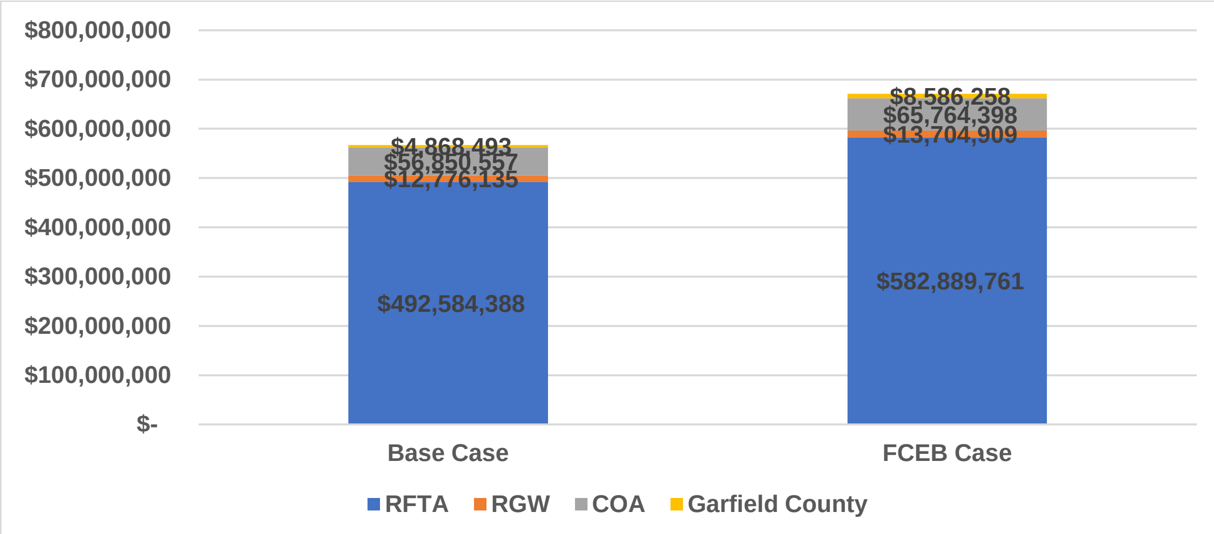
Base and FCEB Case are correlated to new bus procurement or infrastructure updates to facilities. As shown in the figure, 100% FCEB is achieved in the year 2040 with an accelerated transition pace between 2032 and 2035.

Figure 38: Annual Cost Comparison Base Case vs FCEB Case Full Adoption by 2040



Total costs of ownership by RFTA, City of Glenwood Springs, COA and Garfield County are shown in Figure 40. As shown in the figure, most costs are associated with RFTA, followed by city of Aspen, City of Glenwood Springs, and Garfield County. The costs have increased proportionally for each ownership entity and the total cost is 18% or $103.9M more than in the Base Case. Even though there are savings in maintenance costs and refurbishments costs, higher costs of acquisition and fuel make the FCEB Case total costs go up significantly compared to the Base Case for all entities. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 39: FCEB Case Full Adoption by 2040 Total Cost of Ownership by Entity (excluding infrastructure costs)



8.2.2.3 Mixed Case Full Adoption by 2040

RFTA has adopted a policy to diversify the propulsion fuel for its fleet, with the goal to avoid dependence on one type of fuel and fuel specific price increases and shortages. Local voters approved RFTA's Destination 2040 Plan in November 2018 that established a goal out to the year 2040 to maintain a diverse fleet of buses comprised of 1/3 diesel, 1/3 compressed natural gas (CNG), and 1/3 zero-emission bus (ZEB). The diversification approach can be applied to ZE fuels as well. The procurement, operation, and maintenance of mixed fleets has challenges, such as requiring additional training for staff and additional fueling/charging safety infrastructure. The pros for a mixed fleet of BEB and FCEB vehicles include diversification in terms of fuel price, but also the ability to tap into some specific advantages of hydrogen, such as the ability to store compressed hydrogen, and the quick refueling times. Costs for vehicle maintenance, refurbishments, efficiencies, and all other common inputs for the Mixed Case mirrors the corresponding inputs from the BEB only and FCEB only Cases.

The Mixed Case assumes that the AMF facility will be a dedicated BEB facility and that the GMF will be a dedicated hydrogen facility with eight BEB plugs as planned in the 2024 facility upgrades.

The pace of vehicle transition and infrastructure improvements at the two facilities will be similar to the pace as planned for the AMF under the BEB Case and for the GMF under the FCEB Case. The current assumption is that up to 46 BEB vehicles will be operating from the AMF in 2040 and 44 charging dispensers will be available for those vehicles. In addition, up to 71 hydrogen vehicles will be operating at the GMF.

On-route charging infrastructure will ramp up at Rubey Park as the BEB share increases and route coverage includes longer-range blocks. Rubey Park currently has one on-route charger and capacity for two additional chargers that are assumed to be added in 2030 and 2036 for the Mixed 2040 Case. In this analysis the costs assumed for the additional chargers account only for equipment and installation and it was assumed that no additional electrical upgrades will be needed. A summary of the financial model findings for the Mixed Case, assuming full adoption of ZEBs by 2040, is listed below. Total nominal costs for the analysis period 2023 through 2050 are shown in Table 18. Total costs in the Mixed Case are 18% or $106M more compared to the Base Case. There are notable savings in fleet maintenance and some savings in fleet refurbishment costs in the Mixed Case. Higher costs of acquisition, higher fuel costs and additional improvements to infrastructure make the Mixed Case total costs higher than the Base Case total costs.

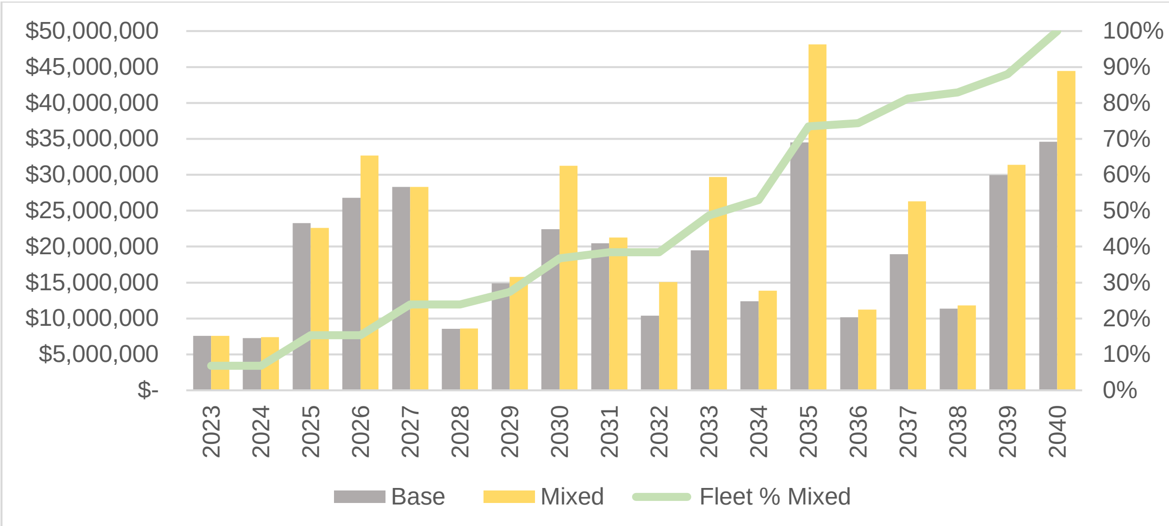
Table 18: Mixed Case Full Adoption by 2040 Total Cost of Ownership (analysis period 2023-2050)

	Accelerated Timeline - 2040 Scenario			
Cost Components	**Base Case**	**Mixed Case**	**Savings**	**Cost difference (Mixed - Base)**
Fleet Acquisition	$ 270,473,175	$ 363,816,837	$ (93,343,662)	$ 93,343,662
Fleet Refurbishment	$ 16,250,101	$ 14,606,232	$ 1,643,869	$ (1,643,869)
Fleet Maintenance	$ 207,577,553	$ 195,297,206	$ 12,280,347	$ (12,280,347)
Fuel/Electricity	$ 72,778,743	$ 76,926,847	$ (4,148,104)	$ 4,148,104
Infrastructure	$ 22,888,623	$ 45,202,703	$ (22,314,080)	$ 22,314,080
Total	*$ 589,968,196*	*$ 695,849,825*	*$ (105,881,629)*	$ 105,881,629

In the Base Case, 46% of the costs are related to fleet acquisition. In the Mixed Case, 52% of the total costs are related to acquisition – a 35% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while they are only 28% of the total costs in Mixed Case – a 6% decrease when compared to the Base Case. In the Base Case, 12.3% of the costs are applied to fuel while in the FCEB Case, 11.1% of the costs are applied to hydrogen. While the proportion of fuel is less of the overall cost in the Mixed Case, the cost in dollars is $4.2M greater. In the Base Case 2.8% of the total costs are related to refurbishment costs; In the Mixed Case only 2.1% of total costs are related to refurbishment costs – a 10% decrease when compared to the Base Case. In the Base Case 3.9% of the total costs are related to infrastructure while they are 6.5% of total costs in the Mixed Case – a 97% increase when compared to the Base Case.

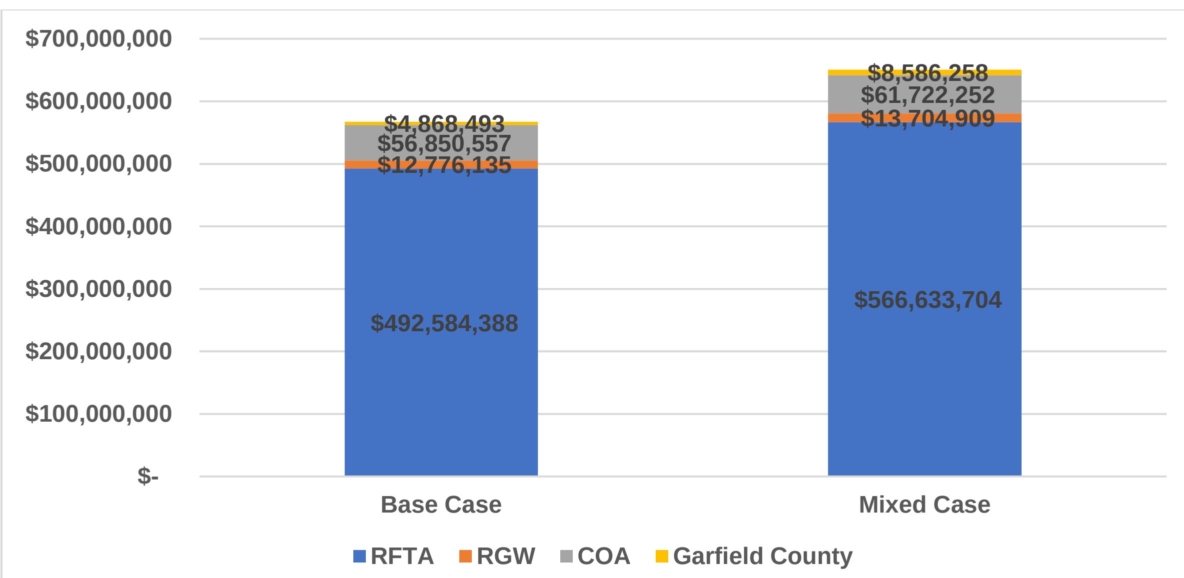
Annual cost comparisons between the Base Case and the Mixed Case are shown in Figure 40. Annual costs for both cases are similar through 2024, as new BEBs and FCEBs are procured and the fleet percentage that is ZEBs increases, costs for the Mixed Case become higher than the Base Case. Spikes in annual costs in the Base and the Mixed Case are correlated to new bus procurement or infrastructure updates to facilities. As shown in the figure, a 100% zero emission bus fleet is achieved in the year 2040 with accelerated transition between 2032 and 2035.

Figure 40: Annual Cost Comparison Base Case vs Mixed Case Full Adoption by 2040



Total costs of ownership by RFTA, City of Glenwood Springs, COA and Garfield County are shown in Figure 41. As shown in the figure, most costs are associated with RFTA, followed by COA, Glenwood Springs, and Garfield County. The costs have increased proportionally for each ownership entity and the total cost is 15% or $84.8M more than base case. Even though there are savings in maintenance costs and refurbishments costs, higher costs of acquisition, and fuel make the Mixed Case costs go up significantly compared to the Base Case for all entities. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 41: Mixed Case Full Adoption by 2040 Total Cost of Ownership by Entity (excluding infrastructure costs)



8.2.3 Full Adoption by 2050

The second set of ZEB cases is grouped under a timeline achieving 100% ZEB by 2050. This timeline allows RFTA to achieve its Climate Action Plan goal and the State's goal to transition the state transit fleet to 100% ZEB by 2050.

Under this timeline major infrastructure improvements will occur later than in the 2040 timeline and that will allow a longer period for fundraising, planning, design, and implementation. An additional advantage of the 2050 timeline is that some ZE bus types that have limited availability on the market now, for example, cutaways with larger battery size and extended range, or 45-ft buses with on-route charging capability, will have more available options in later years as the technologies mature.

One disadvantage of the longer timeline is that the later adoption of ZEVs compared to the accelerated timeline will generate lower GHG emission reductions over the analysis timeline. Additionally, fewer funding sources might be available as the ZEV technologies become mainstream.

8.2.3.1 BEB Case Full Adoption by 2050

Inputs for the BEB Case under the 2050 timeline for all major assumptions not related to the pace of ZEV fleet adoption mirror the BEB Case under the accelerated timeline. The assumptions related to the pace of ZEV adoption are the fleet mix and fleet acquisition schedule by year. While the input assumptions let us say maintenance costs for 40-ft BEB vehicles owned by RFTA are constant between the two timelines, the resulting costs for most categories will differ because the annual occurrences of those costs have a shifted timeline.

On-route charging infrastructure will ramp up at the on-route charging locations as the BEB share increases and route coverage includes longer-range blocks. Rubey Park currently has one on-route charger and capacity for two additional chargers that are assumed to be added in 2035 and 2041 for the BEB 2050 Case. In this analysis the costs assumed for the additional chargers account only for equipment and installation and it was assumed that no additional electrical upgrades will be needed. At West Glenwood Springs Park and Ride, new charging infrastructure is planned for 2039 that will include two chargers. With the expected electrical upgrades and equipment installation in 2048, an additional charger will be installed.

Total nominal costs for the analysis period 2023 through 2050 are shown in Table 19 for the BEB Case assuming full ZEB adoption by 2050. Costs are separated by capital costs and operating costs. Capital costs are those for fleet acquisition, refurbishment, and any infrastructure related costs. Operating costs are fuel/electricity costs and fleet maintenance costs. Total costs in the BEB Case are 11.7% or $69.2M more compared to the Base Case. There are notable savings in fleet maintenance and fuel costs in the BEB Case. Higher costs of acquisition and additional improvements to infrastructure make the BEB Case total costs higher than the Base Case.

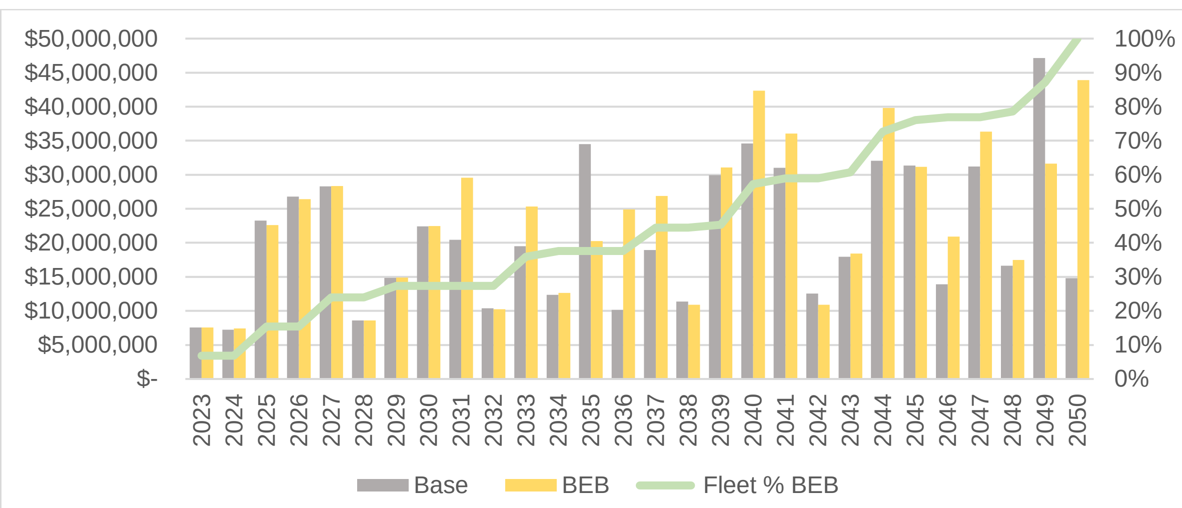
In the Base Case, 46% of the costs are related to fleet acquisition and in the BEB Case, 50% of the total costs are related to acquisition – a 21% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while they are only 30% of the total costs in the BEB Case – a 3.4% decrease when compared to the Base Case. In the Base Case, 12.3% of the total costs are related to fuel costs while in the BEB Case 9.6% of the total costs are related to electricity – a 12.8% decrease compared to the Base Case. In the Base Case, 2.8% of the total costs are related to refurbishments. In the BEB Case, 2.5% of total costs are related to refurbishments – a 1.5% decrease when compared to the Base Case. In the Base Case 3.9% of the total costs are related to Infrastructure while 8% of total costs in BEB Case are related to Infrastructure – a 130% increase when compared to the Base Case.

Table 19: BEB 2050 Case Full Adoption by 2050 Total Cost of Ownership (analysis period 2023-2050)

	BEB 2050 Scenario			
Cost Components	**Base Case**	**BEB Case**	**Savings**	**Cost difference (BEB - Base)**
Fleet Acquisition	$ 270,473,175	$ 325,947,315	$ (55,474,140)	$ 55,474,140
Fleet Refurbishment	$ 16,250,101	$ 16,488,465	$ (238,364)	$ 238,364
Fleet Maintenance	$ 207,577,553	$ 200,523,242	$ 7,054,311	$ (7,054,311)
Fuel/Electricity	$ 72,778,743	$ 63,464,796	$ 9,313,947	$ (9,313,947)
Infrastructure	$ 22,888,623	$ 52,685,565	$ (29,796,942)	$ 29,796,942
Total	*$ 589,968,196*	*$ 659,109,383*	*$ (69,141,187)*	$ 69,141,187

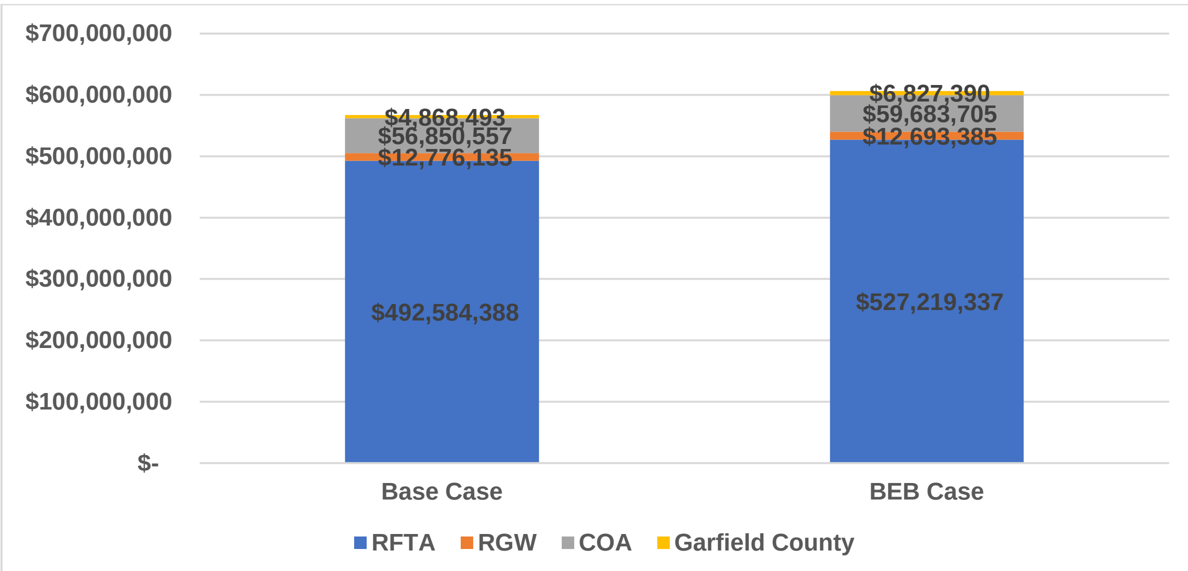
Annual cost comparisons between the Base Case and the BEB Case are shown in Figure 42. Annual costs for both cases are similar through 2030. As new BEBs are procured and the BEB fleet percentage increases, annual BEB costs increase over the Base Case. Spikes in annual costs in the BEB Case are correlated to new bus procurement or infrastructure updates to facilities. The Base Case experiences similar spikes in 2035 and 2049. As shown in the figure, a 100% BEB fleet is achieved in the year 2050.

Figure 42: Annual Cost Comparison Base Case vs BEB Case Full Adoption by 2050



Total cost of ownership by RFTA, City Glenwood Springs, COA, and Garfield County are shown in Figure 43. Most costs are assigned to RFTA, followed by COA, Glenwood, and then Garfield County. The costs have increased proportionally for each ownership entity compared to the Base Case, except for the City of Glenwood Springs for which costs have negligible differences. Even though there are savings in maintenance costs and fuel costs, the higher costs for acquisition make the BEB Case costs increase compared to the Base Case. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 43: BEB Case Full Adoption by 2050 Total Cost of Ownership by Entity (excluding infrastructure costs)



8.2.3.2 FCEB Case Full Adoption by 2050

Inputs for the FCEB Case under the 2050 timeline for all major assumptions not related to the pace of ZEV fleet adoption match the FCEB Case under the accelerated timeline 2040. The assumptions related to the pace of ZEV adoption are the fleet mix and fleet acquisition schedule by year.

Total nominal costs for the analysis period 2023 through 2050 are shown in Table 14 for the FCEB Case assuming full ZEB adoption by 2050. Total costs in the FCEB Case are 14% or $80.6M more compared to the Base Case total costs. There are notable savings in fleet maintenance and in the fleet refurbishment costs in the FCEB Case. Higher costs of acquisition, higher fuel costs, and additional improvements to infrastructure make the FCEB total costs higher than Base Case.

In the Base Case, 46% of the costs are related to fleet acquisition. In the FCEB Case, 49% of the total costs are related to acquisition – a 23% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while they are only 30% of the total costs in the FCEB Case – a 3% decrease when compared to the Base Case. In the Base Case, 12.3% of the total costs are related to fuel costs and in the FCEB Case 13.3% of the total costs are related to hydrogen – a 22.1% increase compared to the Base Case. In the Base Case 2.8% of the total costs are related to refurbishment and in the FCEB Case only 1.8% of total costs are related to refurbishment – a 27% decrease when compared to the Base Case. In the Base Case, 3.9% of the total costs are related to infrastructure while they make up 5.4% of total costs in FCEB Case – a 58% increase when compared to the Base Case.

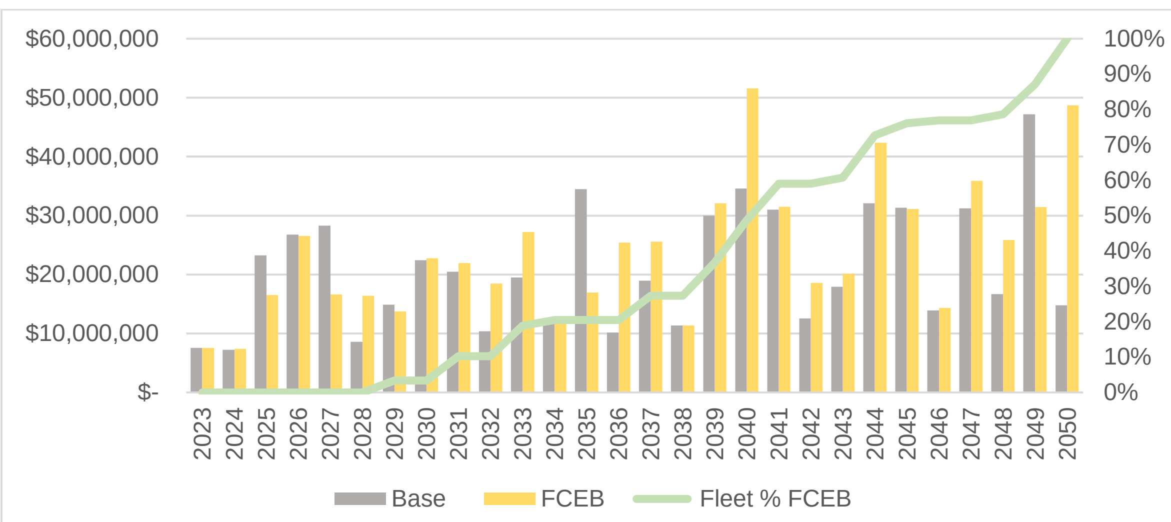
Table 20: FCEB Case Full Adoption by 2050 Total Cost of Ownership (analysis period 2023-2050)

	FCEB 2050 Scenario			
Cost Components	**Base Case**	**FCEB Case**	**Savings**	**Cost difference (FCEB - Base)**
Fleet Acquisition	$ 270,473,175	$ 331,607,322	$ (61,134,147)	$ 61,134,147
Fleet Refurbishment	$ 16,250,101	$ 11,803,705	$ 4,446,396	$ (4,446,396)
Fleet Maintenance	$ 207,577,553	$ 202,062,242	$ 5,515,311	$ (5,515,311)
Fuel/Electricity	$ 72,778,743	$ 88,865,458	$ (16,086,715)	$ 16,086,715
Infrastructure	$ 22,888,623	$ 36,221,516	$ (13,332,893)	$ 13,332,893
Total	*$ 589,968,196*	*$ 670,560,244*	*$ (80,592,049)*	$ 80,592,049

Annual cost comparisons between the Base Case and the FCEB Case are shown in

Figure 44. Annual costs for both cases are similar through 2024. As new FCEBs are procured and the FCEB fleet percentage increases, costs for the FCEB Case becomes higher than the Base Case. Spikes in annual costs in the Base and FCEB Cases are correlated to new bus procurements or infrastructure updates to facilities. As shown in the figure, a 100% FCEB fleet is achieved in the year 2050.

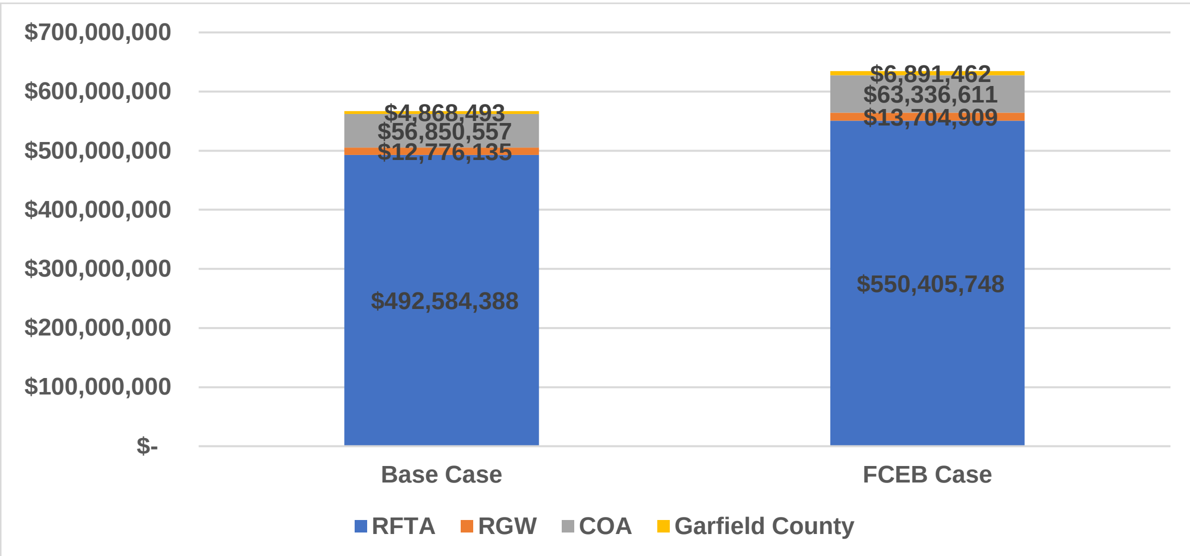
Figure 44: Annual Cost Comparison Base Case vs FCEB Case Full Adoption by 205



Total cost of ownership by RFTA, City of Glenwood Springs, COA and Garfield County are shown in Figure 45. Most costs are assigned to RFTA, followed by COA, Glenwood, and then Garfield County. The costs have increased proportionally for each ownership entity when compared to the Base Case and the total cost is 12% or $67.3M more than the Base Case. Even though there are savings on maintenance and refurbishments costs, higher costs for acquisition, fuel, and infrastructure improvements make the FCEB

Case costs increase significantly compared to the Base Case for all entities. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 45: FCEB Case Full Adoption by 2050 Total Cost of Ownership by Entity (excluding infrastructure costs)



8.2.3.3 Mixed Case Full Adoption by 2050

Inputs for the Mixed Case under the 2050 timeline for all major assumptions not related to the pace of ZEV fleet adoption match the Mixed Case under the accelerated timeline 2040. The assumptions related to the pace of ZEV adoption are the fleet mix and fleet acquisition schedule by year.

On-route charging infrastructure will ramp up at Rubey Park as the BEB share increases and route coverage includes longer-range blocks. Rubey Park currently has one on-route charger and capacity for two additional chargers that are assumed to be added in 2035 and 2041 for the Mixed 2050 Case. In this analysis the costs assumed for the additional chargers account only for equipment and installation and it was assumed that no additional electrical upgrades will be needed.

Total nominal costs for the analysis period 2023 through 2050 are shown in Table 15 for the Mixed Case assuming full ZEB adoption by 2050. Total costs in the Mixed Case are 14.5% or $85.7M more compared to the Base Case. There are notable savings in fleet maintenance and some savings in fleet refurbishment costs in the Mixed Case. Higher costs of acquisition, higher fuel costs, and additional improvements to infrastructure make the Mixed Case total cost higher than the Base Case.

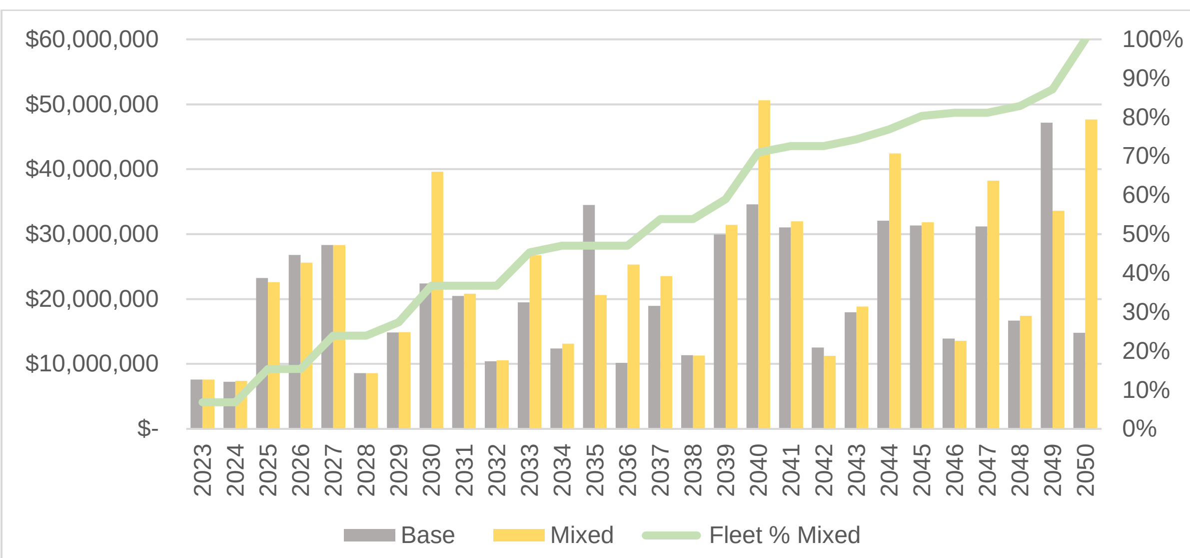
In the Base Case, 46% of the costs are related to fleet acquisition while in the Mixed Case, 51% of the total costs are related to acquisition – a 28% increase when compared to the Base Case. In the Base Case, 35% of the total costs are related to maintenance while they make up 30% of the total costs in the Mixed Case – a 4% decrease when compared to the Base Case. The Base Case applies 12.3% of its cost to fuel while the Mixed Case applies 11.3% of its cost to electricity/hydrogen. The Mixed Case spends $3.4M more in total due to the higher costs of hydrogen fuel – a 4.6% increase compared to the Base Case. In the Base Case, 2.8% of the total costs are related to refurbishment costs while in the Mixed Case 2.2% of total costs are related to refurbishment costs – a 6.5% decrease when compared to the Base Case. In the Base Case, 3.9% of the total costs are related to infrastructure while they are 5.9% of total costs in the Mixed Case – a 74% increase when compared to the Base Case.

Table 21: Mixed Case Full Adoption by 2050 Total Cost of Ownership (analysis period 2023-2050)

	Mixed 2050 Scenario			
Cost Components	**Base Case**	**Mixed Case**	**Savings**	**Cost difference (Mixed - Base)**
Fleet Acquisition	$ 270,473,175	$ 345,376,664	$ (74,903,489)	$ 74,903,489
Fleet Refurbishment	$ 16,250,101	$ 15,198,571	$ 1,051,530	$ (1,051,530)
Fleet Maintenance	$ 207,577,553	$ 199,127,533	$ 8,450,020	$ (8,450,020)
Fuel/Electricity	$ 72,778,743	$ 76,126,955	$ (3,348,212)	$ 3,348,212
Infrastructure	$ 22,888,623	$ 39,819,672	$ (16,931,049)	$ 16,931,049
Total	*$ 589,968,196*	*$ 675,649,395*	*$ (85,681,200)*	$ 85,681,200

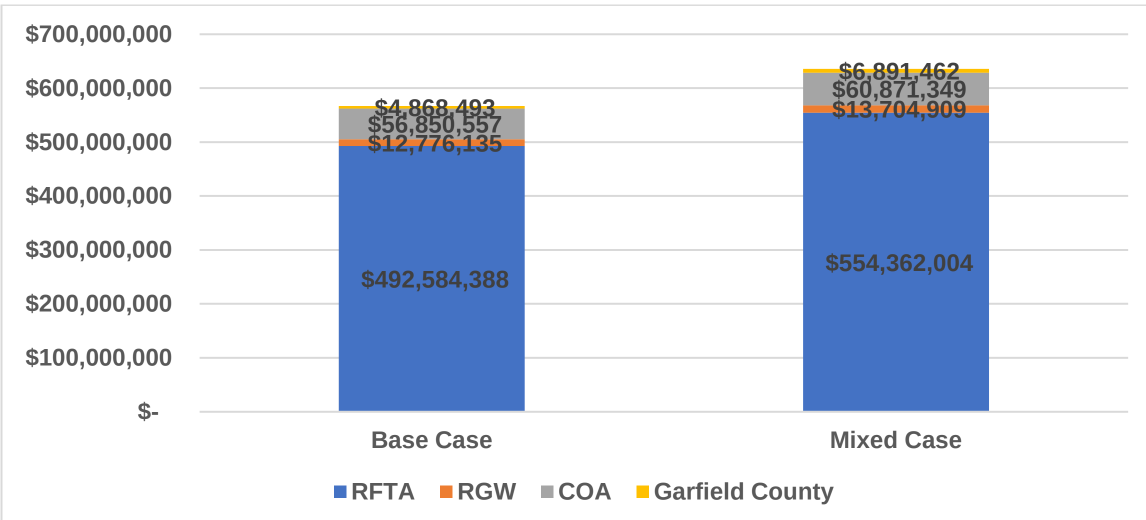
Annual cost comparisons between the Base Case and the Mixed Case are shown in Figure 46. Annual costs for both cases are similar through 2029. As new BEBs and FCEBs are procured and the fleet percentage for ZEBs increases, costs for the Mixed Case become larger than the Base Case. Spikes in annual costs in the Base and the Mixed Case are correlated to new bus procurements or infrastructure updates to facilities. As shown in the figure, a 100% zero emission bus fleet is achieved in the year 2050.

Figure 46: Annual Cost Comparison Base vs Mixed Case Full Adoption by 2050



Total cost of ownership by RFTA, Glenwood Springs, COA and Garfield County are shown in Figure 47. Most costs are assigned to RFTA, followed by COA, Glenwood, and then Garfield County. The costs have increased proportionally for each ownership entity and the total cost is 12% or $68.9M more than the Base Case. Even though there are savings in maintenance costs and refurbishment costs, higher costs for acquisition, fuel and infrastructure improvements make the Mixed Case costs increase compared to the Base Case for all entities. Note that these costs exclude infrastructure costs since RFTA, and its regional partners will need to establish how to share the infrastructure costs for the ZEB transition.

Figure 47: Mixed Case Full Adoption by 2050 Total Cost of Ownership by Entity (excluding infrastructure costs)



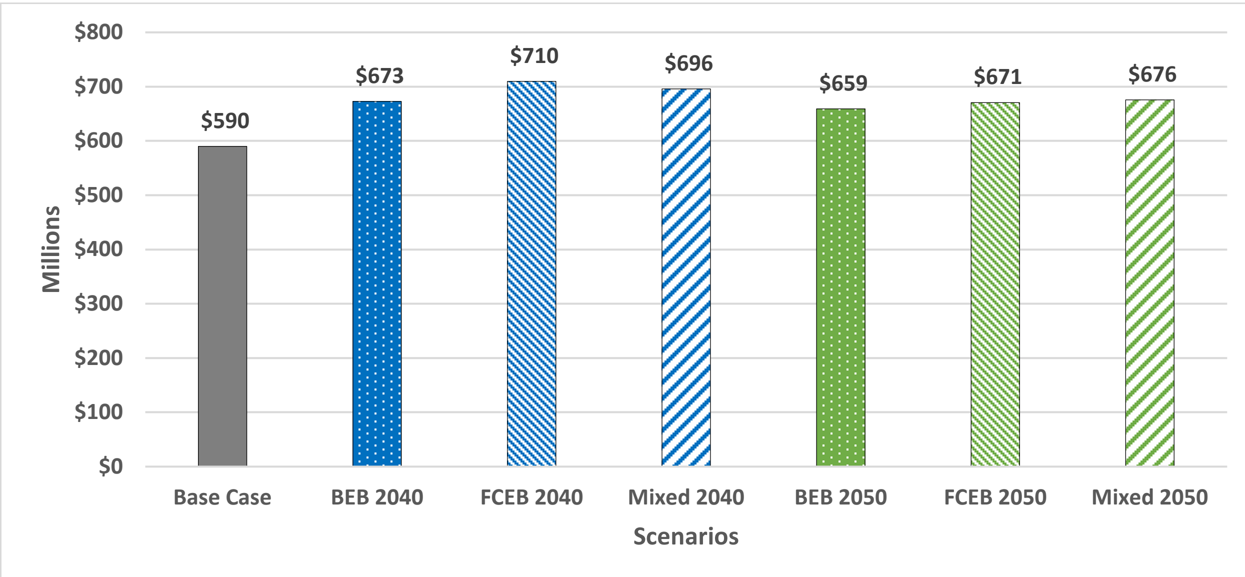
8.2.4 Comparison of all Revenue Fleet Cases

The financial ZEB model was developed to provide comparison against a Base Case (or business as usual with fossil fuel buses) and the six cases considered.

Figure 48 shows that comparison, the 2040 timeline is shown in blue, and the 2050 timeline is shown in green, the pattern fill represents different fuel type cases BEB, FCEB and Mixed.

Implementing the ZEB transition under the accelerated timeline by 2040 will lead to higher costs when compared to the 2050 timeline due to earlier procurement of vehicles, overall, more ZEB vehicles procured during the analysis period, as well as more occurrences of charging infrastructure replacements within the analysis period (scheduled every 20 years). While the 2040 timeline has higher total costs over the analysis period, it also has higher GHG emission reduction impacts. Challenges with the accelerated timeline will include the condensed timeline for infrastructure improvements (planning, design, implementation), as well as purchasing vehicles and systems that are still maturing and have not reached high share of market penetration. The higher costs under the accelerated timeline can be partially or fully mitigated by pursuing federal and state grants. The availability of those grants will diminish over time and some funding sources might not be available for the 2050 adoption timeline. From all six cases, the lowest total cost closest to the baseline case were for the 2050 Timeline BEB Case followed by the 2050 Timeline FCEB Case and third was the 2040 timeline BEB Case.

Figure 48. Total Costs Comparison of Full Adoption by 2040 and 2050 for all Fuel Cases



More detailed comparisons by timeline listing the trade-offs between the Base, BEB, FCEB and Mixed Cases by cost component and with details by ownership are in the following tables and graphics.

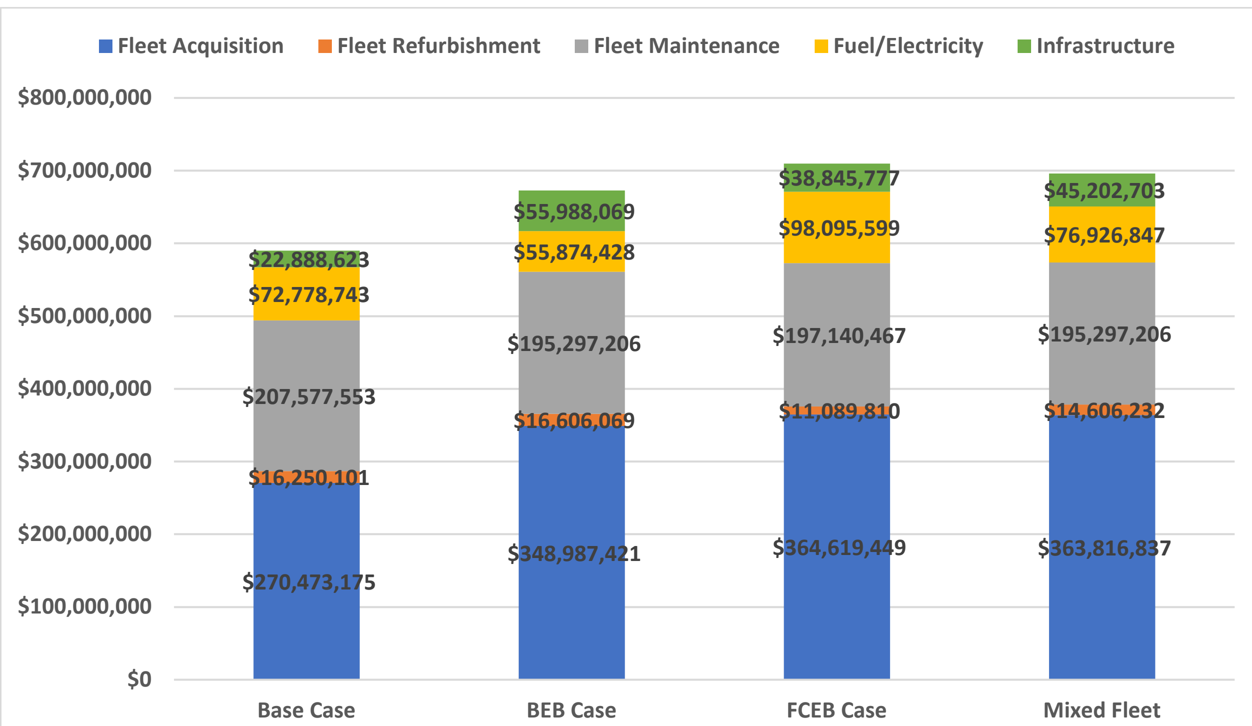
Total nominal costs for the accelerated timeline 2040 group are compared to the Base Case in Table 22. The analysis timeline is 2023 through 2050. Total costs incorporate both capital costs (orange) and operating costs (blue) rows in the table. All the alternate fuel ZEB cases cost more than the Base Case in terms of total costs. All ZEB cases have savings in maintenance costs and some savings in refurbishment costs. Only the BEB Case has savings in fuel costs. All ZEB cases cost more in fleet acquisition and infrastructure improvements, given the scale of these additional costs, total costs for all ZEB cases are higher than the Base Case. The BEB Case total costs are 14% higher than the Base Case, the FCEB and Mixed Case are 20.3% and 17.9% higher than the Base Case.

Table 22: Full Adoption by 2040 - Cost Comparison of all Cases

	Accelerated Timeline - 2040 Scenario						
	Total Costs				Savings (ZEV - Base case)		
Cost Components	Base Case	BEB Case	FCEB Case	Mixed Fleet	BEB Case	FCEB Case	Mixed Fleet
Fleet Acquisition	$ 270,473,175	$ 348,987,421	$ 364,619,449	$ 363,816,837	$ (78,514,246)	$ (94,146,274)	$ (93,343,662)
Fleet Refurbishment	$ 16,250,101	$ 16,606,069	$ 11,089,810	$ 14,606,232	$ (355,967)	$ 5,160,291	$ 1,643,869
Fleet Maintenance	$ 207,577,553	$ 195,297,206	$ 197,140,467	$ 195,297,206	$ 12,280,347	$ 10,437,086	$ 12,280,347
Fuel/Electricity	$ 72,778,743	$ 55,874,428	$ 98,095,599	$ 76,926,847	$ 16,904,316	$ (25,316,856)	$ (4,148,104)
Infrastructure	$ 22,888,623	$ 55,988,069	$ 38,845,777	$ 45,202,703	$ (33,099,446)	$ (15,957,154)	$ (22,314,080)
Total	*$ 589,968,196*	*$ 672,753,192*	*$ 709,791,102*	*$ 695,849,825*	*$ (82,784,997)*	*$ (119,822,907)*	*$ (105,881,629)*
% Difference vs Base		*14.0%*	*20.3%*	*17.9%*			

Total costs of ownership by cost category are shown in the stacked bar chart in Figure 49. Fleet acquisition costs are higher in all ZEB cases compared to the Base Case. FCEB and Mixed fleet acquisition costs are similar and are higher than BEB costs. Fleet maintenance costs are lower in all ZEB cases when compared to the Base Case. The BEB and Mixed Cases have the lowest maintenance costs followed by FCEB Case. Fuel costs in the BEB Case are lower than the Base Case but fuel costs are higher in both FCEB and Mixed Cases given the high cost of hydrogen fuel. Infrastructure costs are higher in all ZEB cases compared to the Base Case given the facility modifications with charger and electricity equipment as well as hydrogen fueling equipment costs.

Figure 49: Full Adoption by 2040 - Total Cost of Ownership Comparison



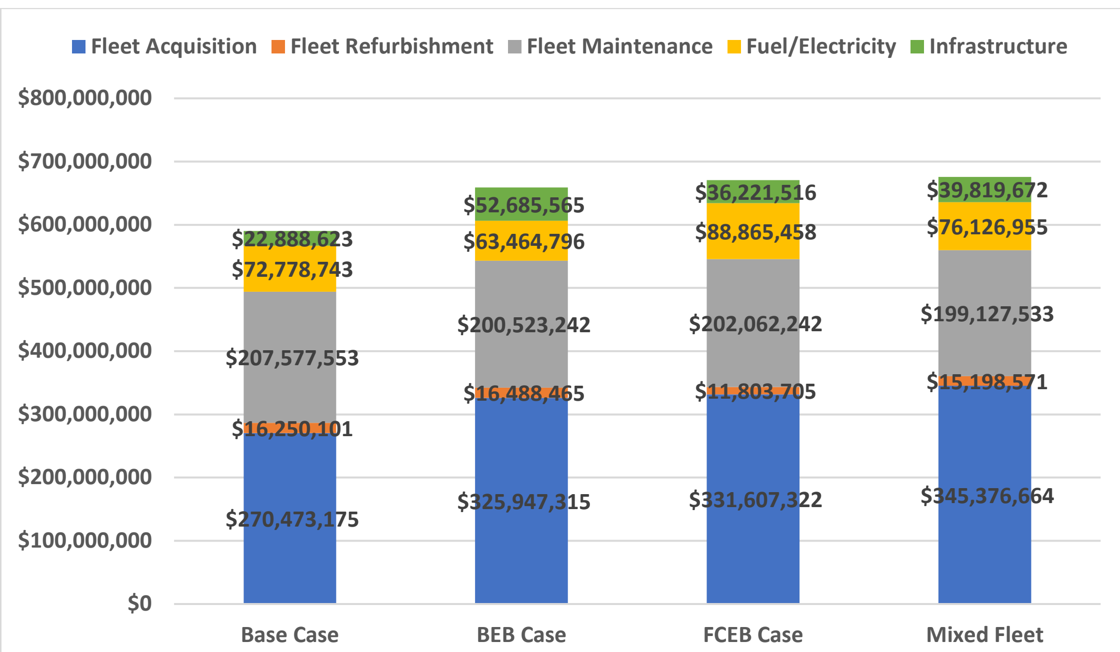
Total nominal costs for the BEB, FCEB and Mixed Cases, assuming Full Adoption by 2050, are compared to the Base Case in Table 23. The analysis timeline is 2023 through 2050. All the ZEB cases have higher total costs when compared to the Base Case. All ZEB cases have savings in maintenance costs and some savings in refurbishment costs. Only the BEB Case has savings in fuel costs. All ZEB Cases cost more in fleet acquisition and infrastructure improvements and given the scale of these additional costs, total costs for all cases are higher than the Base Case. The BEB Case total costs are 11.7% higher than the Base Case, the FCEB and Mixed Cases are 13.7% and 14.5% higher than the Base Case.

Table 23: Full Adoption by 2050 - Cost Comparison of all Cases

	2050 Scenario						
	Total Costs				Savings (ZEV - Base case)		
Cost Components	Base Case	BEB Case	FCEB Case	Mixed Fleet	BEB Case	FCEB Case	Mixed Fleet
Fleet Acquisition	$ 270,473,175	$ 325,947,315	$ 331,607,322	$ 345,376,664	$ (55,474,140)	$ (61,134,147)	$ (74,903,489)
Fleet Refurbishment	$ 16,250,101	$ 16,488,465	$ 11,803,705	$ 15,198,571	$ (238,364)	$ 4,446,396	$ 1,051,530
Fleet Maintenance	$ 207,577,553	$ 200,523,242	$ 202,062,242	$ 199,127,533	$ 7,054,311	$ 5,515,311	$ 8,450,020
Fuel/Electricity	$ 72,778,743	$ 63,464,796	$ 88,865,458	$ 76,126,955	$ 9,313,947	$ (16,086,715)	$ (3,348,212)
Infrastructure	$ 22,888,623	$ 52,685,565	$ 36,221,516	$ 39,819,672	$ (29,796,942)	$ (13,332,893)	$ (16,931,049)
Total	*$ 589,968,196*	*$ 659,109,383*	*$ 670,560,244*	*$ 675,649,395*	*$ (69,141,187)*	*$ (80,592,049)*	*$ (85,681,200)*
% difference vs Base		*11.7%*	*13.7%*	*14.5%*			

Total costs of ownership by cost category are shown in the stacked bar chart in Figure 50. Fleet acquisition costs are higher in all ZEB cases compared to the Base Case.

Figure 50: Full Adoption by 2050 - Total Cost of Ownership Comparison



FCEB and Mixed fleet acquisition costs are similar and are higher than BEB costs. Fleet maintenance costs are lower in all ZEB cases when compared to the Base Case. BEB and Mixed Cases have the lowest maintenance costs followed by the FCEB Case. Fuel costs in the BEB Case are lower than the Base Case but fuel costs are higher in both FCEB and Mixed fleet cases given the high cost of hydrogen fuel. Infrastructure costs are higher in all ZEB cases compared to the Base Case given the facility modifications with charger and electricity equipment as well as hydrogen fueling equipment costs.

8.3 NON- REVENUE SERVICE VEHICLES FINANCIAL ANALYSIS

This section describes the inputs, assumptions, and results from the financial analysis of RFTA's service fleet alternatives. Similarly to the revenue fleet analysis a Base Case was developed reflecting business as usual operations and current fleet replacement plans assuming all vehicles are replaced in in kind. In addition, ZEV-only and FCEV-only cases were developed with 2050 timelines for full transition of the service fleet.

The process for financial evaluation of the service vehicles fleet closely mirrors the process used for the revenue fleet. Some differences are:

- The assumed vehicle useful life for service vehicles was 10 years.
- For service vehicles (fossil fuel, BE, and FCE) no refurbishment costs due to their shorter useful life.

More details about the assumptions and the individual input values for the Base Case and the ZEV Cases can be found in Appendix C: Financial Modeling Inputs and Assumptions.

8.3.1 Fleet Acquisition

Purchase prices for fossil fuel service vehicles by vehicle class and type were derived based on RFTA's inventory data for recent purchases and were converted to 2023 dollars. The purchase costs for BEVs and FCEVs were based on industry research and selecting a close match in vehicle class and Gross Vehicle Weight Rating (GVWR) for each service vehicle type and service function. Some of RFTA's service vehicles, for example, medium sized pickup trucks like a Ford F-250, do not have many close in size and specifications commercially available ZEV options currently on the market. The cost for those vehicles were developed based on the costs for the fossil fuel vehicles of the same size and the expected price differential to account for a fossil fuel to ZEV vehicle price ratio based on guidance in the U.S. Department of Energy (DOE) published in the "2022 Incremental Purchase Cost Methodology and Results for Clean Vehicles" report.

For future vehicle costs 2023-2050, Stantec's team applied a trend for the cost projection of all vehicles based on fuel type and corresponding market trends and experts' predictions. More details about the assumptions and the individual input values for the ZEV Cases can be found in Appendix C: Financial Modeling Inputs and Assumptions.

8.3.2 Infrastructure and Facility Modifications

Service vehicle transition is assumed to piggy-back on the infrastructure improvements carried out to accommodate the revenue fleet conversion for ZEV. In this section, only the incremental costs for infrastructure equipment installation (chargers and hydrogen fueling dispensers) are included. The assumption is that the civil and electrical improvements completed for the revenue fleet will include the needed capacity and backup power for adding fueling equipment and BEV chargers for the service fleet. The exact location and configuration for Level 2 and DC charging stations for the service fleet have not been determined as part of this effort. Hydrogen dispensers for the service fleet are planned at the same fueling islands that will be used by the revenue vehicles.

8.3.2.1 ZEV Case Charging Infrastructure

Under the 2050 Timeline ZEV Case, Level 2 chargers for the service fleet are assumed to be installed at both the AMF and GMF facilities. With the rate of ZEV service fleet adoption listed in Section 5.1, the current assumption is that up to nine active BE service vehicles will be operating from AMF out of those seven will be light duty (sedans, SUVs, vans) requiring Level 2 chargers, and two will be heavy duty one straight truck and one medium pickup requiring DC charging. Eight Level 2 chargers are proposed and two DC chargers. All chargers are assumed to be operational at the facility starting in 2031 and no phasing for their implementation was assumed.

At the GMF facility, the current assumption is that up to 28 active BE service vehicles will be operating at full transition and that up to 20 Level 2 chargers and 10 DC chargers will be available.

All service vehicles will charge at AMF and GMF and no BEV charging is considered at the remote sites that currently host some active service vehicles: CMF, GWS, Bunker.

8.3.2.2 Hydrogen Infrastructure for FCEBs

As part of the infrastructure costs for the FCEB infrastructure, single-hose H70 dispensers and H70 cryopumps were considered in addition to the H35 dispensers and cryopumps which will be installed for revenue buses at the AMF and GMF facilities. No incremental costs are considered for FCE infrastructure for the service fleet FCE service vehicle financial analysis.

8.3.2.3 Operating Costs

Operating costs include fuel costs for the service vehicles. Fuel costs for existing traditional fuel vehicles are estimates from 2024 RFTA budget costs and vary by fuel type (unleaded gasoline for service vehicles). For BE service vehicles the electricity costs vary by location AMF, GMF, and by utility provider Holly Cross, and City of Glenwood. While the current assumption is that most revenue fleet charging will be able to avoid charging at peak-hours, that will not be the case for BE service vehicles. The pattern of use for service vehicles is not scheduled and service vehicles can be needed with short notice. Charging of service vehicles will be needed after each trip to maximize the availability of service vehicles throughout the day.

The hydrogen costs per kilogram for FCE service vehicles as well as the future cost of electricity and trends for other fossil fuels were assumed to be the same as in the revenue fleet analysis.

8.3.2.4 Maintenance Costs

Maintenance costs per mile inclusive of labor and parts for scheduled and unscheduled maintenance are included in these costs. Maintenance costs vary by service vehicle type, and vehicle mileage was estimated from the 2022 Vehicle Maintenance data shared by RFTA. Maintenance costs exclude fuel costs. For BEVs and FCEVs, Stantec's assumption is that the maintenance costs will be 10% less than those for fossil-fuel service vehicles. This assumption has been validated by other transit agencies, since maintaining ZEV involves fewer mechanical components and fewer oils, lubricants, etc.

8.3.2.5 Fuel Efficiency

Fuel efficiency takes into consideration the energy consumption of each vehicle type on a per mile basis. It is represented as miles/gallon, miles/DGE, mi/kWh, or mi/kg based on fuel type. These estimates are calculated from the service fleet usage shared by RFTA. For BEVs and FCEVs efficiency estimates are derived from Stantec' market scan and supplemented with information published by the U.S. Department of Energy (DOE) in the "2022 Incremental Purchase Cost Methodology and Results for Clean Vehicles" report.

8.3.2.6 Vehicle Utilization

This refers to the average yearly mileage of the service vehicles. The level of utilization is based on the 2022 fleet mileage with details as provided by RFTA by vehicle number. The individual vehicle data was aggregated by function and vehicle type (for example Maintenance-Small-Pickup). For the ZEV Cases, annual total mileage is assumed to remain constant to help with comparison across different ZEV Cases for the service fleet and the Base Case (business as usual).

8.3.3 Base Case

The Base Case service fleet consists of 37 active vehicles, and it remains constant in size over time. The size of the fleet is based on the number of active vehicles as of September 2023.

This model is inclusive of all scheduled fleet replacements required during the 2050 analysis horizon. For example, an unleaded passenger van procured in 2013 with a 10-year useful life would be replaced in 2023.

8.3.4 BEV Case

The BEV Case for the service fleet foresees the transition to 100% BEV operations by 2050. The transition follows the service fleet replacement schedule presented previously in Section 6.1. In the BEV Case modeling, it was assumed that all 37 active service vehicles will be charged at AMF and GMF.

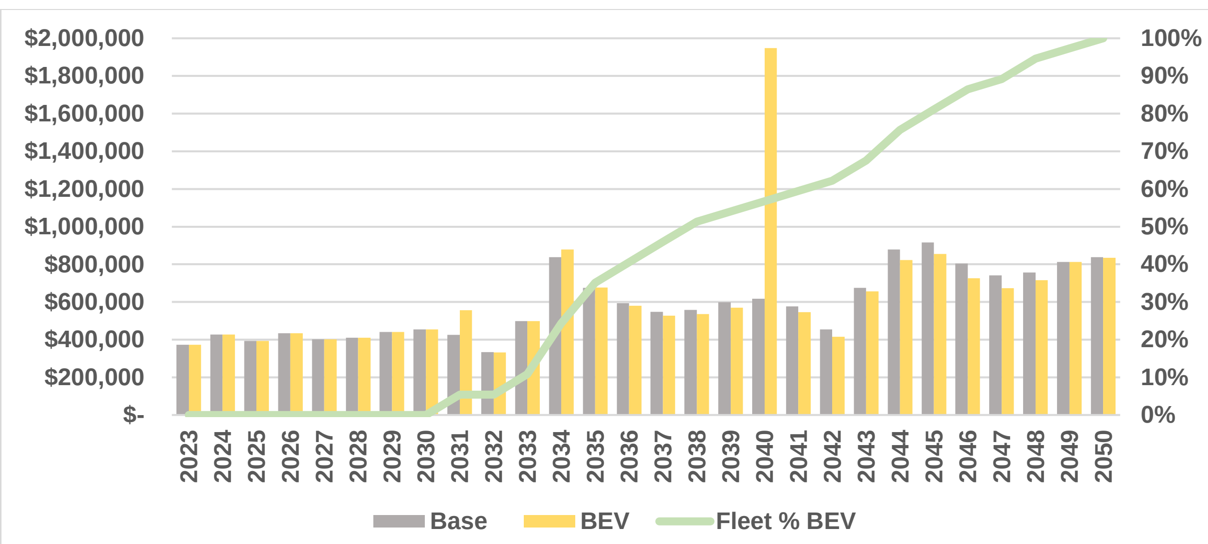
Total nominal costs for the analysis period 2023 through 2050 are shown in Table 24 for the BEV Service Fleet Case. Costs are separated by capital costs and operating costs. Capital costs are those for fleet acquisition and infrastructure-related costs. Operating costs are fuel/electricity costs and fleet maintenance costs. Total costs in the BEV Case are 6.2% or $1.02M more, compared to the Base Case. There are notable savings of $0.93M in fleet maintenance and fuel costs in the BEV Case. Overall higher costs of acquisition and additional improvements to infrastructure make the BEV Case total costs higher than the Base Case.

Table 24: Service Fleet BEV 2050 Case Total Cost of Ownership (period 2023-2050)

	Service Vehciles BEB 2050 Case			
Cost Components	**Base Case**	**BEV Case**	**Savings**	**Cost difference (BEV - Base)**
Fleet Acquisition	$ 7,854,299	$ 8,317,452	$ (463,153)	$ 463,153
Fleet Maintenance	$ 6,436,274	$ 6,188,518	$ 247,756	$ (247,756)
Fuel/Electricity	$ 2,180,192	$ 1,500,262	$ 679,930	$ (679,930)
Infrastructure	$ -	$ 1,488,315	$ (1,488,315)	$ 1,488,315
Total	*$ 16,470,765*	*$ 17,494,546*	*$ (1,023,781)*	$ 1,023,781

Annual cost comparisons between the Base Case and the BEV Case are shown in Figure 51. Annual costs for both cases are the same through 2030. As new service BEVs are procured and the BEV fleet percentage increases, annual BEV costs increase over the Base Case. Spikes in annual costs in the BEV Case are correlated to new vehicle procurement or infrastructure updates to facilities. The Base Case experiences similar spikes in 2035 and 2049. As shown in the figure, a 100% service BEV fleet is achieved in the year 2050.

Figure 51: Annual Cost Comparison Service Fleet Base Case vs BEV Case Full Adoption by 2050



8.3.5 FCEV Case

The FCEV Case for the service fleet foresees the transition to 100% FCEV operations by 2050. The transition follows the service fleet replacement schedule presented previously in Section 6.1. In the FCEB Case modeling, it was assumed that all 37 active service vehicles will be refueled at AMF and GMF.

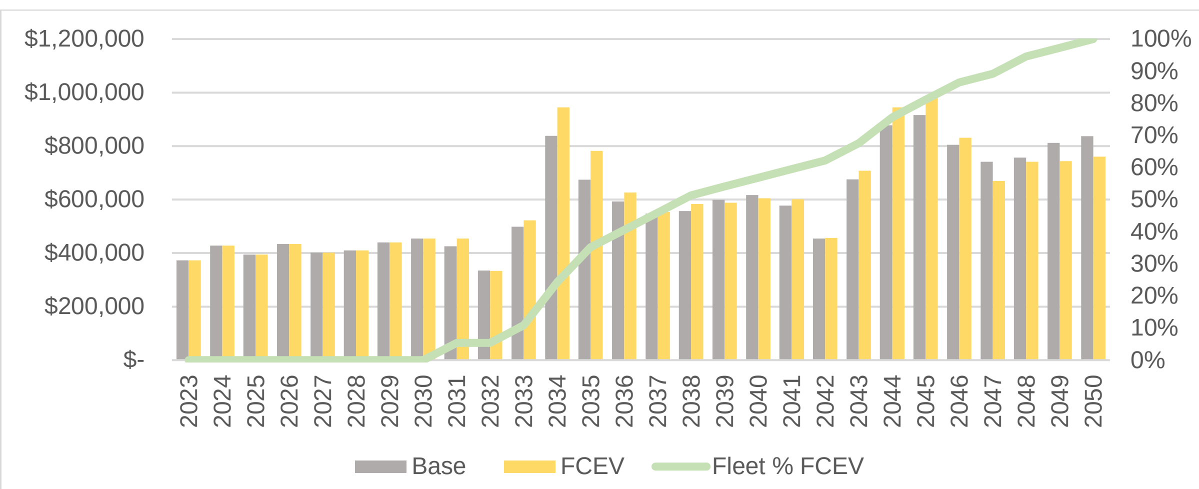
Total nominal costs for the analysis period 2023 through 2050 are shown in Table 25 for the FCEV Service Fleet Case. Costs are separated by capital costs and operating costs. Capital costs are those for fleet acquisition and infrastructure-related costs. Operating costs are fuel/electricity costs and fleet maintenance costs. Total costs in the FCEV Case are 1.8% or $0.3M more compared to the Base Case. There are notable savings of $0.79 in fleet maintenance and fuel costs in the FCEV Case. Overall higher costs of acquisition and additional improvements to infrastructure make the FCEV Case total costs higher than the Base Case.

Table 25: Service Fleet FCEV 2050 Case Total Cost of Ownership (period 2023-2050)

	Service Vehicles FCEV 2050 Case			
Cost Components	**Base Case**	**FCEV Case**	**Savings**	**Cost difference (FCEV - Base)**
Fleet Acquisition	$ 7,854,299	$ 8,946,086	$ (1,091,787)	$ 1,091,787
Fleet Maintenance	$ 6,436,274	$ 6,188,518	$ 247,756	$ (247,756)
Fuel/Electricity	$ 2,180,192	$ 1,636,063	$ 544,129	$ (544,129)
Infrastructure	$ -	$ -	$ -	$ -
Total	$ *16,470,765*	$ *16,770,667*	$ *(299,902)*	$ 299,902

Annual cost comparisons between the service fleet Base Case and the FCEV Case are shown in Figure 52. Annual costs for both cases are similar through 2032.

Figure 52: Annual Cost Comparison Service Fleet Base Case vs FCEV Case Full Adoption by 2050

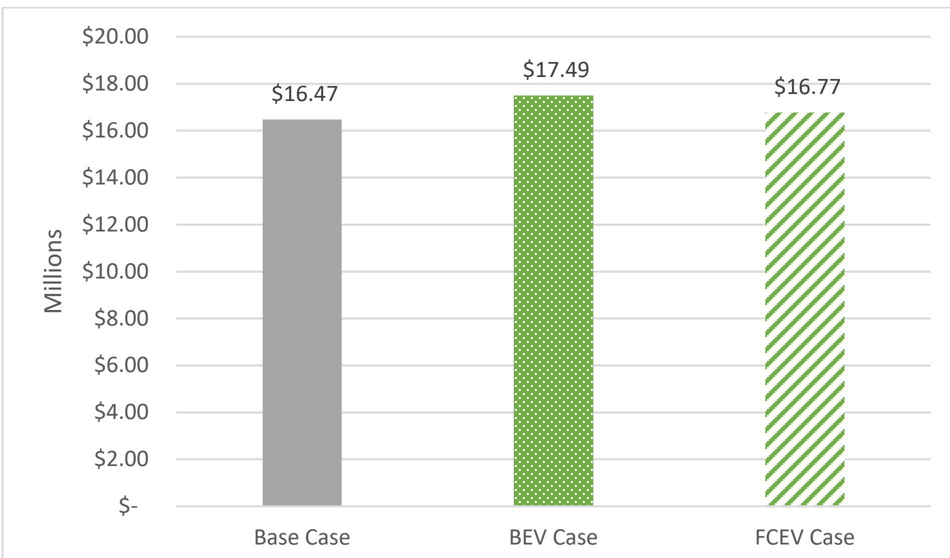


As new FCEVs are procured and the FCEV fleet percentage increases, annual FCEV costs increase over the Base Case. Spikes in annual costs in the FCEV Case are correlated to new vehicle procurement. The Base Case experiences similar spikes in 2034 and 2044/2045. As shown in Figure 52, a 100% service FCEV fleet is achieved in the year 2050.

8.3.6 Comparison of Service Fleet Cases

The financial model for the service fleet was developed to provide comparison against a Base Case (or business as usual with fossil fuel vehicles) and the two cases considered. Figure 53 shows that comparison and the pattern fill represents different fuel type cases BEV and FCEV. The FCEV case has the lowest total cost closest to the baseline case for the 2050 Timeline followed by the BEV Case. Most of the cost difference is due to the additional costs for infrastructure dedicated to service vehicle chargers (Level 2 and, DC chargers) in the BEV case. The FCEV case for service vehicles is assumed to piggy-back on the infrastructure build for the revenue vehicles and no service vehicle specific fueling infrastructure costs were assumed.

Figure 53. Service Fleet Base Case vs BEV and FCEV Cases Full Adoption by 2050



9.0 SELECTED ZEB FLEET CASE AND TIMELINE

Following the modeling and the financial evaluation of the proposed timelines and ZEV technology cases, Stantec met with RFTA staff for a final workshop on the feasibility of the different solutions. Based on the scoring developed with input from the final workshop, the preferred fleet concept that best fits the needs of RFTA is the Mixed 2050 Case.

9.1 WORKSHOP SCORING

In the final evaluation workshop with RFTA staff, each alternative was scored from 0 to 100. Modeling results and total cost of ownership were converted into the 0 to 100 scale, creating quantitative criteria. For qualitative criterion, Stantec outlined a list of relevant considerations (aka sub-criteria) and developed a scoring scale based on how critical the sub-criteria are, as follows:

- High - 15-point reduction
- Medium - 10-point reduction
- Low - 5-point reduction

Table 26 shows the resultant evaluation matrix. In the table, the weights established for each criterion as discussed in Section 6 of this report are listed in the yellow columns. The grey columns under each criterion reflect the scores for the six fleet alternatives developed by Stantec and refined based on RFTA staff comments from the February 2024 workshop.

The final score by alternative was calculated as the summation of the weight times and the scores from all criteria and is listed in the last column. The highest score in the Final Scores column indicates the most desirable alternative.

The highest score was 79 out of 100 for the Mixed 2050 Case, closely followed by the FCEB 2050 Case. In third and fourth place were the BEB 2050 case and the Mixed 2040 case, respectively.

Table 26. Evaluation Matrix Example

Alternatives	Scheduling		Cost of Ownership		Dispatch		Technology Availability/ OEM/ Procurement		Resiliency/ Redundancy		Fueling/ Charging Infrastructure		Training		Rider Experience		Environmental Considerations		Final Scores
	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Weight	Score	Score
BEB 2040	0.15	30	0.13	88	0.13	49	0.12	55	0.11	50	0.10	45	0.09	70	0.10	90	0.08	24	55
FCEB 2040	0.15	93	0.13	87	0.13	89	0.12	55	0.11	70	0.10	45	0.09	85	0.10	80	0.08	24	72
Mixed 2040	0.15	63	0.13	89	0.13	87	0.12	70	0.11	85	0.10	40	0.09	70	0.10	90	0.08	26	71
BEB 2050	0.15	64	0.13	95	0.13	66	0.12	70	0.11	50	0.10	55	0.09	70	0.10	100	0.08	11	66
FCEB 2050	0.15	98	0.13	98	0.13	93	0.12	70	0.11	70	0.10	50	0.09	85	0.10	100	0.08	9	78
Mixed 2050	0.15	78	0.13	92	0.13	93	0.12	85	0.11	85	0.10	55	0.09	80	0.10	100	0.08	27	79

9.2 RECOMMENDED FLEET

Following the modeling results, the pros and cons of each fleet alternative were compared across a range of topics as described in the evaluation criteria and sub-criteria. Stantec and RFTA staff evaluated the alternatives and chose a preferred fleet concept that best fits the needs of RFTA. It is noted that RFTA is already committed to diversifying its fleet and on a path to meet the goals of its “Destination 2040 Plan” with a desired fleet of 1/3 diesel, 1/3 CNG, and 1/3 ZEV. The Mixed 2050 Case supports that fleet diversification goal and aligns the RFTA’s Climate Action Plan goal of an 100% zero-emissions fleet. The Mixed 2050 Case allows the agency to future-proof its operations by investing into both FCEBs and BEBs, while considering the opportunities at the upgraded GMF and the constraints at AMF. The recommended ZE approach is summarized in Table 27 for GMF and in

Table 28 for AMF.

Table 27: Recommended fleet summary at GMF

Vehicle type	Tank size (hydrogen)	Active Vehicles Quantity	Notes
Hydrogen Motorcoach*	50 kg	27	• High capital investment for on-site hydrogen fueling station. • Higher purchase price for hydrogen vehicles. • Large footprint required for hydrogen refueling equipment. • Similar operations to CNG. • Fueling yard requires large footprint. • Hydrogen distribution availability (i.e., how many H2 providers are in the region?). • Fast refueling. • The modeling is reflecting a conservative tank size. • *No hydrogen motorcoach currently available that is Altoona tested.
40-ft hydrogen buses	50 kg	28	
30-ft hydrogen buses	37.5 kg	2	
Hydrogen Cutaways*	13.5 kg	8	• *No hydrogen cutaway currently available. • The modeling is trying to reflect a potential efficiency using the hydrogen vans as a reference. • Would require waiting for the technology to hit the market to transition the service to ZEV. • Can explore the feasibility of using hydrogen vans instead of cutaways.

Table 28: Recommended fleet summary at AMF

Vehicle type	Battery size	Active Vehicles Quantity	Notes
40-ft electric buses	525 kWh	**36**	• High capital investment for BEB chargers and associated electrical upgrades. • Higher purchase price for BEB vehicles. • Required collaboration with local utilities, and direct reliance on the utilities' level of green and renewable power.
35-ft electric buses	450 kWh	**5**	
Electric Cutaways	120 kWh	**11**	• Limited BEB cutaways currently available. • Would require waiting for the technology to hit the market to transition the service to ZEV.

9.3 SELECTED FLEET CASE PHASING AND IMPLEMENTATION

Table 29 provides an overview of the phasing plan for RFTA's ZEB rollout strategy. Note that expenses are in the year of cost incurred. See Section 5.0 for more details regarding the fleet replacement schedule.

The table lists the proposed phasing of infrastructure improvements, and vehicle procurement by year. The last three columns in the table reflect the capital, operating and total expenses for the operations of the full fleet by year as modelled in the financial analysis for the Mixed 2050 Case.

This plan is a living document that is intended to provide a practical framework for RFTA to deploy and transition to ZEBs. Similar to any other strategic plan, the implementation and transition plan should be revisited and adjusted in response to funding realities, changes in service delivery, and the needs of RFTA and its ridership, particularly given the long-term (~27 years) outlook.

Table 29: ZEB implementation phasing plan

Year	Construction – maintenance facility, hydrogen specific infrastructure	Fleet (purchases)		Capital Expenses (2023$)	Operating Expenses (2023$)	Total Expenses (2023$)
		Conventional	ZEV			
2023		2-Cutaway Unleaded		$762,000	$6,824,000	$7,585,000
2024		3-Cutaway Unleaded		$524,000	$6,886,000	$7,410,000
2025	AMF:	1-40ft Diesel 2-Cutaway Unleaded	10-40ft BEB	$15,784,000	$6,804,000	$22,588,000

	8-150 kWh chargers (previously committed and budgeted)	2-Cutaway CNG				
2026		1-35ft Diesel 13-45ft Diesel 1-Cutaway Unleaded		$18,285,000	$7,344,000	$25,628,000
2027	AMF: 4-150 kWh chargers		10-40ft BEB	$20,897,000	$7,431,000	$28,328,000
2028		2-Cutaway Unleaded		$989,000	$7,610,000	$8,599,000
2029	AMF: 8-150 kWh chargers	5-Cutaway Unleaded	4-35ft BEB	$7,126,000	$7,772,000	$14,898,000
2030	GMF: Construct and install hydrogen fueling equipment for high and low-pressure refueling (H35 and H70), including a generator, but minus the redundancy equipment. Installation of hydrogen gas detection system in maintenance bays		2-40ft FCEB 9-45ft FCEB	$33,083,000	$8,307,000	$41,390,000

2031		2-Cutaway Unleaded	8-40ft BEB	$12,241,000	$8,564,000	$20,805,000
2032					$8,829,000	$8,829,000
2033		2-Cutaway Unleaded	10-40ft FCEB	$17,864,000	$8,875,000	$26,739,000
2034		3-Cutaway Unleaded	2-30ft FCEB	$3,997,000	$9,151,000	$13,148,000
2035	AMF: 13-150 kWh chargers	5-45ft Diesel 2-Cutaway Unleaded 2-Cutaway CNG		$11,209,000	$9,435,000	$20,644,000
2036		15-40ft Diesel 1-Cutaway Unleaded		$15,623,000	$9,716,000	$25,339,000
2037			8-40ft BEB	$13,761,000	$9,786,000	$23,547,000
2038		2-Cutaway Unleaded		$1,215,000	$10,086,000	$11,301,000

2039			10-40ft BEB 1-40ft FCEB 5-Cutaway BEB	$21,045,000	$10,378,000	$31,423,000
2040	GMF: Addition of redundancy equipment (second compressor, evaporator, etc.) for the hydrogen fueling.		1-35ft BEB 13-45ft FCEB	$39,893,000	$10,732,000	$50,625,000
2041	AMF: 6-150 kWh chargers		10-40ft BEB 2-Cutaway FCEB	$21,406,000	$10,586,000	$31,992,000
2042				$366,000	$10,904,000	$11,270,000
2043			4-35ft BEB 1-Cutaway BEB 1-Cutaway FCEB	$7,600,000	$11,230,000	$18,829,000
2044			2-40ft FCEB 9-45ft FCEB 3-Cutaway BEB	$30,900,000	$11,550,000	$42,450,000
2045	AMF: 8-150 kWh chargers		8-40ft BEB 2-Cutaway BEB 2-Cutaway FCEB	$19,944,000	$11,888,000	$31,831,000
2046			1-Cutaway FCEB	$1,295,000	$12,265,000	$13,560,000

2047	AMF: 9-150 kWh chargers		10-40ft FCEB	$25,624,000	$12,631,000	$38,255,000
2048			2-30ft FCEB 2-Cutaway FCEB	$4,394,000	$13,012,000	$17,406,000
2049	AMF: 8-150 kWh chargers		5-45ft FCEB 5-Cutaway BEB	$20,321,000	$13,259,000	$33,579,000
2050			15-40ft FCEB	$34,248,000	$13,403,000	$47,651,000

10.0 OPERATIONAL AND PLANNING CONSIDERATIONS

This section provides guidance and strategies for various operational and planning requirements when implementing FCEBs and BEBs.

10.1 OPERATOR NEEDS

As FCEBs have different components and controls than conventional buses, FCEB performance also differs. Operations staff should be trained to understand the limitations of FCEBs such as variability in energy consumption from HVAC under different weather conditions as well as expected refueling times and procedures. Interaction at the depot should be like what is done with the CNG fleet, which is fueled as part of the service line process.

The presence of hydrogen gas and the safety issues that relate to this must be addressed as well as any differences in gauges and instrumentation. An overview of the technology should be provided to staff as part of the training. Training sessions will address the technology and its unique safety considerations. As well as guidance on the different start-up and shut-down procedures and proper procedures regarding what to do if there is a failure on-route should be accounted for as well.

BEB performance also differs from conventional buses. Operators should understand how to maximize BEB efficiency—such as mastering regenerative braking and handling during slick conditions—and have hands-on experience prior to ZEB deployment for revenue service. Operations staff should be briefed on the expected range and limitations of BEBs (such as variability in energy consumption from HVAC under different weather conditions) as well as expected recharging times and procedures.

BEB operators should be able to understand battery SOC, remaining operating time, estimated range, and other system notifications as well as become familiar with the dashboard controls and warning signals. In addition, operators should be familiar with the correct procedures when a warning signal appears.

It is well known that driving habits have a significant effect on BEB energy consumption and overall performance and range (i.e., fuel economy can vary significantly between operators). Training is required to ensure operators are knowledgeable about the principles of regenerative braking, mechanical braking, hill holding, and rollback. Operators should also be trained on optimal driving habits including recommended levels of acceleration and deceleration that will maximize fuel efficiency. Another option is to implement a positive incentive program that encourages operators to practice optimal driving habits for BEBs. This can be accomplished through rewards like priority parking in the employee lot, certificates, or other incentives. The Antelope Valley Transit Authority in Lancaster, California, an early adopter of BEBs, has a program of friendly competition between operators, where, for instance, an operator with the best average monthly fuel economy (the lowest kWh per mile) receives one month of a preferred parking spot in the employee lot.

Finally, ZEBs are much quieter than conventional fuel buses. Operators should be aware of this and that pedestrians or people around the bus may not be aware of its presence or that it is approaching. CARB has also stated that due to the vehicle's lack of noise, some operators forget to turn off the bus after parking. Operator training and internal processes should include a check-in for proper engine shutdown.

10.2 PLANNING, SCHEDULING, AND RUNCUTTING

FCEBs come closest to matching current CNG bus ranges and the APTA White Book Guidelines for heavy-duty buses (between 280-365 miles). However, BEBs are only expected to reach 207 miles in range. Therefore, RFTA can first launch BEBs on routes/blocks with shorter daily distances and electrify the longer routes once the procurement of FCEBs starts. Non-revenue tests should be conducted to understand the actual driving range and fuel economy, particularly as a function of route operating conditions, ambient temperature, passenger loads, and driver behavior.

Key considerations for BEB planning and scheduling include the fact that the useable energy of the battery is 80% of the nameplate capacity. In other words, while RFTA may purchase buses that have a 525-kWh battery, for instance, it should plan for 80% of that capacity or ~420 kWh. Together with the modeling conducted by the Stantec team in this study, this will help guide the deployment and charging parameters for BEBs in RFTA's operations' scheduling.

Developing a guide like the depot planning tool from Siemens that tracks the requirements for SOC, energy (kWh), estimated and planned mileages, and fuel economy (kWh per mile) will be important for planning and dispatching see Figure 54.

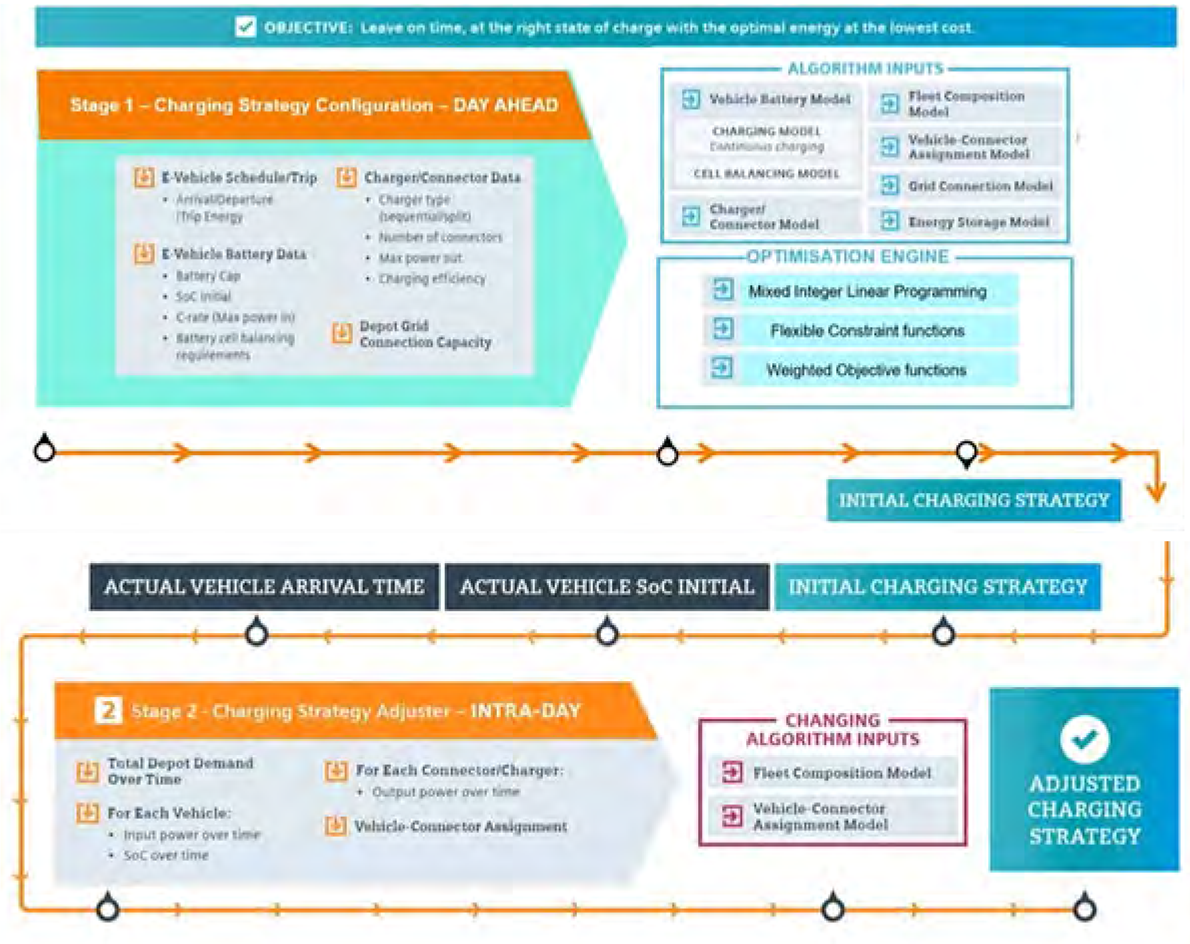
Non-revenue tests during vehicle commissioning should be conducted in different parts of RFTA's service area to establish actual range and fuel economy on longer routes, routes with topography variations, and with simulated passenger loads and HVAC testing. Regarding HVAC testing, it is important to keep in mind that energy consumption varies with seasonality.

Training for the staff responsible for scheduling and planning will be needed to understand the importance of scheduling BEBs to the correct blocks and to account for hybrid deployments of ZE and FF buses.

Planning and operations staff will have new critical tasks supporting BEB operations that will include:

- Tracking real-time SOC
- Evaluation of SOC at dispatch and/or adopting scheduled grouping of blocks into vehicle assignments to optimize off-peak and spare ratios.
- On-route charging schedules - created to optimize the charging order and priority so that vehicles charge only when needed and as much as needed.

Figure 54: Depot Planning Tool to Understand Scheduling and Operations of BEBs
(Source: Siemens)



The risks associated with these tasks include insufficient charge to complete trips, crowding at the on-route charging locations and low spare ratios. The successful completion of these tasks will require obtaining new software tools for dispatch and vehicle tracking and IT integration see details in Section 11.5. Training and establishing in-house protocols will further mitigate the risks associated with these critical tasks.

In the long term, it is also important to consider battery capacity degradation; most BEB battery warranties specify that the expected end of life capacity is 70% to 80% of the original capacity over six to twelve years. With an estimated 2% battery degradation per year, RFTA will also need to rotate buses so that older buses are assigned shorter blocks, while newer BEBs are assigned the longest blocks. Transit agencies can improve battery outcomes through efforts like avoiding full charging and discharging events, avoiding extreme temperature exposure, and performing regular maintenance on auxiliary systems that consume energy.

Developing specific performance measures, goals, and objectives for ZEB deployment can also help to track progress and understand if adjustments to the ZEB deployment strategy will be required.

10.3 MAINTENANCE NEEDS

The elimination of the internal combustion engine and powertrain will reduce operating maintenance costs in labor, material, and outsourcing. However, maintenance staff will still need to be trained on safety, scheduled maintenance, diagnostics, and repair of multiple systems that may be new to them. It is recommended that RFTA require OEMs to provide a list of activities, preventative maintenance time intervals, skills needed, and required parts needed to complete each preventative maintenance task for ZEBs.

In terms of preventative maintenance, BEB propulsion systems are more efficient than internal combustion engines and thus can result in less wear and tear. Without the diesel engine and exhaust, there are 30% fewer mechanical parts on a BEB. BEBs also do not require oil changes and the use of regenerative braking can help to extend the useful life of brake pads. Early studies from King County Metro show that the highest percentage of maintenance costs for BEBs came from the cab, body, and accessories' system.

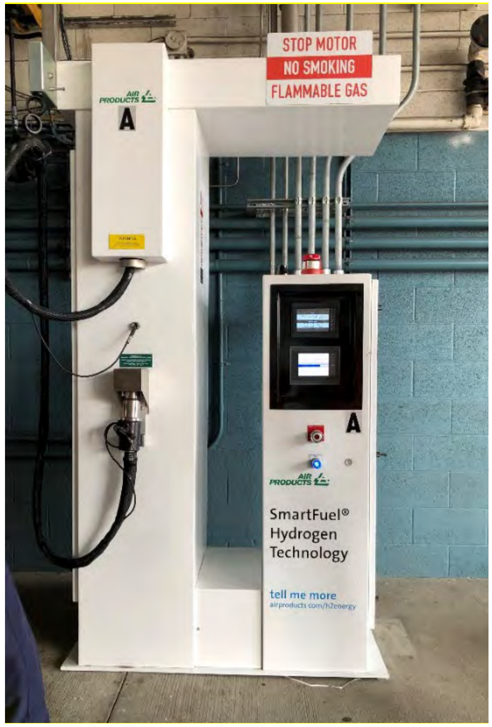
For FCEBs specifically, while a smaller high-voltage battery installation is present it will also require inspection and eventual changeout, the inspection and replacement of hydrogen fuel cell apparatus may be necessary. Tanks will have the same ruggedness as CNG products and should fulfill more than the heavy-duty bus 14-year service design life cycle.

Many current ZEBs also contain on-board communication systems, which are helpful in providing detailed bus performance data and report error messages, which can assist maintenance personnel in quickly identifying and diagnosing maintenance issues.

10.4 REFUELING CYCLE

Fueling an FCEB is very similar to fueling a traditional CNG bus. Attaching a dispenser nozzle to the vehicle and fueling for ~8 - 12 minutes will yield a full tank. The hydrogen nozzle is completely sealed to the bus while refueling due to the high-pressure delivery method (above 350 bars). The operation of the nozzle and the pump are the same but specific training needs to be provided to staff for safety reasons.

Figure 55: Example of Hydrogen fueling dispenser at OCTA for heavy-duty transit buses



Overall, the concept design for the hydrogen fueling station at the GMF facility calls for three low-pressure dispensers (H35) in the vicinity of the current fueling lanes to create a seamless transition to ZEBs by maintaining the current practices around servicing and fueling procedures for RFTA. Additionally, the design considers one high-pressure dispenser (H70) to refuel cutaways and service vehicles. The pressure difference between H35 and H70 dictates how much hydrogen can be stored in the tanks and is limited by the design specifications of each vehicle. While cutaway could refuel at H35, they would only get half the tank fill capacity. However, a 40-ft bus is unable to fill using a H70 dispenser.

BEB recharging is different than fueling a fossil fuel bus. As part of the recommendations, plug-in 150 kW chargers are proposed for BEB charging at the AMF maintenance facility. Once BEBs return to the yard and are parked, the operator or a service line technician would plug in the dispenser to recharge the bus. Smart charging software, described in Section 11.2 would monitor and control overall charging levels to balance energy needs with overall power demand, helping ensure that BEBs are charged but also that charging is spread out to avoid large surges in power demand.

10.5 TECHNOLOGY

Technology for ZEBs will help RFTA manage the fleet and its investment into zero-emission propulsion. First, for BEBs operating from AMF under the mixed case, charge management or smart charging technology is imperative to manage electrical demand and to curb potential costly demand charges and to mitigate maximum power requirements of bus charging. Second, fleet tracking software, also known as telematics, typically provided by an OEM, will help track useful analytics related to the fleet operations to help RFTA make informed decisions.

10.5.1 Smart Charging

To optimize BEB charging by minimizing charging during peak times of the day and to restrain the total power demand required for a BEB fleet, transit agencies deploy smart charging. Smart charging refers to software, artificial intelligence, and switching processes that control when and how much charging occurs, based on factors such as time of day, number of connected BEBs, and SOC of each BEB. This requires chargers that are capable of being controlled as well as a software platform that can effectively aggregate and manage these chargers. A best practice is to select chargers where the manufacturers are participants in the Open Charge Point Protocol (OCPP), a consortium of over 330 members focused on bringing standardization to the communications of chargers with their network platform.

A simple example of smart charging is if buses A, B and C return to the bus yard and all have an SOC of about 25%, all have 525 kWh battery packs, and all are plugged in in the order they arrived (A, B, C, though within a few minutes of each other). Without smart charging, they would typically get charged sequentially based on arrival time or based on SOC, with A getting charged first in about 2.2 hours, then B would be charged after 4.4 hours, and C about 6.6 hours. But if bus C is scheduled for dispatch after three hours, it would not be adequately charged. Furthermore, while vehicles can potentially charge all at once, such strategy is not recommended since the utility provider HCE has peak period tariff, and a high price tag can be passed to RFTA.

By implementing smart charging, the system would ‘know’ that bus C is to be dispatched first and therefore would get the priority, charging first in 2.2 hours so it is ready in time for its ‘hour three’ rollout.

Another implementation is to mitigate energy demand when possible. For example, if two buses are each connected to their own 150 kW charger and they both need 300 kWh of energy and if the buses do not need to be dispatched for five hours, the system will only charge one bus at a time, thus generating a demand of only 150 kW, while still fully charging both buses in four hours. However, if both buses need to be deployed in two hours, the system will charge both simultaneously as needed to make rollout. A smart charging system would help optimize costs by also avoiding or minimizing charging during the most expensive times of day and help curb potential demand charges.

Well-planned and coordinated smart charging can significantly reduce the electric utility demand by timing when and how much charging each bus receives. Estimations on the ideal number of chargers is critical to the successful implementation of smart charging strategies.

There are several offerings in the industry for smart charging, charger management, and fleet management from companies such as ViriCiti, IoTecha, IO-Dynamics, AMPLY Power, BetterFleet (previously EVenergi), and Siemens. Additionally, the charger manufacturers all have their own native charge management software and platforms. These platforms have management functionality and integration that often exceeds the abilities of the other platforms and provide data and functionality similar to that of the third-party systems, particularly in the yard when BEBs are connected to the chargers. However, the third-party platforms provide more robust data streams while the BEBs are on route, including real-time information on SOC and usage rates. These platforms can cost well over $1,000 per bus per month, depending on the number of buses, and type of package procured, in addition to set up costs. BetterFleet's cost is approximately $15,000 for initial set-up and systems integration, while ongoing operating costs can be approximately $20,000 per year.

Three leading charge management system (CMS) providers have been evaluated as shown in Table 30. Information within this table was provided by the providers. At the time of procurement, the available features and criteria should be verified with the provider. Note that ViriCiti was purchased by ChargePoint in 2021, the intent is to operate ViriCiti separately from ChargePoint. A Buy America evaluation will be required for these providers.

Table 30: Charge Management System Vendor Comparison (based on manufacturer's information)

Item No.	Criteria Description	Amply Power - OMEGA	ViriCiti - Agnostic Management Platform	ChargePoint - CMS
1	Number of installations (facilities) with multiple high voltage direct current chargers utilizing the software	14	More than 300	300+
2	Quantify uptime % of cloud base service	99.99%	99.99%	99.99%
3	What networking protocols or modes are supported, i.e., wired Ethernet, cellular, other	Hardwired ethernet is recommended, cellular and facility WIFI are supported	Cellular is recommended, wired Ethernet, and WIFI are supported	Cellular
4	OCPP 1.6 compatibility	Yes	Yes	Yes
5	OCPP 2.0 compatibility	Yes	Yes	Yes
6	List available data fields that can be reported (such as starting and ending SoC, bus ID, charging power, etc.)	SOC: start and end of charging session, SOC all the time whether bus in plugged in, parked or in the field. Rate of charge (kW) of each charger port. Bus ID all the time whether bus is plugged in or not. Location of bus (in-depot, in field, etc.) Charging session: Energy dispensed Duration of charging Power and energy consumed at electrical meter and dispensed at each charger port. Charger health: Available Faulted Maintenance needed, etc.	Reports: Uptime, Downtime, and Offline chargers (in hours, percentage, and total for a group) Energy Reports (in kWh and hours of duration) Transactions: Charger OEM, Charger Name, Connector type, Connector/port number (1 or 2) Vehicle Name/Number Start Time and End Time Start SOC and End SOC Power Reason for ending charge session Duration of Charging session kWh Charged Range at start of transaction Range at the end of the transaction A visual graph representation of Power, SOC, and Energy throughout each transaction A complete list of charging transactions (equipped with the data previously stated) A complete list of user logs and documentation of user interactions.	
7	OpenADR2.0b or better common signals	Yes. In addition to OpenADR, also support custom DR integrations including CPower and Leap Energy.		Yes

Item No.	Criteria Description	Amply Power - OMEGA	ViriCiti - Agnostic Management Platform	ChargePoint - CMS
8	Support Network Time Protocol (NTP/UTC) time synchronization	Yes	Yes	Yes
9	Describe software security features for system integrity and reliability	AMPLY has implemented security procedures at multiple levels for protecting customer information: • AMPLY databases are encrypted using industry standard AES-256 encryption • Both the database and application are running inside a VPC which has tightly managed access using IAM • The database is accessible only to the application nodes • No passwords are stored in the database and authentication is done using AWS Cognito • Authorization is tightly managed as part of the lower layers of the Amply software framework • Credentials are not stored in the database or code and are managed via the AWS systems manager • Software packages and dependencies are regularly reviewed for security vulnerabilities • Cloud infrastructure, roles & security groups are regularly reviewed for ensuring security		ISO 27000:2015
10	Capable of remote software upgrades	Yes – automatic, over the air updates	Yes – Updates happen though the Cloud	Yes
11	Is user interface web based or is any local app or software required	Web based UI accessible from any web enabled device	The system operates through a cloud-based platform which can be accessed through any web browser on a computer or mobile device. Web base only.	Web based
12	Ability to set charge-power limit to reduce energy charges while also maximizing bus availability	Yes. Pause or curtail charging session during peak energy costs. Optimized charging during off-peak or vehicle dwell times to achieve target SOC by defined roll-out times.	Yes, this is a customizable application which allows the user to create and manipulate charging parameters as needs or schedules change.	Yes
13	Ability to set charging to minimize demand charges while also maximizing bus availability	Demand (kW) management and reduction to achieve roll-out but will spread out charging. Sequential, dynamics and parallel charging capable (limitations are determined by EVSE not AMPLY system).	Yes, this is a customizable application which allows the user to create and manipulate charging parameters as needs or schedules change.	Yes
14	Ability to recognize bus stall and bus number and evaluate charge needs by block and state of charge (i.e., park management)	Yes	Yes	Yes

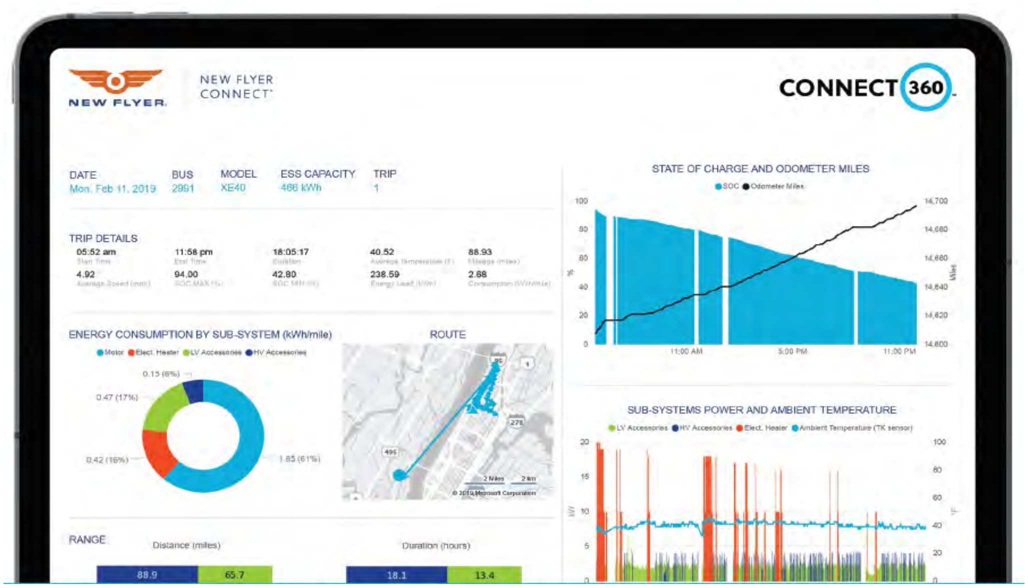
Item No.	Criteria Description	Amply Power - OMEGA	ViriCiti - Agnostic Management Platform	ChargePoint - CMS
15	Manual override (computer/HMI input) for selection of (bus) charging sequence	Yes. Manual override button located within UI accessible by a specific user creditable. Override can also be performed by email, phone call or ticket request.	Yes, users can manually prioritize groups of chargers or single chargers in order to meet the demand as needed.	Yes
16	Describe desktop output/reports for charge telematics	• Energy Report - net (panel) load, modelled load (assuming no CMS), aggregate and individual charger load • Charge Detail Records - plug-in and session start & stop times, session duration, session energy, vehicle start & end soc, vehicle ID • Health Records - % normal, faulted, offline and uptime for EVSEs, controllers, system & software components • Vehicle Logs - Geo location and SOC information • Charge Ready Transport - CRT formatted report for PG&E, SCE, and other Utilities Fleet Ready Programs	• Uptime, Downtime, and Offline chargers (in hours, percentage, and total for a group) • Energy Reports (in kWh and hours of duration) • A complete list of charging transactions (equipped with the data previously stated) • A complete list of user logs and documentation of user interactions.	No response
17	Is there a local controller to preserve the same control functionality in case cloud connectivity fails (e.g., WIFI outage)?	Yes, AMPLY Site Controller (ASC) installed at electrical main and is connected to breaker. CT's will meter 3- phases of power for real- time demand management. ASC can be hardwired to each EVSE via CAT6 to send OCPP directly to charger. If CMS cellular connection temporarily down, ASC has programmed commands to continue charging until cellular connection is restored.	With all communications we send to the charger, there are two signals that are sent: The set parameter and a failsafe value. If connection is disrupted for any reason or duration of time, the charger will revert to the failsafe value until connectivity is reestablished.	Yes
18	Other features criteria, or comments	OMEGA supports algorithmic optimization across a wide set of use cases in addition to TOU energy management including load management, tariff-based optimization across usage, demand, and subscription charges, factoring in unmanaged loads, demand response signals from OpenADR and other providers. It also offers flexible alerting and notifications for EVSE faults and other conditions.	• Provided system is built to scale. If charging needs change or if a new OEM is desired, the system is able to monitor any charging infrastructure (assuming that charger OEM is OCPP compliant) and easily exchange chargers in the system. • Through an API, there is the ability to integrate with other planning or ITCMS platforms to optimize planning. • Other features may include our agnostic telematics system, which is capable of monitoring any vehicle OEM and operates off the same platform as the charger monitoring infrastructure - decreasing operational complexity by reducing software applications and increasing visibility into energy usage/expenditure.	No response

10.5.2 Fleet Tracking Software and Telematics

Software like Fleetwatch provides agencies with the ability to track vehicle mileage, work orders, fleet maintenance, consumables, and other items. However, with more complex technologies like ZEBs, it becomes crucial to monitor the status of batteries, fuel consumption, and so on of a bus in order to track its performance and understand how to improve fuel efficiency. Many OEMs offer fleet tracking software. Tracking fuel consumption and fuel economy will start to form important key performance metrics for fleet management as well as help inform operations planning (by informing operating ranges, among other elements).

The screenshot below is an example of New Flyer's tool (New Flyer Connect 360; Figure 56), Lightning's dashboard (Figure 57), while other OEMs also offer similar tools (like ViriCiti) all depending on an agency's preference.

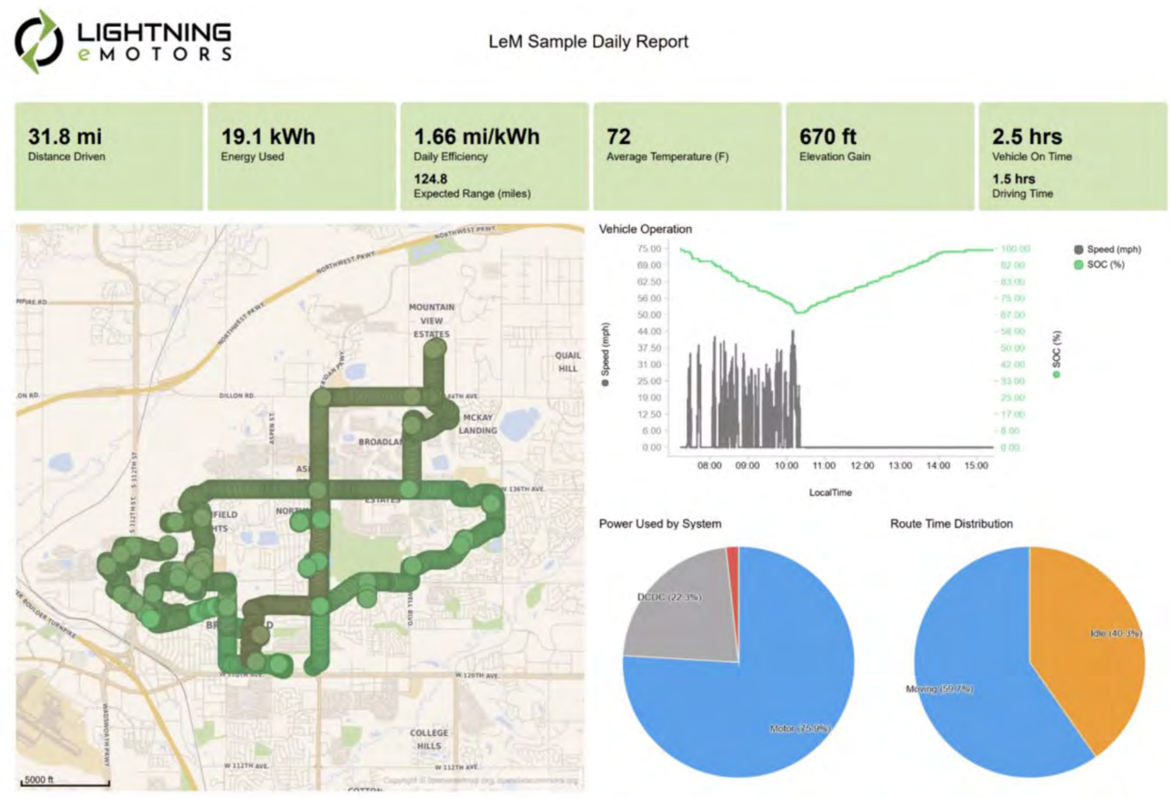
Figure 56: Example of New Flyer Connect 360 [12]



At a minimum, the fleet tracking software should track a vehicle's SOC, energy consumption, distance traveled, hours online, etc. Tracking these key performance indicators (KPIs) can help compare a vehicle's performance on different routes, under different ambient conditions, and even by different operators.

[12] https://www.newflyer.com/tools/new-flyer-connect/

Figure 57: Example of Lighting eMotors daily report summary

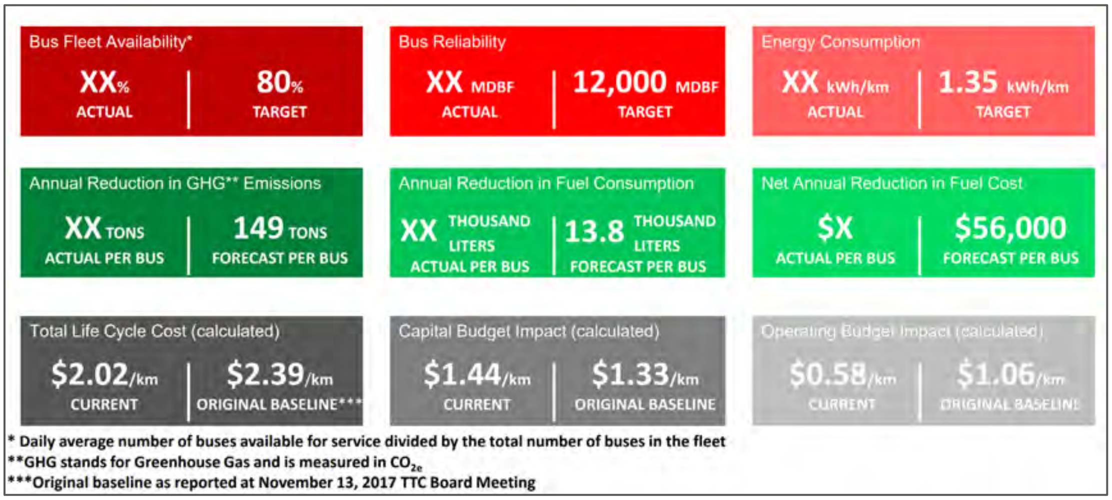


As RFTA transitions from a fossil fuel fleet to ZEB fleet, it will be important to collect and compare data between the fleet types to understand the benefits (and costs) of the transition. Some example KPIs can include:

- ZEB vs. non-ZEB miles traveled,
- ZEB vs. non-ZEB maintenance cost per mile,
- ZEB vs. non-ZEB fuel/energy costs by month ($ per kWh vs. $ per gallon),
- ZEB vs. non-ZEB fuel/energy cost per mile,
- Average fuel consumption/fuel economy per month,
- Total ZEB vs. non-ZEB fuel and maintenance costs per month,
- Mean distance between failures, and/or
- ZEB vs. non-ZEB fleet availability.

The Toronto Transit Commission (TTC) is currently testing BEBs from three different OEMs and is tracking the following KPIs for its BEBs to compare with its fossil fuel buses (Figure 58). This example is to provide some insights into what RFTA could be tracking as comparable KPIs between fossil fuel vehicles and ZE vehicles.

Figure 58: Example of TTC Bus KPIs.[13]



All BEB equipment should be connected to RFTA's current data collection software, networks, and integrated with any existing data collection architecture. All data should be transmitted across secure VPN technology and encrypted.

Beyond the BEB itself, charger data should be collected as well, such as the percentage of battery charge status and kWh rate of charge. Furthermore, it will be important for RFTA to track utility usage data to understand energy and power demand and costs.

13 https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2018/June_12/Reports/27_Green_Bus_Technology_Plan_Update.pdf

11.0 WORKFORCE TRAINING

Transitioning to zero-emission vehicles presents complexities for all areas of transit operations including scheduling, maintenance, and yard operations. RFTA has specified a fleet replacement schedule for its current fleet (fixed route and paratransit services) and aims to transition to a 100% ZEB fleet by 2050. To ensure a qualified workforce is ready to support ZEB deployment it will be essential to provide effective training and align workforce development with the fleet transition timeline.

11.1 CURRENT SITUATION

RFTA has over 380 employees, 140 of which are operators, and represented by Amalgamated Transit Union (ATU) Local 1774. In July 2023, RFTA and ATU agreed to raise starting wages for union members to $30/hour.

As early adopters of BEBs, RFTA operates eight New Flyer 40-ft electric buses for its fixed-route. While operating and maintaining eight BEBs, RFTA has been provided training for operations and maintenance staff by the OEM. RFTA has worked on increasing the share of its current employees that are proficient in operating and maintaining electric buses. There will be no displacement of the existing workforce throughout the transition to an electric fleet.

While some RFTA staff have experience operating and maintaining BEBs and related infrastructure, this has evolved organically over time. When considering the broader adoption of BEBs and FCEBs and the introduction of new OEMs, RFTA will use this opportunity to build upon existing training procedures, protocols, and materials by adopting such resources from well-established and trusted sources in the industry.

11.2 REQUIRED SKILL SETS TO OPERATE AND MAINTAIN A ZEB FLEET

Under RFTA's goal to move to a Mixed ZEB fleet by 2050, there are additional skill sets required to ensure that the staff is fully trained on the unique aspects of ZEBs and associated equipment. For all staff, it will be critical to ensure that this training includes safety protocols. Maintenance staff will need to be provided with all the appropriate equipment including items such as fall protection when working at heights on roof-mounted equipment (e.g., batteries) and with overhead charging.

As the fleet continues to transition to ZEBs, RFTA will need to:

- Enhance standard operating procedures/policies for training on ZEBs and related equipment (including but not limited to chargers, tools, software, etc.) to fully document the current equipment and procedures; ensure that all staff have relevant manuals and other necessary documentation; and make procedure handbooks readily available at workstations and in buses;

- Confirm and document standard operating procedures/policies, as well as provide and mandate the use of appropriate personal protection equipment associated both with an industrial workplace and with handling high voltage components;
- Arrange for courses on basic electricity fundamentals for any non-ZEB shop staff that may be in work areas; and
- Post illustrated warning signage at entrances to shop areas and enforce the safety policies on visitors. Warning signs include the federally or state-mandated workplace requirements as well as anything related to high-voltage electrical equipment; for instance, personal protective equipment must be worn when handling high-voltage vehicle components.

The required overall skill sets/knowledge areas on ZEBs include:

- **Maintenance Staff**
  - Safety protocols for high-voltage batteries and chargers
  - Preventative maintenance – buses (and passenger vehicles)
  - Onboard diagnostic systems
  - Multiplexing
  - HVAC
  - Brake systems
  - Energy Storage System, lithium-ion battery, and energy management hardware and software
  - Electric propulsion
  - Monitoring alerts and necessary updates to maintenance management software
  - Charging dispensers – both depot and on-route (pantographs)
    - Preventative maintenance
    - Charger diagnosis and repair
    - Smart Charger software
- **Bus Operators**
  - BEB and FCEB driving techniques, including methods to maximize range and battery life
  - BEB and FCEB vehicle and associated systems orientation including onboard diagnostics
  - Safety protocols
  - Proper use of any chargers
- **First Responders**
  - Training on layout, componentry, safety devices, and other BEB and FCEB features
- **Planning/Scheduling/Dispatching Staff**
  - Training on BEB- and FCEB-specific features that impact operating parameters
- **Towing Staff/Contractors**
  - Schedule and test towing training with staff and any contractors who will tow the ZEBs for each type of ZEB

Table 31 below provides a framework of potential training methods and strategies to bolster RFTA's workforce development and successfully transition to a ZEB fleet.

Table 31: Potential Training Methods

Plan	Description
Train-the-trainer	Small numbers of staff are trained and subsequently train colleagues. This maintains institutional knowledge while reducing the need for external training.
Bus vendor training and fueling vendor	OEM training provides critical, equipment-specific operations and maintenance information. Prior to implementing ZEB technology, RFTA staff will work with the OEMs to ensure all employees complete the necessary training.
Retraining & refresher training	Entry level, intermediate, and advanced continuous learning opportunities will be offered to all agency staff.
ZEB training from other transit agencies	RFTA should leverage the experience of agencies who were early ZEB adopters, such as the ZEB University program offered by AC Transit. RFTA should also collaborate with partner transit agencies in the state and beyond to share lessons learned during ZEB transition.
National Transit Institute (NTI) training	NTI offers zero-emissions courses such as ZEB management, benchmarking, and performance.
Local partnerships and collaborations	RFTA could work with local schools to showcase potential careers in bus and facilities management to students.
Professional associations	Associations such as the Zero Emission Bus Resource Alliance offer opportunities for sharing and lessons learned across transit agencies.

11.2.1 Maintenance Staff Skills – Additional Details

Once the basic electrical skills have been mastered, the next set of skills addresses the basic aspects of multiplexing, a more advanced and streamlined structure that controls the vehicle's electrical system, replacing an extensive system of electrical hard wiring.

Multiplexing skills include the ability to:

- read and interpret ladder logic diagrams,
- use LED indicator lights to troubleshoot the system, and
- identify symbols used for input and output electrical signals.

The next set of skills pertains to electronics dealing with solid-state devices using transistors, microchips, and other such components. Every bus system is now controlled by electronic devices, which has increased significantly with the introduction of ZEBs.

Electronic skills include:

- ability to inspect and test capacitors, diodes, and other electronic modules;
- differentiate between analog and digital signals;
- the ability to describe the purpose of data communication protocols CAN/SAE J1939 and SAE J1708;
- differentiate between direct current (DC) and alternating current (AC);

- demonstrate the use of an oscilloscope and a graphing multimeter; and
- inspect and troubleshoot gateway modules.

11.3 GAPS AND TRAINING NEEDS

The skills of existing workers will be assessed by reviewing any previous training on their records and on an individual basis by their immediate supervisor to identify gaps and training needs. The evaluation approach is to prepare a skills gap survey identifying each employee's current skill sets and comparing them against the relevant Required ZEB Skills Sets as described in the preceding sections.

The outcome will be to produce a skills gap inventory that identifies specific weaknesses and/or across-the-board training needs for everyone. Formalized certification programs, such as the American Public Transportation Association (APTA) Standard for Training on Electrical and Electronic Systems, will be particularly useful in making these assessments for maintenance personnel. After completion of the assessment, since the transition to a fully BEB fleet will occur over time, a schedule will be developed to determine when specific staff members need to have their training completed.

As RFTA transitions to a ZEB fleet, it is expected that all technicians will eventually require an acceptable electrical/electronic (E/E) level of proficiency or will require training related specifically to ZEBs; RFTA may also look to hire an electrical engineer if deemed appropriate.

For the maintenance staff, skills will be assessed first using the National Institute for Automotive Service Excellence (ASE) transit bus certifications for H6 E/E Systems (as further described below). Technicians with similar ASE electrical certifications from the automobile and heavy-truck sectors will also be included and classified. These ASE certification tests are widely regarded in the ground transportation industry as a standardized way to classify those with requisite job skills.

RFTA will also explore other ways to supplement this training through resources like the OEM, APTA training programs, National Transit Institute (NTI) training, and any other programs that may become available.

11.3.1 Overall Training – All Personnel Categories

The primary source of training could be two-fold: (1) training by OEMs, which will be specified as part of the purchase contracts, and (2) training provided by experienced 'trainers' on staff. As needed, this will be supplemented with online courses, technical schools, and community colleges. Once staff has been trained, ongoing refresher training will be programmed for relevant staff.

RFTA will continue communication with peer agencies who are entering into ZEB operations and maintenance and compare practices; facility interaction with peers at the shop management level to seek help or opinion on emerging issues and "informal borrowing of parts in emergencies" to keep a bus on the road.

At some point in the future, RFTA may like to explore the possibility of collaborating with local secondary schools and/or technical colleges to formalize training on ZEBs (or all such vehicles using battery electric technology) to ensure there is a continuity of capable and credentialed personnel for succession planning. RFTA can present the occupation as “upmarket” because of the electrical, electronic, and computer-based diagnostic process in addition to the more physical routines such as replacing a blown suspension air bag.

Maintenance. Training will be provided to ensure that maintenance technicians understand how to service and troubleshoot ZEB propulsion systems, balance of plant for ZEBs, and auxiliary systems. They will also be trained on onboard diagnostic systems, and safe work practices for high-voltage systems, including the handling, storage, and disposal of batteries. Finally, training will be required to maintain and repair bus chargers.

As previously mentioned, for the maintenance staff, skills are first assessed using the ASE transit bus certifications for H6 E/E Systems. Technicians with similar ASE electrical certifications from the automobile and heavy-truck sectors will also be considered and classified. These ASE certifications tests are widely regarded in the ground transportation industry as a standardized way to classify those with requisite job skills.

This systematic assessment approach involves participation from both labor and management using the various training resources and partners described here to close the skills gap. The training will be directed into two areas, one to achieve a higher level of foundational E/E skills, and the other to build ZEB-specific skills.

Finally, training will be required on maintaining and repairing bus charging and hydrogen refueling equipment. The training will be ongoing as new skills are required with periodic refresher training across critical topics, as well as necessary maintenance of certifications.

Once the vehicles are out of general warranty, servicing, inspection, and repair procedures will be documented by RFTA as necessary to supplement manuals. In addition, it will be important to both incorporate the OEM-recommended preventative maintenance intervals as well as monitor observed work routines for necessary changes based on the different characteristics of BEBs and FCEBs. For example, due to regenerative braking, brake pads or shoe/lining wear will decrease, and the mileage interval will be two to three times greater.

11.3.1.1 APTA Standard for Training on Electrical and Electronic Systems

The APTA Standard for Training on Electrical and Electronic Systems covers the information to instruct and prepare transit bus technicians and mechanics for the ASE H6 Transit Bus E/E certifications and to evaluate, develop, or enhance current training programs for the diagnosis, repair, and maintenance of transit bus electrical/electronic systems. The stated criteria in this program or an approved equal will be used as the basis to evaluate skill sets.

The APTA learning objective levels represent 100 (introductory), 200 (intermediate), and 300 (advanced). When a transit bus mechanic demonstrates proficiency in the learning objectives, that individual should be capable of attaining the corresponding ASE Transit Bus Technician Certification.

BEB Operators. The approach for BEB operators will be to train them to understand and use readings such as the battery state of charge (remaining energy), remaining operating time, estimated range, and other system notifications that may occur during operation. This will equip them to identify the notifications that require immediate action as opposed to ones that are noting items for diagnostic purposes and/or system upgrades.

When RFTA deploys additional on-route opportunity charging, the appropriate markings will be put in place to assist the drivers in the proper alignment of each type/model of BEB. This will be accompanied by training to ensure that the BEB operators can efficiently park the BEBs in the proper location for charging without needing to repark, thus both assuring charging and avoiding any delays in the schedule; particularly if other buses are queuing for a recharge. BEB operators will also be informed/trained on their order of charging among other BEBs at the on-route location(s) based on the route schedule criteria.

As driving habits can significantly affect BEB efficiency and performance, the curriculum will also address training drivers on optimal driving habits, such as the recommended levels of acceleration and deceleration to maximize efficiency and battery life. Consideration will be given to providing additional training or incentives to promote efficient driving behaviors; balancing energy efficiency with safe operation of the bus, as well as demands on operators to adhere to schedule points.

As recommended by FTA, in addition to the physical components of the bus, training will include concepts, working principles, and details of regenerative braking, mechanical braking, hill holding, and rollback. Other areas to address include the dangers of silent operation to avoid risks to pedestrians and the importance of turning off the BEBs when parked.

First Responders. With a focus on safety, RFTA will continue to provide local fire and emergency response departments training on the layout, componentry, safety devices, and other features of the new technology.

RFTA will also work with its utility providers and the local fire department to share their experience, training, and best practices around high-voltage and battery safety.

11.3.1.2 Example Training from New Flyer of America

The following is an excerpt of the Training Plan for the XE35/40 Xcelsior Electric Buses from New Flyer. It illustrates the volume of training New Flyer offers.

Program Overview

The New Flyer training program is designed to provide Maintenance personnel with the knowledge and skills required to operate, and perform preventative maintenance (PM) inspections, daily maintenance, running and major repairs to the New Flyer Transit Bus.

Program Objective

The learner will demonstrate the knowledge and skills required to operate, perform PM inspections, daily maintenance, running and major repairs to the New Flyer Transit Bus.

Enabling Objectives

- Safely and efficiently manage all operating systems, safety, emergency functions, and emergency procedures of the New Flyer Transit Bus
- Troubleshoot, diagnose, service, and maintain the coach electrical, multiplexing charging and electric drive systems
- Troubleshoot, diagnose, repair, and maintain the electric entrance and exit doors
- Troubleshoot, diagnose faults, and perform adjustments and repairs to the wheelchair ramp system
- Repair and maintain the axles and disc brakes
- Troubleshoot, diagnose, service and maintain the anti-lock braking system (ABS)
- Troubleshoot, diagnose, service and maintain the air system
- Troubleshoot, diagnose, service and maintain the suspension, steering and kneeling systems
- Perform the coolant loop fill procedure
- Tow the bus using proper and safe procedures
- Troubleshoot, diagnose, service and maintain the body and structure
- Troubleshoot, diagnose, service and maintain the propulsion and energy storage systems
- Troubleshoot, diagnose, service and maintain the electric air conditioning system
- Troubleshoot, diagnose, service and maintain the fire suppression system
- Troubleshoot, diagnose, service, maintain and program the destination signs

This program of instruction consists of multiple instructional modules. Modules are designed to be facilitated independently or grouped with other instructional modules. The list below provides the name of each module and time required to complete each module:

Module	Hours
Module A – Operator Orientation	4
Module B – Maintenance Orientation	4
Module C – Multiplex System	32
Module D – Electric Entrance and Exit Doors	4
Module E – Wheelchair Ramp	4
Module F – Brake Systems and Axles	16
Module G – Air System and ABS	8
Module H – Front and Rear Suspension, Steering and Kneeling	8
Module I – Coolant Loop Fill Procedure	4
Module J – Towing and Recovery	4

Module	Hours
Module K – Body and Structure	4
Module L – Propulsion & ESS Fam/HV Safety	32
Module M – Propulsion & ESS Troubleshooting	16
Module N – Electric HVAC, AC Maintenance (OEM supplied)	8
Module O – Fire Suppression (OEM supplied)	8
Module P – Destination Signs (OEM supplied)	8
Module Q – Siemens Propulsion System (OEM supplied)	Up to 24
Module R – XALT ESS (OEM supplied)	Up to 16

Additionally, RFTA will be implementing an initial hydrogen training. Within one month of receiving the first hydrogen vehicles, all RFTA mechanics, workers, specialists, bus operators, and office staff will attend the one-day OEM Tier 1 training. Within six weeks, facility and maintenance mechanics will receive Tier 3 training. Tier 1 and Tier 3 courses are summarized in Table 32.

Table 32: OEM tier 1 & tier 3 training

Tier	Hydrogen Course
Tier 1	Introduction to system schematics
	Corrective maintenance
	Diagnostics
	Basic and advanced troubleshooting
	Integration basics
	Remote data analysis
Tier 3	Fuel cell 101
	Fuel cell system basics
	Hydrogen safety
	Servicing basics and schedule
	Preventative maintenance

11.4 IMPLICATIONS OF ZEBS ON WORKFORCE

Early data suggest that BEBs may require less preventative maintenance than their diesel or CNG counterparts since they have fewer moving parts. However, BEBs are so new that there is not enough data to provide detailed insights into long-term maintenance practices for large-scale BEB deployments in North America.

Since BEBs have fewer moving components that can malfunction and require replacement, repair, and general maintenance, transit agencies could theoretically save on maintenance costs because: 1) fewer parts could break and need replacement (capital) and 2) less labor is needed to work on the vehicles (operating). The broader concern throughout the industry is related to a reduction in the number of maintenance staff required for a BEB fleet vs. a traditional diesel fleet. However, a reduction of staff should not be a major concern for the agency; marginal cost savings are possible. While fewer maintenance practices may be needed, such as oil and lube changes, new ones may emerge, such as checking cabling and other electric motor components. As technology continues to mature and become more sophisticated, technicians will need to be trained not only on machinery and high-voltage safety but also on components that require computer and diagnostic skills.

All the training described above will upskill and reskill current staff, enhancing their proficiency with and understanding of ZE technology. There will also be opportunities to strengthen and diversify the technical workforce by offering in-house training programs for workers in other job categories who may want to move into skilled technician positions. Furthermore, industry experience has demonstrated that some of the most effective recruiters are current workers who know the work and come from the communities that agencies are targeting. Finally, current workers' experience and skills make them excellent candidates to be mentors (trainers) for newly hired staff.

12.0 POTENTIAL FUNDING SOURCES

Transit agencies require external financial aid to fund their ZE transition. RFTA constantly monitors existing funding and financing opportunities and is aware of when new sources are created. Below are the major current programs available for ZEV transition (Table 34).

An important source of potential funding is the FTA's Low-No and Bus and Bus Facility funding opportunity. In FY 2024 RFTA is pursuing in FTA 5339b Bus & Bus Facilities and 5339c Low or No Emissions (Low-No) funding in collaboration with the State of Colorado. The FTA's Low-No and Bus and Bus Facility funding application requires a Zero-Emission Fleet Transition plan. The FTA Zero-Emission Fleet Transition plan includes six major elements, presented in Table 33. Moving forward, to qualify for these funding opportunities, RFTA can use much of the material in the ZEV Rollout Plan document to update its ZE Fleet Transition Plan to comply with the FTA's requirements[14].

Table 33: FTA Zero-Emission Fleet Transition Plan Requirements

Element	Description
1: Long-Term Fleet Plan and Application Request	Demonstrate a long-term fleet management plan with a strategy for how the applicant intends to use the current application and future acquisitions.
2: Current and Future Resources to Meet Transition	Address the availability of current and future resources to meet costs for the transition and implementation
3: Policy and Legislative Impacts	Consider policy and legislation impacting relevant technologies.
4: Facility Evaluation and Needs for Technology Transition	Include an evaluation of existing and future facilities and their relationship to the technology transition.
5: Utility Partnership	Describe the partnership of the applicant with the utility or alternative fuel provider.
6: Workforce Training and Transition	Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers.

[14] To view a list of winners and projects, please see https://www.transit.dot.gov/funding/grants/fy22-fta-bus-and-low-and-no-emission-grant-awards

Table 34: Grant and potential funding options for ZEB transition

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
Federal	Federal Transit Administration (FTA)	Low or No Emission Program (Low-No Program) (5339(c))	Low-No provides competitive funding for the procurement of low or no-emission vehicles, including the leasing or purchasing of vehicles and related supporting infrastructure and workforce development. This has been an annual program under the FAST Act since FY2016 and is a subprogram of the Section 5339 Grants for Bus and Bus Facilities There is a stipulation for a 20% local match.	FY2023 the FTA awarded $1.2 billion to 83 projects for the Low-No program.[15] $1.1 billion has been announced for FY2024 projects.[16]
		Buses and Bus Facilities Program (5339(a) formula, 5339(b) competitive)	Grants applicable to rehab buses, purchase new buses, and invest and renovate related equipment and facilities for low or no emission vehicles or facilities. A 20% local match is required.	FY2023 funding totaled $473.1 million in grants to 47 projects.[17] $390 million has been announced for FY2024 projects.[18]
		Urbanized Area Formula Grants (5307)	5307 grant funding makes federal resources available to urbanized areas for transit capital and operating assistance. Eligible activities include capital investments in bus and bus-related activities such as replacement, overhaul, and rebuilding of buses. The federal share is not to exceed 80% of the net project cost for capital expenditures. The federal share may be 90% of the cost of vehicle-related equipment attributable to compliance with the Clean Air Act.	Typically, the MPO or another lead public agency is the direct recipient of these funds and distributes these to local transit agencies based on TIP allocation. Agencies can allocate these funds for the purchase of ZEBs. An urbanized area is an area that has been defined and designated by the U.S. Department of Commerce, Bureau of the Census as an 'Urban Area' with a population of 50,000 or more.
	Federal Highway Administration (FHWA)	Congestion Mitigation and Air Quality Improvement Program (CMAQ)	The Congestion Mitigation and Air Quality Improvement (CMAQ) Program provides funds to states for transportation projects designed to reduce traffic congestion and improve air quality, particularly in areas of the country that do not attain national air quality standards.	Projects that reduce criteria air pollutants regulated from transportation-related sources, including ZEBs.

15 https://www.transit.dot.gov/funding/grants/fy23-fta-bus-and-low-and-no-emission-grant-awards
16 https://www.transit.dot.gov/about/news/biden-harris-administration-announces-availability-15-billion-federal-funding-modernize
17 https://www.transit.dot.gov/funding/grants/fy23-fta-bus-and-low-and-no-emission-grant-awards
18 https://www.transit.dot.gov/bus-program

Type	Agency	Fund/Grant/Program	Description	Applicability & Details
	United States Department of Transportation (USDOT)	Local and Regional Project Assistance Program (RAISE)	Previously known as BUILD and TIGER, RAISE is a discretionary grant program aimed to support investment in infrastructure. RAISE funding supports planning and capital investments in roads, bridges, transit, rail, ports, and intermodal transportation. A local match is required.[19]	FY2023 provided $1.5 billion in grants to 162 projects in all 50 states, the District of Columbia, Puerto Rico, and the Northern Mariana Islands. $1.5 billion has been announced for FY2024 projects.[20]
State	Colorado Energy Office (CEO)	Fleet Zero-Emission Resource Opportunity (Fleet-ZERO)	Fleet-ZERO grant program strategically addresses greenhouse gas emissions and air pollution from the fleet sector by funding electric vehicle (EV) charging to support the transition of light-, medium-, and heavy-duty fleets to EVs. The program offers competitive grant funding with prioritized investments in disproportionately impacted communities and enhanced incentives for public, private, and non-profit fleets. Government Agencies are a Qualifying Entity.[21]	Standard application round (April through May 2024) budget of $3 million. Rolling application is open year-round only for Qualifying Entities requesting $50,000 or less. Program is on-going. Minimum 10% match for Qualifying Entities.
	Colorado Department of Transportation (CDOT)	Clean Transit Enterprise (SB260)	This enterprise is created within the Colorado Department of Transportation (CDOT) to support public transit electrification planning efforts, facility upgrades, fleet motor vehicle replacement, as well as construction and development of electric motor vehicle charging and fueling infrastructure. The bill allows the enterprise to impose a clean transit retail delivery fee to fund its operations, and to issue grants, loans, or rebates to support electrification of public transit.	Agencies may apply for grants on a competitive basis. FY2023 provided $297,000 in grants to 4 projects.[22] FY2024 funding has not yet been announced.
		Zero Emission Vehicle (ZEV) Workforce Development Grant	To develop and attract the skills and talent necessary to meet the changing demands of the transportation electrification sector. This grant addresses multiple challenges that Colorado and the wider mobility and electrification industry are facing: talent shortages, gaps in new skillsets, and the growing need for training due to technological advances.	FY2024 projects eligible for between $20,000 and $100,000. Local cash or in-kind match of 20% is highly encouraged but not required.[23]

19 https://www.transportation.gov/RAISEgrants/about
20 https://www.transportation.gov/RAISEgrants
21 https://energyoffice.colorado.gov/fleet-zero
22 https://www.codot.gov/programs/innovativemobility/assets/cte/cte-annual-report-cy2023.pdf
23 https://www.codot.gov/programs/innovativemobility/assets/zev_workforce_development_rules_-_selection_criteria-2024-round-1-2.pdf

13.0 GHG IMPACTS

GHG emission reductions over time is compared using the time horizons of 2040 and 2050. Annual vehicle mileage (revenue and nonrevenue) is assumed to be consistent. Across each time horizon, three technology profiles or fleet compositions are compared against the "business as usual" or Base Case scenario. The three technology profiles are all BE vehicles, all FCE vehicles, and a mixed fleet of both technology types. GHG emission reductions are compared at both the annual level as well as cumulative emission reductions over the period.

Inputs consider the different utilities providing power to each facility as well as their goals for decarbonization. The different emissions from energy and hydrogen production can be seen in Table 35 below. Emissions from the production of energy prior to use propelling a vehicle are considered upstream emissions and have carbon intensity reductions outside of RFTA's zero-emission goals. Table 35 shows carbon intensity in grams of carbon dioxide per kilo-watt hour from the two electric utility providers servicing RFTA facilities as well as a 50/50 blend. While RFTA plans to deploy FCEBs with green hydrogen, the assumption is that hydrogen exclusively from solar/electrolysis will not be available until 2030. For current conditions through 2030, the carbon intensity for hydrogen reflects a blend 67/33 of hydrogen production from SMR and green hydrogen produced through solar electrolysis, respectively.

Table 35: Carbon intensity by zero-emission source

Energy Type/Source	Carbon Intensity		
	Current	2030	2050
Electricity – Glenwood (gCO2/kWh) (At GMF and West Glenwood Park and Ride)	300	300	-
Electricity - HCE (gCO2/kWh) (at AMF)	381	-	-
Electricity - Aspen Electric Department (at Rubey Park)			
Electricity - Blend (gCO2/kWh)	340	150	-
Hydrogen - SMR/electrolysis (gCO_2e/kg)	12,552	12,552	12,552
Hydrogen - solar electrolysis (gCO_2e/kg)	1,261	1,261	1,261

Carbon intensity for each energy provider varies over the timeline. In the current conditions at AMF electricity provided by Holy Cross Energy (HCE) comes from a 50% renewable grid and HCE has a goal of reaching a 100% renewable grid[24] by 2030. At GMF where electricity is provided by the Glenwood Springs Utility (which purchases energy from the Municipal Energy Agency of Nebraska or MEAN), carbon intensity is linked to MEAN operations. Currently MEAN operates a 53% renewable grid, it is assumed that there will be no significant emission reductions between now and MEAN's furthest published projection for 2038[25]. While MEAN is anticipated to reach its 2050 goal of 100% renewable energy, there was no assumed gradual step down of emissions.

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[24] HCE_Co2-Report-2022.pdf (holycross.com)
[25] MEAN 2022 Integrated Resource Plan FINAL.pdf (nmppenergy.org) Figure I-33, pg. 36

The energy source each facility utilizes is an important factor in how the most GHG reductions can be realized. The analysis made two simplifications, the first was that the energy sources specific to the on-route charging locations were not considered. The second simplification was to use a 50/50 blend of the carbon intensity for electricity for the BEB Case when RFTA vehicles utilize both Glenwood/MEAN and HCE. It should be noted that all of the electric vehicles under the mixed fleet concept are assumed to be fueled at the AMF facility and thus utilize energy from HCE and realize zero-upstream emissions as early as 2030. Lastly emissions from external heaters for the BEB vehicles were not accounted for in this analysis.

13.1 2040 TIMELINE

The results from the 2040 transition timeline are shown in Figure 59 and show initial decreasing emissions for all technology profiles as the Base Case will continue to increase the BEBs share of the fleet through 2030. It should be noted that both timelines have stagnant emissions during the early stages of FCE deployment. This is due to the delay in deployment as well as the assumed lack of green hydrogen until 2030. Following the 2030 'inflection point,' emission reductions are realized at a rapid rate.

The downward emissions trend from the other fleet compositions is consistent across technology profile until 2029/2030 when the share of ZE vehicles in the Base Case scenario is no longer expanding. The BE and mixed fleets continue decreasing in annual emissions until 100% deployment, at which point a plateau in emission reductions is met. Not until the MEAN energy grid is 100% renewable in 2050 are more emission reductions realized.

Figure 59: Annual Emissions for the 2040 Adoption Timeline

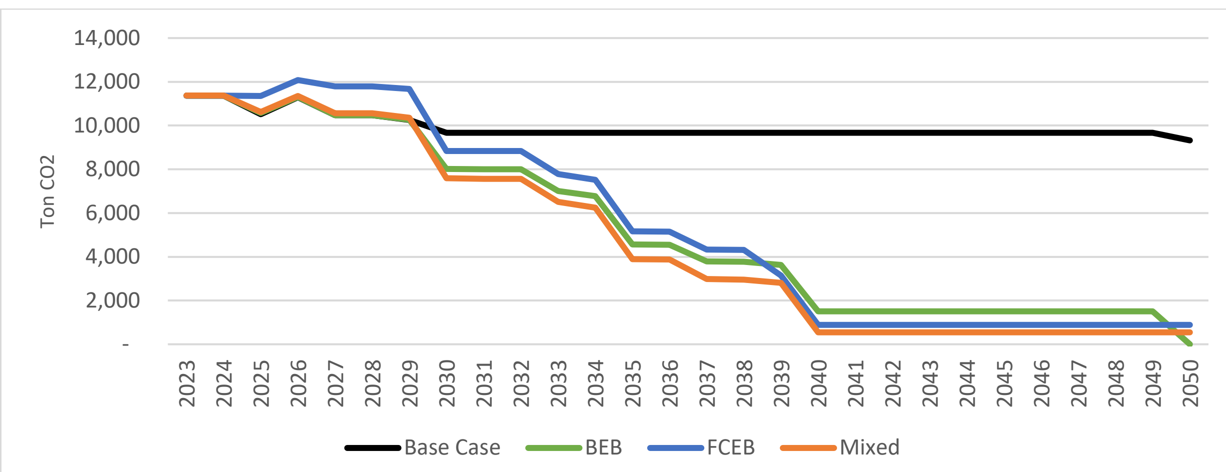
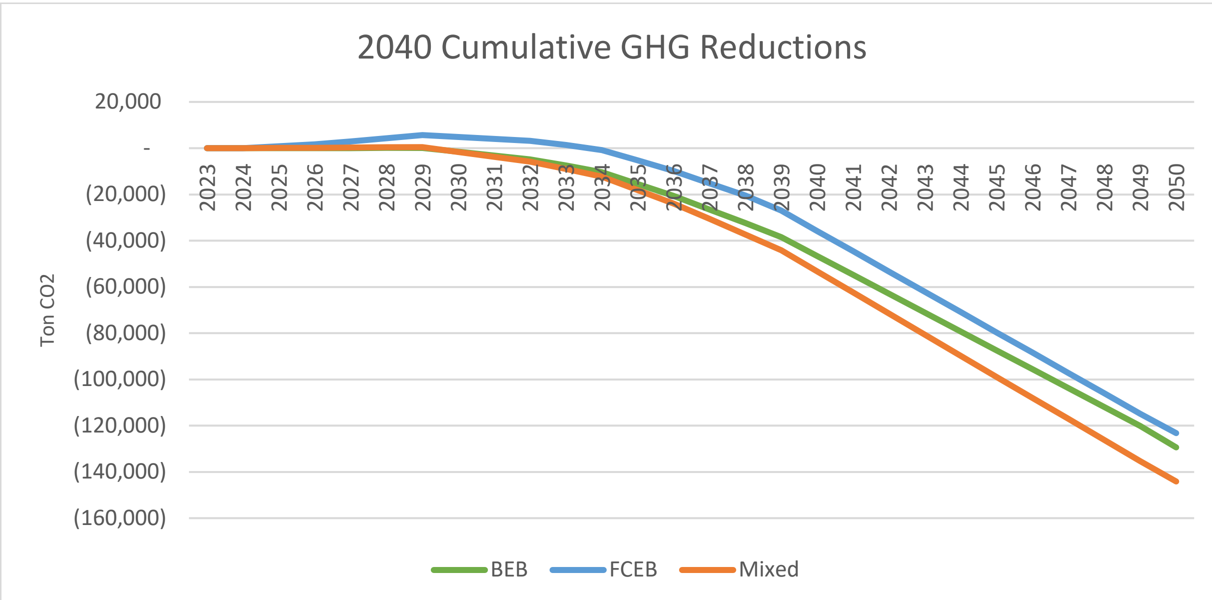


Figure 60 shows the cumulative GHG reductions (or under the FCE scenario minor increases until the 'inflection point') through 2050. Following the above results, GHG emissions are most significant under the Mixed case with average annual emissions 52% lower than the Base Case and a total of 144 thousand tons of CO_2 reduced through the deployment of a mixed fleet. The mixed fleet concept has the lowest annual emissions and thus realizes the greatest cumulative emissions reductions due to a combination of early BE deployments, earlier hydrogen deployment, and the elimination of all electricity-related carbon emissions from a 100% clean HCE grid after 2030.

Figure 60: Cumulative GHG Reductions for the 2040 Adoption Timeline



When considering a deployment timeline under 20 years, the deployment of a mixed fleet will deliver significantly more GHG reduction than an exclusively BEB or FCEB technology profile for RFTA.

13.2 2050 TIMELINE

When considering the 2050 horizon, the investment in a mix of battery electric and hydrogen remains compelling. Trends under the 2050 horizon are similar to those for the 2040 horizon, but somewhat prolonged in time. A mixed fleet has the lowest emissions over this timeline for the same reasons (clean hydrogen deployment and a 100% renewable HCE grid) as the 2040 timeline. As shown in Figure 61 overall, by 2050 all ZE technology profiles reach emissions at or below 1,000-ton CO_2 annually. By 2050, an all BEB fleet is estimated to make the most substantial reductions in annual GHG emissions because the MEAN grid is expected to have realized 100% renewable energy production.

Figure 61: Annual Emissions for the 2050 Adoption Timeline

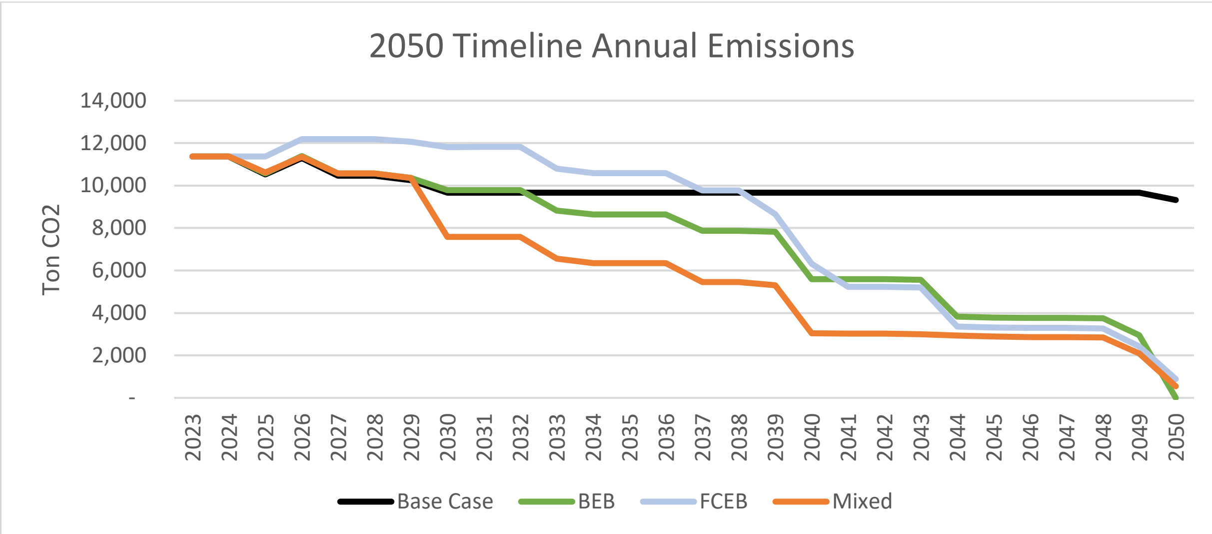
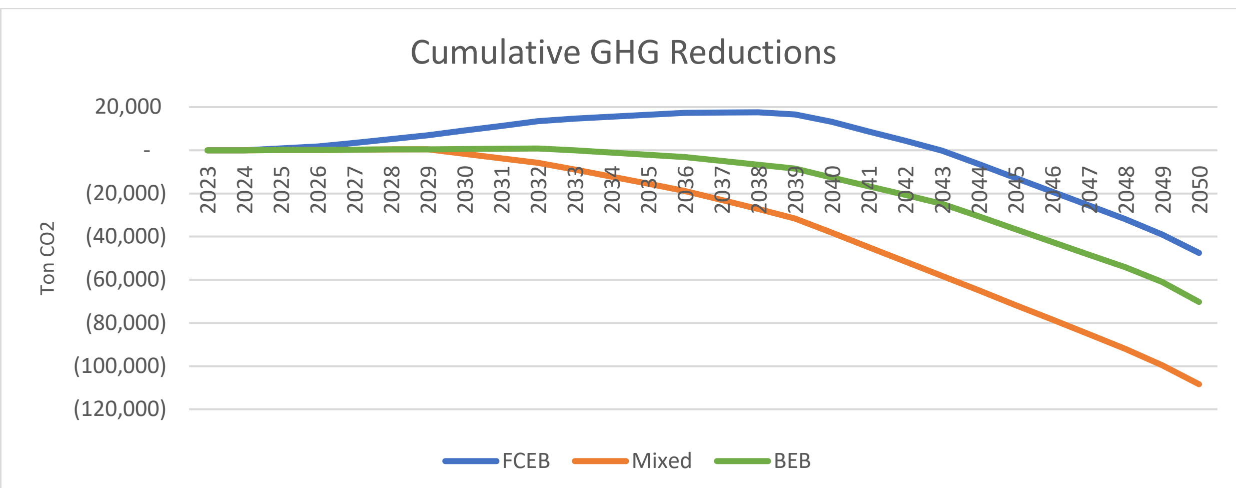


Figure 62 shows that in terms of cumulative reductions in GHG emissions the mixed technology fleet reduces the most emissions.

Figure 62: Cumulative GHG Emission Reductions for the 2050 Adoption Timeline



When comparing time horizons and technology selection, the deployment of a BEB or mixed fleet under the 2040 horizon stands out as resulting in the most significant cumulative GHG reductions. In absolute terms, as shown in Table 36, a mixed fleet, fully transitioned by 2040 will cumulatively reduce 144 thousand tons of CO_2 by 2050 and an exclusively BEB fleet 129 thousand in the same period. To compare timelines, a mixed fleet with a 2050 goal will reduce 108 thousand tons of CO_2 through 2050, 36 thousand fewer than a mixed fleet with a 2040 transition goal.

Table 36: Cumulative reductions by technology type and timeline

	Total Reductions (Ton CO_2) by		Reduction from Base
2040 Horizon	2040	2050	
BEB2040	(46,591)	(129,400)	-46%
FCEB2040	(35,804)	(123,200)	-44%
Mixed2040	(53,306)	(144,100)	-52%
2050 Horizon			
BEB2050	(12,583)	(70,300)	-25%
FCEB2050	13,239	(47,600)	-17%
Mixed2050	(38,211)	(108,400)	-39%

In conclusion, a more aggressive transition goal (2040), regardless of technology selection, will deliver the most significant GHG reductions. When looking at just technology deployment, under both timelines a mixed fleet delivers the most reductions respectively.

APPENDIX A: SITE PLAN

APPENDIX B: COST ESTIMATES

GMF BEB Case Cost Estimates Summary ($2023)					
Site and Electrical Improvements				**$**	**2,215,355**
Emergency Power (generator)				**$**	**1,519,468**
BEB Chargers				**$**	**6,798,600**
150kW chargers	$	158,620		$	4,758,600
Dispensers	$	34,000		$	2,040,000
SUBTOTAL				$	10,533,423
Escalation			**8%**	$	842,674
SUBTOTAL				$	11,376,097
General requirements			**15%**	$	1,706,415
SUBTOTAL				$	13,082,511
Estimate/Design			**20%**	$	2,616,502
SUBTOTAL				$	15,699,014
Phasing factor			**3.5%**	$	549,465
SUBTOTAL				$	16,248,479
Bonds and Insurance			**2%**	$	324,970
Contractor's fee			**7%**	$	1,137,394
				$	17,710,842
TOTAL				**$**	**17,710,842**

AMF BEB Case Cost Estimates Summary ($2023)			
Site and Electrical Improvements		**$**	**399,725**
Emergency Power (generator)		**$**	**870,819**
Building Mechanical Modifications		**$**	**491,275**
Hydrogen Fueling Modifications		**$**	**170,126**
Hydrogen Fueling Yard		**$**	**4,831,230**
SUBTOTAL		$	6,763,175
Escalation	**8%**	$	541,054
SUBTOTAL		$	7,304,229
General requirements	**15%**	$	1,095,634
SUBTOTAL		$	8,399,863
Estimate/Design	**20%**	$	1,679,973
SUBTOTAL		$	10,079,836
Phasing factor	**3.5%**	$	352,794
SUBTOTAL		$	10,432,630
Bonds and Insurance	**2%**	$	208,653
Contractor's fee	**7%**	$	730,284
		$	11,371,567
TOTAL		**$**	**11,371,567**

GMF FCEB Case Cost Estimates Summary ($2023)			
Site and Electrical Improvements		**$**	**399,725**
Emergency Power (generator)		**$**	**713,333**
Building Mechanical Modifications		**$**	**330,000**
Hydrogen Fueling Modifications		**$**	**157,441**
Hydrogen Fueling Yard		**$**	**4,697,113**
SUBTOTAL		$	6,297,612
Escalation	**8%**	$	503,809
SUBTOTAL		$	6,801,421
General requirements	**15%**	$	1,020,213
SUBTOTAL		$	7,821,634
Estimate/Design	**20%**	$	1,564,327
SUBTOTAL		$	9,385,961
Phasing factor	**3.5%**	$	328,509
SUBTOTAL		$	9,714,470
Bonds and Insurance	**2%**	$	194,289
Contractor's fee	**7%**	$	680,013
		$	10,588,772
TOTAL		**$**	**10,588,772**

AMF BEB Case Cost Estimates Summary ($2023)			
Site and Electrical Improvements		**$**	**399,725**
Emergency Power (generator)		**$**	**870,819**
Building Mechanical Modifications		**$**	**491,275**
Hydrogen Fueling Modifications		**$**	**170,126**
Hydrogen Fueling Yard		**$**	**4,831,230**
SUBTOTAL		$	6,763,175
Escalation	**8%**	$	541,054
SUBTOTAL		$	7,304,229
General requirements	**15%**	$	1,095,634
SUBTOTAL		$	8,399,863
Estimate/Design	**20%**	$	1,679,973
SUBTOTAL		$	10,079,836
Phasing factor	**3.5%**	$	352,794
SUBTOTAL		$	10,432,630
Bonds and Insurance	**2%**	$	208,653
Contractor's fee	**7%**	$	730,284
		$	11,371,567
TOTAL		**$**	**11,371,567**

NOTE:

APPENDIX C: FINANCIAL MODELING INPUTS AND ASSUMPTIONS AND DRAFT REVENUE FLEET

Table 37 presents a description as well as the sources for the revenue fleet cost inputs (in 2023$) that will be used to calculate the Total Cost of Ownership for each Zero-Emission Bus cases and the Base Case (or business as usual).

Table 37: Summary of cost inputs (revenue fleets)

Main Category	Item	Description	Inputs for Base Case	Inputs for ZEB Case	Sources and comments
Capital					
Fleet acquisition	Bus purchase price	Purchase price of a bus/vehicle inclusive of options and taxes and extended warranty	30ft_CNG $555,000 35ft_Diesel $704,024 40ft_BEB $1,431,521 40ft_CNG $828,326 40ft_Diesel $739,750 45ft_CNG $1,171,099 45ft_Diesel $978,635 Cutaway_Unleaded $119,358 Cutaway_CNG $154,715	30ft_BEB $859,800 35ft_BEB $1,154,160 40ft_BEB $1,431,521 45ft_BEB $1,893,797 Cutaway_BEB $339,240 30ft_FCEB $988,770 35ft_FCEB $1,327,284 40ft_FCEB $1,646,249 45ft_FCEB $2,177,866 Cutaway_FCEB $359,827	**Disel, CNG, and BEB costs:** Information provided by RFTA in the fleet inventory data, adjusted with a 12% increase rate from 2021 prices to 2022 and an increase rate of 20% from prices in 2022 to the present in 2023$'s. Cost for diesel 30-ft bus was taken from California open procurement contracts. **FCEBs:** For all FCEBs (including cutaways) a 15% increase of costs on BEB costs is applied. In general, FCEBs are 15-20% more expensive than BEB from Stantec research. **Projections:** Stantec applied a trend for the cost projection of all bus types based on market trends and experts' predictions. See Figure 63 for details.

Fleet refurbishment	Mid-life rehabs	Any heavy mid-life work needed to achieve the useful life minimum benchmark	For engine and transmission rebuild: 45-ft CNG bus: $58,000 45-ft Diesel bus: $41,800 40-ft CNG bus: $36,400 40-ft Diesel bus: $28,900 35-ft Diesel bus: $39,900 Cutaways: N/A	FCEB: $30,000 per bus for fuel cell replacement BEB: 416 $/kWh (2023) price trend changes based on the year. Cutaways: no battery replacement assumed for BEBs	**CNG and Diesel buses**: based on estimates provided by RFTA in NFI capital charges data from 2014 through 2023 and updated to 2023$ **FCEB:** Stantec estimate based on information from Ballard. A 3% inflation per year is applied to the costs. **BEB:** Projections based on Bloomberg NEF 2021 Report. See Figure 64 for details. A 3% inflation per year is applied to the BEB battery replacement costs.
Infrastructure and Facility Modifications	Infrastructure Modification Costs	Includes equipment, installation (chargers and hydrogen fueling), testing, civil and electrical work, as well as contractor's fees and escalation factors. Includes backup generator for hydrogen fueling equipment and BEB chargers.	Aspen and Glenwood for a total of 40 plugs: $11,380,000 in 2023$	Glenwood BEB: $17,711,000 in 2023$ but scalation of 8% per year will be applied to any charging infrastructure installed past 2023. Glenwood FCEBs: $10,600,000 in 2023$ Aspen BEB: $13,950,000 in 2023$ Aspen FCEB: $11,380,000 in 2023$	Based on cost estimated produced by subconsultant Johan Kemp Inc. 3% inflation per year is used for BEB and FCEB equipment and 8% inflation per year for construction and labor costs was applied.
Vehicle Useful Lifetime	When vehicles are retired	Year of replacement for each vehicle type	40ft CNG: 14 years 40ft Diesel: 14 years 45ft Diesel: 14 years 45ft CNG: 14 years	40ft BEBs: 14 years 45ft BEBs: 14 years 40ft FCEBs: 14 years 45ft FCEBs: 14 years	Based on current RFTA goals for their upcoming procurement and assumed the same lifespan for ZEBs.

		after year in service	Cutaways: 10 years	Cutaways: 10 years	
Operating and Maintenance					
Operating	Vehicle fuel	Cost of fuel commodity for revenue vehicles	CNG: $1.95/DGE Diesel: $3.05/gallon Gasoline $2.57/gallon	Hydrogen: $8/kg as a start, ramping down to $6/kg in 2030 with a goal of $3/kg past 2040 Electricity_COA $0.095 Electricity_Glenwood $0.106 Electricy_RGW $0.113 Electricity_Garfield $0.113	**CNG, Diesel and gasoline:** RFTA data. **Electricity:** It will be based on the current rates provided by each utility provider and based on the past stakeholder engagements. A cost model was developed to estimate the charging at peak and off-peak hours based on the anticipated charging profile for each site. **Projections:** Stantec applied a trend for the cost projection of fuel types based on EIA energy projections. See Figure 65 for details. A 3% inflation per year is applied to the fuel costs. **Hydrogen:** based on estimates from past clients in California and assuming a green tax. Bloomberg NEF 2021 report had a similar trend for green hydrogen cost projections. A 3% inflation per year is applied to the hydrogen costs.

Maintenance	Vehicle maintenance costs	Maintenance costs (per mile) inclusive of labor and parts for scheduled and unscheduled maintenance	30ft CNG $0.89 35ft Diesel $1.93 40ft BEB COA $1.50 40ft BEB RFTA $1.69 40ft CNG RFTA $0.79 40ft Diesel RFTA $0.92 40ft Diesel RGW $1.34 45ft CNG RFTA $1.04 45ft Diesel RFTA $1.04	40ft BEB COA $1.50[26] 40ft BEB RFTA NEW $0.77 45ft BEB RFTA $0.94 40ft FCEB COA $1.50 40ft FCEB RFTA $0.77 45ft FCEB RFTA $0.94	**Disel, CNG, and BEB:** RFTA provided maintenance costs per vehicle, fuel type, and fleet ownership. **BEBs and FCEB 40-ft bus:** Stantec assumption is for current price will remain as of current BEBs maintenance cost for RFTA with a gradual reduction until maintenance cost is 10% of the fossil-fuel baseline buses given assumed training efficiency and parts availability.
Fuel Efficiency	Fuel consumption by vehicle type	Considers the energy consumption of each vehicle type on a per mile basis	See table 1 for details	See table 1 for details	Based on RFTA ZEV 1.7 Fleet Usage Fuel Type data **ZEB:** based on modeling conducted by Stantec
Vehicle Utilization	Yearly mileage	The level of utilization is based on the data recorded for current fleet	See table 2 for details	See table 2 for details	Based on RFTA 2022 vehicle maintenance costs data. **ZEB:** yearly mileage assumed to remain constant with base case

[26] While the labor cost and parts expenses are expected to be the same for vehicles operating COA and RFTA services, in the future Stantec assumed the level of mileage operated for COA will remain constant, while the mileage for RFTA services ran by the 40-ft BEBs will be increased thanks to availability of on-route charging.

Figure 63. Price trend for the future cost of buses

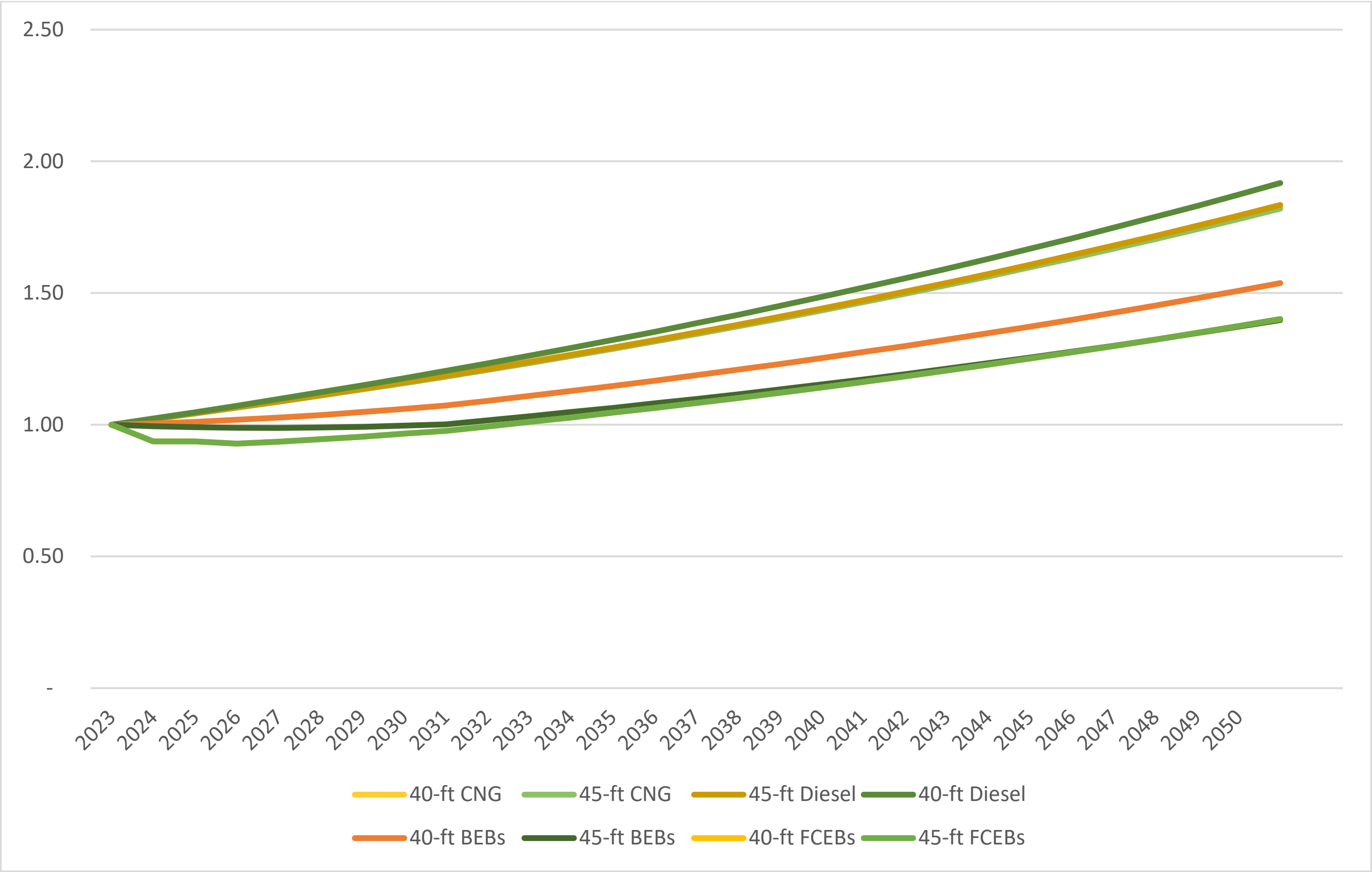


Figure 64. Price trend for battery cost in the future

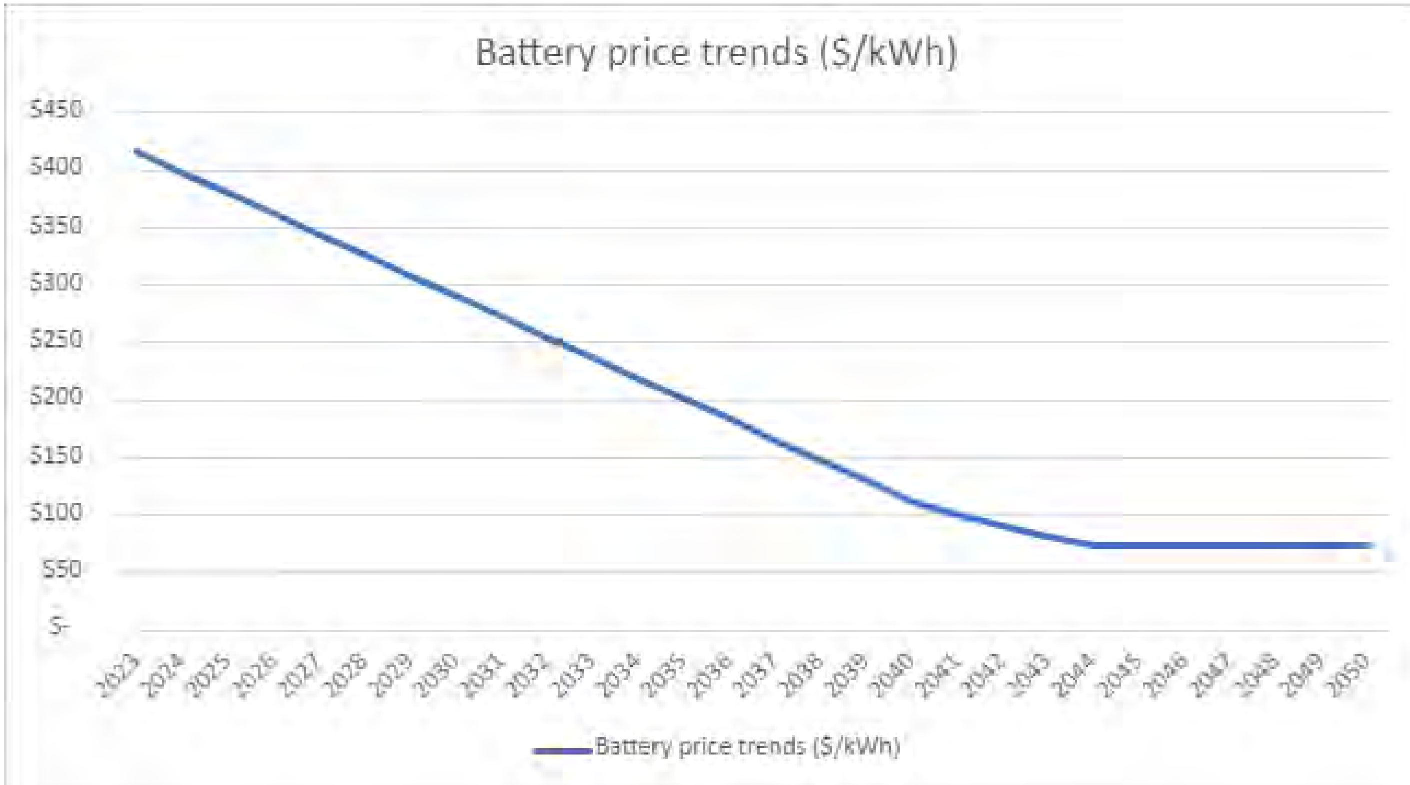


Figure 65. Price trend for Fuel and Energy Costs

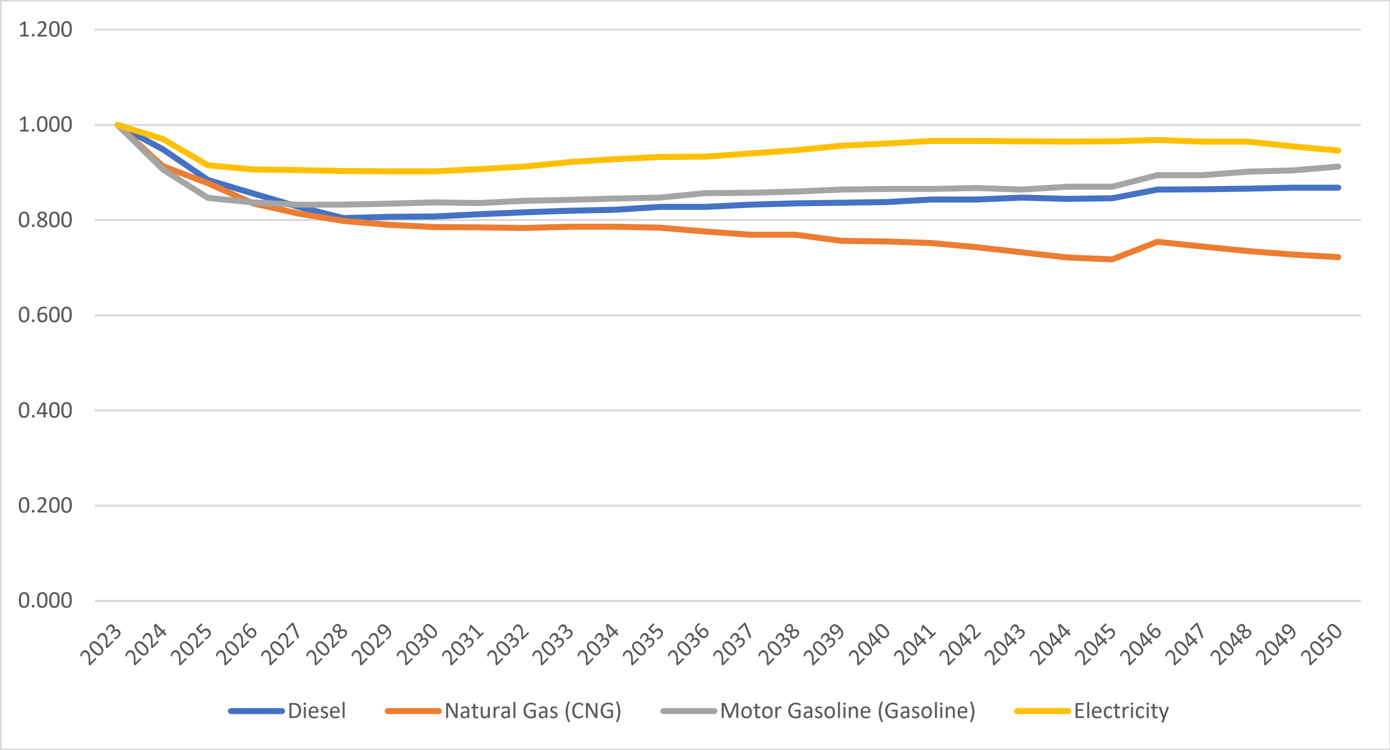


Table 38. Assumed fuel efficiency

Vehicle Type	Fuel Efficiency	Unit
30ft_CNG_RGW	4.52	miles/DGE
35ft_Diesel_COA	5.20	miles/diesel gallon
40ft_BEB_COA	0.48	mi/kWh
40ft_BEB_RFTA	0.48	mi/kWh
40ft_CNG_RFTA	5.37	miles/DGE
40ft_Diesel_RFTA	5.97	miles/diesel gallon
40ft_Diesel_RGW	5.97	miles/diesel gallon
45ft_CNG_RFTA	4.48	miles/DGE
45ft_Diesel_RFTA	5.43	miles/diesel gallon
Cutaway_ADA_Unleaded_RFTA	7.75	miles/gallon
Cutaway_Cdale_Unleaded_RFTA	7.75	miles/gallon
Cutaway_Senior_Unleaded_RFTA	7.75	miles/gallon
Cutaway_Senior_Unleaded_COA	7.75	miles/gallon
Cutaway_ADA_Unleaded_COA	7.75	miles/gallon
Cutaway_Traveler_CNG_Garfield County	8.77	miles/DGE
Cutaway_Traveler_Unleaded_Garfield County	7.75	miles/gallon
Cutaway_Woody Creek_Unleaded_RFTA	7.75	miles/gallon
30ft_BEB_RGW	0.52	mi/kWh
35ft_BEB_COA	0.43	mi/kWh
40ft_BEB_RGW	0.46	mi/kWh
40ft_BEB_RFTA_NEW	0.48	mi/kWh
45ft_BEB_RFTA	0.47	mi/kWh
Cutaway_ADA_BEB_RFTA	0.47	mi/kWh
Cutaway_Cdale_BEB_RFTA	0.47	mi/kWh
Cutaway_Senior_BEB_RFTA	0.47	mi/kWh
Cutaway_Senior_BEB_COA	0.47	mi/kWh
Cutaway_ADA_BEB_COA	0.47	mi/kWh

Cutaway_Traveler_BEB_Garfield County	0.47	mi/kWh
Cutaway_Woody Creek_BEB_RFTA	0.47	mi/kWh
30ft_FCEB_RGW	8.37	miles/Kg
35ft_FCEB_COA	7.49	miles/Kg
40ft_FCEB_COA	6.89	miles/Kg
40ft_FCEB_RFTA	6.89	miles/Kg
40ft_FCEB_RGW	6.89	miles/Kg
45ft_FCEB_RFTA	7.68	miles/Kg
Cutaway_ADA_FCEB_RFTA	8.33	miles/Kg
Cutaway_Cdale_FCEB_RFTA	8.33	miles/Kg
Cutaway_Senior_FCEB_RFTA	8.33	miles/Kg
Cutaway_Senior_FCEB_COA	8.33	miles/Kg
Cutaway_ADA_FCEB_COA	8.33	miles/Kg
Cutaway_Traveler_FCEB_Garfield County	8.33	miles/Kg
Cutaway_Woody Creek_FCEB_RFTA	8.33	miles/Kg

Table 39. Assumed vehicle utilization.

Vehicle Type	Mileage	Unit
30ft_CNG_RGW	39,163	mi/ veh/ year
35ft_Diesel_COA	28,809	mi/ veh/ year
40ft_BEB_COA	19,887	mi/ veh/ year
40ft_BEB_RFTA	19,449	mi/ veh/ year
40ft_CNG_RFTA	47,922	mi/ veh/ year
40ft_Diesel_RFTA	47,922	mi/ veh/ year
40ft_Diesel_RGW	28,468	mi/ veh/ year
45ft_CNG_RFTA	63,664	mi/ veh/ year
45ft_Diesel_RFTA	63,664	mi/ veh/ year
Cutaway_ADA_Unleaded_RFTA	12,734	mi/ veh/ year
Cutaway_Cdale_Unleaded_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_Unleaded_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_Unleaded_COA	12,734	mi/ veh/ year
Cutaway_ADA_Unleaded_COA	12,734	mi/ veh/ year
Cutaway_Traveler_CNG_Garfield County	7,190	mi/ veh/ year
Cutaway_Traveler_Unleaded_Garfield County	7,190	mi/ veh/ year
Cutaway_Woody Creek_Unleaded_RFTA	12,734	mi/ veh/ year
30ft_BEB_RGW	39,163	mi/ veh/ year
35ft_BEB_COA	28,809	mi/ veh/ year
40ft_BEB_RGW	28,468	mi/ veh/ year
40ft_BEB_RFTA_NEW	47,922	mi/ veh/ year
45ft_BEB_RFTA	63,664	mi/ veh/ year
Cutaway_ADA_BEB_RFTA	12,734	mi/ veh/ year
Cutaway_Cdale_BEB_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_BEB_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_BEB_COA	12,734	mi/ veh/ year

Cutaway_ADA_BEB_COA	12,734	mi/ veh/ year
Cutaway_Traveler_BEB_Garfield County	7,190	mi/ veh/ year
Cutaway_Woody Creek_BEB_RFTA	12,734	mi/ veh/ year
30ft_FCEB_RGW	12,734	mi/ veh/ year
35ft_FCEB_COA	39,163	mi/ veh/ year
40ft_FCEB_COA	28,809	mi/ veh/ year
40ft_FCEB_RFTA	19,887	mi/ veh/ year
40ft_FCEB_RGW	47,922	mi/ veh/ year
45ft_FCEB_RFTA	28,468	mi/ veh/ year
Cutaway_ADA_FCEB_RFTA	63,664	mi/ veh/ year
Cutaway_Cdale_FCEB_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_FCEB_RFTA	12,734	mi/ veh/ year
Cutaway_Senior_FCEB_COA	12,734	mi/ veh/ year
Cutaway_ADA_FCEB_COA	12,734	mi/ veh/ year
Cutaway_Traveler_FCEB_Garfield County	12,734	mi/ veh/ year
Cutaway_Woody Creek_FCEB_RFTA	7,190	mi/ veh/ year

APPENDIX D: FINANCIAL MODELING INPUTS AND ASSUMPTIONS FOR THE SERVICE FLEET

Table 40 presents a list of the fossil fuel service vehicle types by department and the identified ZEV replacement for each, along with the assumptions adopted for EV range, battery size, efficiency, and costs.

Table 40. BE Service Vehicle Assumptions

FF Service Vehicle Type	Identified BEV	BEV Range	Battery Size[kWh]	Efficiency mi/kWh	BE Vehicle Costs (2023$)
Admin_Sedan	Nissan / LEAF SV PLUS	212	60	3.53	$ 39,498
MP_Sedan	Nissan / LEAF SV PLUS	212	60	3.53	$ 39,498
Facilities _Pickup - Medium	Mullen / Three	130	89	1.46	$ 72,858
Facilities _Pickup - Small	Ford / F-150 Lightning XLT (Standard)	240	98	2.45	$ 61,551
MP_Passenger Van	Ford / e-Transit Cargo Low Roof	126	68	1.85	$ 59,121
Finance_Sedan	Nissan / LEAF SV PLUS	212	60	3.53	$ 39,498
HR_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500
IT_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500
Maint_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500
Maint_Passenger Van	Ford / e-Transit Cargo Low Roof	126	68	1.85	$ 59,121
Maint_Straight truck	Freightliner / eM2	150	194	0.77	$ 224,424
Maint_Pickup - Medium	Mullen / Three	130	89	1.46	$ 72,858
Maint_Pickup - Large	SEA 5e	140	138	1.01	$ 113,807
MP_Pickup - Small	Ford / F-150 Lightning XLT (Standard)	240	98	2.45	$ 61,551
OPS_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500
OPS_Passenger Van	Ford / e-Transit Cargo Low Roof	126	68	1.85	$ 59,121
TRAV_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500
MP_SUV	Hyundai / Ioniq 5	303	77	3.91	$ 47,500

Table 41 presents a list of the fossil fuel service vehicle types by department and the identified FCEV replacement for each, along with the assumptions adopted for FCEV range, tank size, efficiency, and costs.

Table 41. FCE Service Vehicle Assumptions

FF Service Vehicle Type	Identified FCEV	FCEV Range	Tank Size [kg]	mi/kg	FCE Vehicle Costs (2023$)
Admin_Sedan	Toyota / Miria (XLE)	402	5.6	71.8	$ 50,190
MP_Sedan	Toyota / Miria (XLE)	402	5.6	71.8	$ 50,190
Facilities _Pickup - Medium	FCEB Pickup - Medium	300	6.7	44.8	$ 108,721
Facilities _Pickup - Small	FCEB Pickup - Small	300	6.7	44.8	$ 89,806
MP_Passenger Van	FCEB Passenger Van	300	6.7	44.8	$ 65,446
Finance_Sedan	Toyota / Miria (XLE)	402	5.6	71.8	$ 50,190
HR_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135
IT_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135
Maint_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135
Maint_Passenger Van	FCEB Passenger Van	300	6.7	44.8	$ 65,446
Maint_Straight truck	FCEB Straight truck	300	6.7	8.9	$ 210,597
Maint_Pickup - Medium	FCEB Pickup - Medium	300	6.7	44.8	$ 108,721
Maint_Pickup - Large	FCEB Pickup - Large	300	6.7	15.0	$ 120,721
MP_Pickup - Small	FCEB Pickup - Small	300	6.7	44.8	$ 89,806
OPS_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135
OPS_Passenger Van	FCEB Passenger Van	300	6.7	44.8	$ 65,446
TRAV_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135
MP_SUV	Hyundai / Nexo	380	6.3	60.0	$ 60,135

Table 42 lists the service fleet, the vehicle status and the transition readiness by service vehicle type and department.

Table 42. Service Vehicle Inventory

Quantity	Vehicle Type	Fuel	Year	ULB	ULB Retire	Planned Retire (Input)	Age at Retire	Event Type	Expansion	Vehicle ID	Facility new	Transition Readiness Indicator	Assumptions & Notes	Status
	Admin_Sedan	Unleaded	2024	10	2034	**2034**	10	Replace	No	EXP1		High	New to replace Admin to MP	Not active on 9/2023
1	MP_Sedan	Unleaded	2008	10	2018	**2025**	17	Replace	No	L2	AMF	low	Move from Admin to MP	
	MP_Sedan	Unleaded	2013	10	2023	**2025**	12	Replace	No	L3		low	Move from Admin to MP	ACTIVE SURPLUS
	Facilities _Pickup - Medium	Unleaded	2023	10	2033	**2034**	11	Replace	No	F30,F31,F32		low	Stay in Facilities	Not active on 9/2023
	Facilities _Pickup - Small	Unleaded	2024	10	2034	**2036**	12	Replace	No	EXP9,EXP10		High	Added to fleet to account for vehicle moved to MP	Not active on 9/2023
	Facilities _Pickup - Small	Unleaded	2007	10	2017	**2024**	17	Replace	No	F10		High	Stay in Facilities	ACTIVE SURPLUS
	Facilities _Pickup - Medium	Unleaded	2008	10	2018	**2024**	16	Replace	No	F12		low	Stay in Facilities	ACTIVE SURPLUS
1	Facilities _Pickup - Medium	Unleaded	2012	10	2022	**2023**	11	Replace	No	F15	GMF	low	Stay in Facilities	
1	Facilities _Pickup - Small	Unleaded	2013	10	2023	**2025**	12	Replace	No	F17	GMF	High	Stay in Facilities	
1	Facilities _Pickup - Medium	Unleaded	2013	10	2023	**2025**	12	Replace	No	F18	GMF	low	Stay in Facilities	
1	Facilities _Pickup - Small	Unleaded	2014	10	2024	**2026**	12	Replace	No	F19	GMF	High	Stay in Facilities	
2	Facilities _Pickup - Medium	Unleaded	2014	10	2024	**2026**	12	Replace	No	F20,F21	GMF	low	Stay in Facilities	
1	Facilities _Pickup - Small	Unleaded	2016	10	2026	**2028**	12	Replace	No	F22	GMF	High	Stay in Facilities	
1	Facilities _Pickup - Medium	Unleaded	2019	10	2029	**2031**	12	Replace	No	F24	GMF	low	Stay in Facilities	
2	Facilities _Pickup - Medium	Unleaded	2020	10	2030	**2034**	14	Replace	No	F25,F26	GMF	low	Stay in Facilities	
2	Facilities _Pickup - Small	Unleaded	2023	10	2033	**2035**	12	Replace	No	F27,F28	GMF	High	Stay in Facilities	
	Facilities _Pickup - Medium	Unleaded	2023	10	2033	**2035**	12	Replace	No	F29		low	Stay in Facilities	ACTIVE PREP
1	MP_Passenger Van	Unleaded	2013	10	2023	**2023**	10	Replace	No	L4	GMF	low	Move from Facilities to MP	
1	Finance_Sedan	Unleaded	2013	10	2023	**2024**	11	Replace	No	L5	GMF	High	Stay in Finance	
1	HR_SUV	Unleaded	2021	10	2031	**2030**	9	Replace	No	L6	GMF	High	Stay in HR	
	IT_SUV	Unleaded	2013	10	2023	**2023**	10		No	X1		High	no replacement	
	IT_SUV	Unleaded	2006	10	2016	**2023**	17		No	X3		High	no replacement	
1	IT_SUV	Unleaded	2022	10	2032	**2031**	9	Replace	No	X4	GMF	High	Stay in IT	
	IT_SUV	Unleaded	2023	10	2033	**2033**	10	Replace	No	X5,X6,X7		High	Stay in IT	Not active on 9/2023
	Maint_SUV	Unleaded	2023	10	2033	**2033**	10	Replace	No	M3		High	Stay in Maint	Not active on 9/2023
	Maint_Passenger Van	Unleaded	2008	10	2018	**2024**	16		No	G09		low	No replacement	
1	MP_Sedan	Unleaded	1995	10	2005	**2024**	29	Replace	No	L1	GMF	low	Move from Maint to MP	
2	Maint_Passenger Van	Unleaded	2020	10	2030	**2028**	8	Replace	No	M1,M2	AMF	low	Stay in Maint	
1	Maint_Straight truck	Diesel	1998	10	2008	**2029**	31	Replace	No	T10	AMF	low	Stay in Maint	
1	Maint_Straight truck	Diesel	2018	10	2028	**2030**	12	Replace	No	T11	GMF	low	Stay in Maint	
1	Maint_Pickup - Medium	Unleaded	2020	10	2030	**2032**	12	Replace	No	T12	AMF	Low/Medium	Stay in Maint	
	Maint_Pickup - Medium	Unleaded	2023	10	2033	**2033**	10	Replace	No	T13		Low/Medium	Stay in Maint	ACTIVE PREP
1	Maint_Pickup - Large	Unleaded	2008	10	2018	**2027**	19	Replace	No	T7	GMF	low	Stay in Maint	
	Maint_Pickup - Medium	Unleaded	2023	10	2033	**2035**	12	Replace	No	T14		Low/Medium	Stay in Maint	ACTIVE PREP
1	MP_Pickup - Small	Unleaded	2005	10	2015	**2024**	19	Replace	No	F8	GMF	High	Stay in MP	
	OPS_SUV	Unleaded	2008	10	2018	**2024**	16		No	C11		High	previously replaced	ACTIVE SURPLUS
1	OPS_SUV	Unleaded	2013	10	2023	**2023**	10	Replace	No	C13	GMF	High	Stay in OPS	
1	OPS_SUV	Unleaded	2014	10	2024	**2024**	10	Replace	No	C14	GMF	High	Stay in OPS	
1	OPS_SUV	Unleaded	2016	10	2026	**2026**	10	Replace	No	C15	GMF	High	Stay in OPS	
2	OPS_SUV	Unleaded	2017	10	2027	**2027**	10	Replace	No	C16,C17	AMF	High	Stay in OPS	
1	OPS_SUV	Unleaded	2018	10	2028	**2028**	10	Replace	No	C18	AMF	High	Stay in OPS	
1	OPS_SUV	Unleaded	2019	10	2029	**2029**	10	Replace	No	C19	AMF	High	Stay in OPS	
1	OPS_SUV	Unleaded	2022	10	2032	**2031**	9	Replace	No	C20	GMF	High	Stay in OPS	
	OPS_SUV	Unleaded	2023	10	2033	**2033**	10	Replace	No	C21,C22,C23		High	Stay in OPS	ACTIVE PREP,NA
	OPS_SUV	Unleaded	2003	10	2013	**2032**	29		No	C6		High	previously replaced	Not active on 9/2023
	OPS_Passenger Van	Unleaded	2024	10	2034	**2034**	10	Replace	No	EXP5		low	Stay in Ops	Not active on 9/2023
2	OPS_Passenger Van	Unleaded	2008	10	2018	**2024**	16	Replace	No	G01,G05	GMF	low	replace only 1 van	
1	TRAV_SUV	Unleaded	2012	10	2022	**2025**	13	Replace	No	C12	GMF	High	Stay in TRAV	
	TRAV_SUV	Unleaded	2023	10	2033	**2033**	10	Replace	No	EXP6		High	Stay in TRAV	Not active on 9/2023
	MP_SUV	Unleaded	2024	10	2034	**2034**	10	Replace	No	MP1		High	Stay in OPS	Not active on 9/2023
1	TRAV_SUV	Unleaded	2006	10	2016	**2023**	17	Replace	No	G07	GMF	High	Owned by Grafield Co	