Mountain Line Transit

Zero-Emission Bus
Fleet Transition Study

Presented by Center for Transportation and the Environment

March 24, 2025

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List of Acronyms

BEB	Battery Electric Bus
CTE	Center for Transportation and the Environment
DCC	Downtown Connection Center
EV	Electric Vehicle
FCEB	Fuel Cell Electric Bus
GHG	Greenhouse Gas
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
kW	Kilowatt
kWh	Kilowatt Hour
kWh/mi	Kilowatt-hour/mile
MCC	Mall Connection Center

MW	Megawatt
MWh	Megawatt-hours
OEM	Original Equipment Manufacturer
ZE	Zero-Emission
ZEB	Zero-Emission Bus

Table 1 - Changes to the ZEB Plan

Note(s)	Date
Due to federal funding challenges in 2025, Mountain Line has paused the purchase of four battery electric buses identified in this report and full transition to all-electric is pushed four years out.	3/28/2025

Executive Summary

Project Goals

The primary goals of this project were to assess the feasibility of transitioning the entirety of Mountain Line's fixed-route fleet to 100% zero-emission technology and to understand technology options, transition timelines, and relevant costs. Mountain Line facilities are space constrained, but the agency is interested in scenario requirements to still reach 100% zero emission.

Within the scope of the plan, CTE estimated select capital and operational costs, planned project phases and timelines, and determined infrastructure requirements necessary to adopt ZEB fleet vehicles.

Preferred Charging Scenario

Current electric bus battery capacity cannot achieve Mountain Line's service blocks on a single charge today or through 2040. They have two options: either swap out buses at midday, resulting in 15 additional buses to support the depot-only charging strategy, or add on-route charging to cover the gap between battery capacity and block energy requirements.

Based on the results of the 2020 ZEB Plan and 2025 ZEB Plan update, Mountain Line staff believe the on-route and depot charging scenario makes the most sense based on their climate, topography, and service structure at the time of this study. Following the on-route and depot charging scenario, Mountain Line anticipates approximately $31 million in incremental cost above baseline diesel hybrid buses in cumulative fuel, fleet, and maintenance costs through 2040; this is the lowest through the full transition among the options. Additionally, the on-route and depot charging scenario has the highest emission savings with a 68% reduction from baseline hybrid diesel. (Please note maintenance costs and emissions were carried forward from the 2020 ZEB Plan as they were not analyzed in this update.)

The ZEB Plan is a guiding document that applies industry best practices to Mountain Line's set of conditions at the time of analysis. As circumstances and assumptions change and opportunities arise, Mountain Line is encouraged to pivot how and when they achieve a zero-emission future using resources in this Plan, and document those changes in **Table 1** Changes to the ZEB Plan.

Introduction

This project is funded by the Joint Office of Energy and Transportation through the Clean Bus Planning Awards Program (CBPA), which offers free technical assistance for planning and implementing zero-emission charging and fueling infrastructure, as well as zero-emission transit and school buses. Administered by the National Renewable Energy Laboratory (NREL), the program engaged the Center for Transportation and the Environment (CTE) to update key components of Mountain Line's Zero-Emission Bus (ZEB) implementation plan originally completed by CTE in 2020. Subsequent adjustments to the Mountain Line Transit BEB rollout and charging infrastructure construction timelines necessitate targeted updates rather than a full transition plan overhaul.

This effort focuses on optimizing Mountain Line's infrastructure deployment and utilization strategies to ensure a cost-effective and operationally efficient transition. The project will evaluate the existing charging infrastructure plan, recommending updates where necessary to charger locations, power levels, and deployment timelines. Additionally, it will assess operational strategies to maximize the efficiency of planned charging assets.

The transition plan updated specific sections of the 2020 ZEB Implementation Plan, incorporating current technology trends and Mountain Line's revised deployment schedule. These updates will cover route and bus modeling, service planning recommendations, rate modeling, infrastructure requirements, battery configurations, charging details, and infrastructure cost estimates.

About Mountain Line

Mountain Line, operated by Northern Arizona Intergovernmental Public Transportation Authority (NAIPTA), provides fixed-route bus service to Flagstaff, Arizona and seasonal bus service to Arizona Snowbowl Ski Resort. In 2008, voters approved a sales tax increase allowing Mountain Line to adopt low and zero-emissions bus technologies as their fleet expands and is replaced, and a subsequent increase was approved in 2024 that included the continued transition to electric vehicles.

Additionally, in 2018 the Flagstaff City Council adopted a Climate Action and Adaptation Plan which aims to reduce greenhouse gas emissions in Flagstaff by 30% by 2030 and by 80% by 2050.

Transit Agency's Name: Mountain Line Transit (Mountain Line)

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Project Goals

The primary goals of this project were to assess the feasibility of transitioning the entirety of Mountain Line's fixed-route fleet to 100% zero-emission technology and to understand technology options, transition timelines, and relevant costs. Mountain Line facilities are space constrained, but the agency is interested in scenario requirements to still reach 100% ZE.

Within the scope of the plan, CTE estimated select capital and operational costs, planned project phases and timelines, and determined infrastructure requirements necessary to adopt ZEB fleet vehicles.

Zero-Emission Transition Overview

The zero-emission technologies considered in this study includes only BEBs. Mountain Line decided to not consider FCEBs in this analysis but expressed interest in FCEBs if smaller 35' models become available. Additional challenges with FCEBs include boil-off inefficiencies and a lack of fueling sources, making Mountain Line hesitant to adopt this technology at this time. These buses have similar electric drive systems that feature a traction motor powered by a battery. The primary differences between BEBs and FCEBs are the respective amount of battery storage and the method by which the batteries are recharged. The electric drive components and energy source for a diesel bus, BEB, and FCEB are illustrated in Error! Reference source not found.

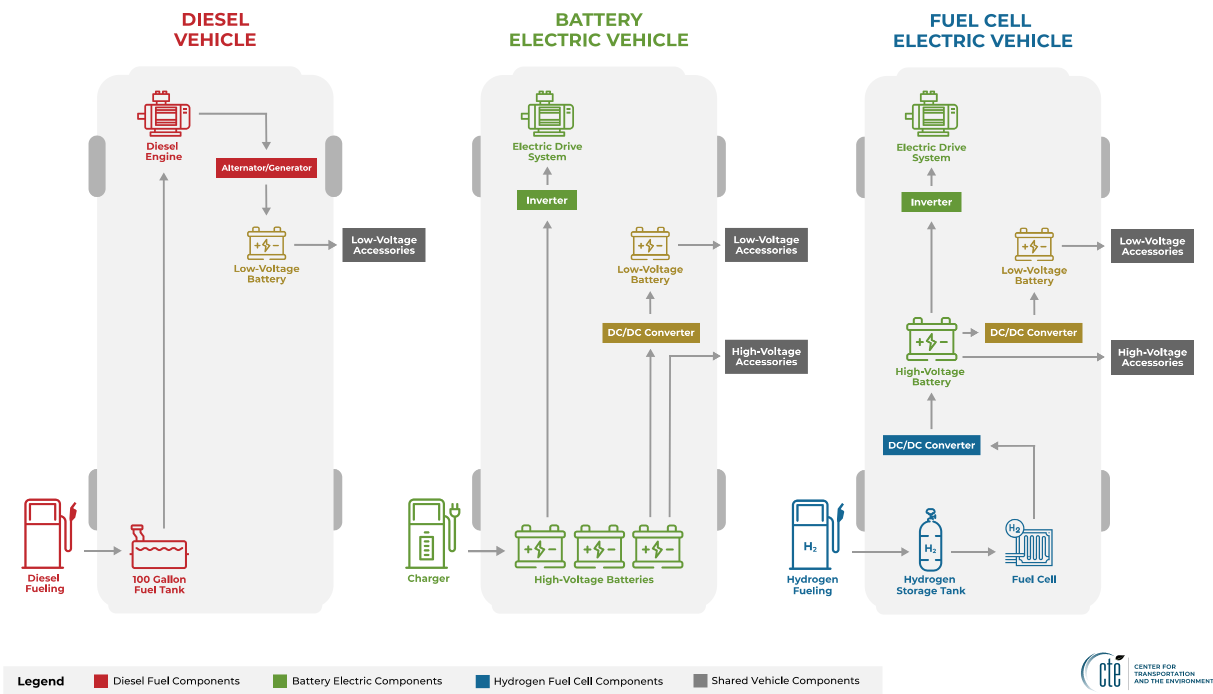

Figure 1 - Battery and Fuel Cell Electric Bus Schematic

Emissions Reductions

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

Criteria pollutants include carbon monoxide (CO), nitrogen oxides (NOx), particulate matter under 10 and 2.5 microns (PM_{10} and $PM_{2.5}$), volatile organic compounds (VOC), and sulfur oxides (SO_X). These pollutants are considered harmful to human health because they are linked to cardiovascular issues, respiratory complications, or other adverse health effects.[1] These compounds are also commonly responsible for acid rain and smog. Criteria

[1] Institute of Medicine. Toward Environmental Justice: Research, Education, and Health Policy Needs. Washington, DC: National Academy Press, 1999; O'Neill MS, et al. Health, wealth, and air pollution: Advancing theory and methods. Environ Health Perspect. 2003; 111: 1861-1870; Finkelstein et al. Relation between income, air pollution and mortality: A cohort study. CMAJ. 2003; 169: 397-402; Zeka A, Zanobetti A, Schwartz

pollutants cause economic, environmental, and health effects locally where they are emitted.

By transitioning to ZEBs from diesel buses, Mountain Line's zero-emission fleet will produce fewer carbon emissions and fewer harmful pollutants from the vehicle tailpipes. Environmental impacts, both from climate change and from local pollutants, disproportionately affect transit riders. For instance, poor air quality from tailpipe emissions and extreme heat harm riders waiting for buses at roadside stops. The transition to zero-emission technology will benefit the region by reducing fine particulate pollution and improving overall air quality. In turn, the fleet transition will support better public health outcomes for residents in disadvantaged communities served by the selected routes.

Disadvantaged communities are both socioeconomically disadvantaged and environmentally disadvantaged due to local air quality. Lower income neighborhoods are often exposed to greater vehicle pollution levels due to proximity to freeways and the ports, which puts these communities at greater risk of health issues associated with tailpipe emissions.[2] Communities disadvantaged by pollution served by Mountain Line's fleet will also directly benefit from the reduced tailpipe emissions of ZEBs compared to ICE buses.[3]

For an Emissions Assessment for each of the charging scenarios from a different CTE study, see page 63 of Mountain Line's 2020 ZEB Plan Phase One: Fleet Technology Analysis on their website at https://mountainline.az.gov/about-us/reports-plans/.

Purpose of Transition Planning

Developing a transition plan helps provide a holistic view of long-term fleet management, the availability of current and future infrastructure requirements, and the agency's workforce development goals. This not only supports identifying funding constraints for procurements over the entire transition period, but it also aids multi-year contracts with vehicle OEMs, fuel providers, and gives utilities the opportunity to plan ahead.

J. Short term effects of particulate matter on cause specific mortality: effects of lags and modification by city characteristics. Occup Environ Med. 2006; 62: 718-725.

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

[3] U.S. DOT 2022 Transportation Disadvantaged Census Tracts (Historically Disadvantaged Communities)

CTE ZEB Transition Planning Methodology

The phases specific to this study are outlined below:

For the **Requirements & Data Collection**, CTE collects GPS data on selected routes and utilizes software models to estimate ZEB performance. The results from this modeling are used to estimate feasibility of every block in Mountain Line's network using ZEVs.

The **Service Assessment** phase initiates the technical analysis of the study. The results from the Service Assessment are used to guide ZEB procurements in the Fleet Assessment and to determine energy requirements (depot charging and/or hydrogen) in the Fuel Assessment. CTE met with Mountain Line to define assumptions and requirements used throughout the study and to collect operational data. This process was conducted for the fixed service blocks for buses.

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

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

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

Transition Plan Scenarios

The approach for the study is based on analysis of two ZEB technology scenarios compared to a baseline scenario:

0. Baseline (Current Fleet: Diesel/Hybrid)
1. BEB Depot (Plug-in) Only Charging
2. BEB Depot (Plug-in) and On-Route (Pantograph) Charging

Requirements Analysis

Baseline Data Collection

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

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

CTE prepared and distributed the Mountain Line Data Collection Template to the agency to begin the **Requirements Analysis & Data Collection** stage of the project.

Fleet Composition

Table 2 summarizes Mountain Line's 2024 fleet by vehicle size, fuel type, and bus length. The fleet currently consists of two Electric 35', 22 35' diesel hybrid and six 60' diesel hybrid buses.

Table 2 - Fleet Summary by Length and Fuel Type

Bus Make	Bus Length	First Service Year	Bus Quantity
Diesel Hybrid	35’	2008	2
		2011	7
		2012	1
		2013	6
		2014	2
		2015	2
		2016	2
	60’	2014	1
		2017	5
Electric	35’	2023	2
			Total: 30

Miles and Fuel Consumption

Data on Mountain Line’s current fuel consumption is used to estimate energy costs throughout the transition period. **Table 3** provides the average annual fleet mileage and fuel use.

Table 3 - Average Annual Service Miles and Annual Fuel Consumption by Bus Length

Fuel Type / Length	Average Annual Mileage (miles)	Average Annual Diesel Fuel Consumption (gallons)
Diesel Hybrid 35’	34,497	7,208
Diesel Hybrid 60'	19,003	5,541
Electric 35’	18,068	-

Service Assessment

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

Bus efficiency and range are primarily driven by bus specifications; however, both metrics can be impacted by a number of variables including the route profile (e.g., distance, dwell time, acceleration, sustained top speed over distance, average speed, traffic conditions, deadhead), topography (e.g., grades), climate (e.g., temperature), driver behavior, and operational conditions (e.g., passenger loads and auxiliary loads). As such, the efficiency and range of a given ZEB model can vary dramatically from one agency to another. Therefore, it is critical to determine efficiency and range estimates that are based on an accurate representation of Mountain Line's operating conditions.

Modeling and Analysis Methodology

The first task in the Service Assessment is to develop route and bus models and run operating simulations for typical Mountain Line routes. In order to accomplish this, the efficiency values that were obtained through modeling based on the collected GPS data of Mountain Line's routes were used to determine the amount of energy required for each of Mountain Line's blocks. The Service Assessment determines the percentage of the agency's blocks that will be achievable in a given year considering the energy demand of the blocks and the battery capacity of the buses (for 35' and 40') with an assumed battery capacity improvement factor of five percent every two years. This improvement in battery capacity increases the estimated range of the buses over time, which gradually increases the percentage of blocks that are achievable by 2040. This process was conducted for the fixed service blocks for buses. CTE modeled Mountain Line's route and the vehicle energy demand to predict which of Mountain Line's blocks can feasibly be transitioned to ZEB technology and the timeline of when the transition can occur.

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

NOMINAL LOAD conditions assume average passenger loading and a moderate temperature over the course of the day, which places marginal demands on the motor and the heating, ventilation, and air conditioning (HVAC) system. **STRENUOUS LOAD** conditions assume high or maximum passenger loading and near-maximum output of the HVAC system. These strenuous loading conditions represent a hypothetical and unlikely worst-case scenario, but one that is necessary to establish an outer bound for the analysis. This nominal/strenuous approach offers a range of operating efficiencies, measured in kilowatt-hour/mile (kWh/mi), to use for estimating average annual energy use (nominal) or planning maximum service demands (strenuous).

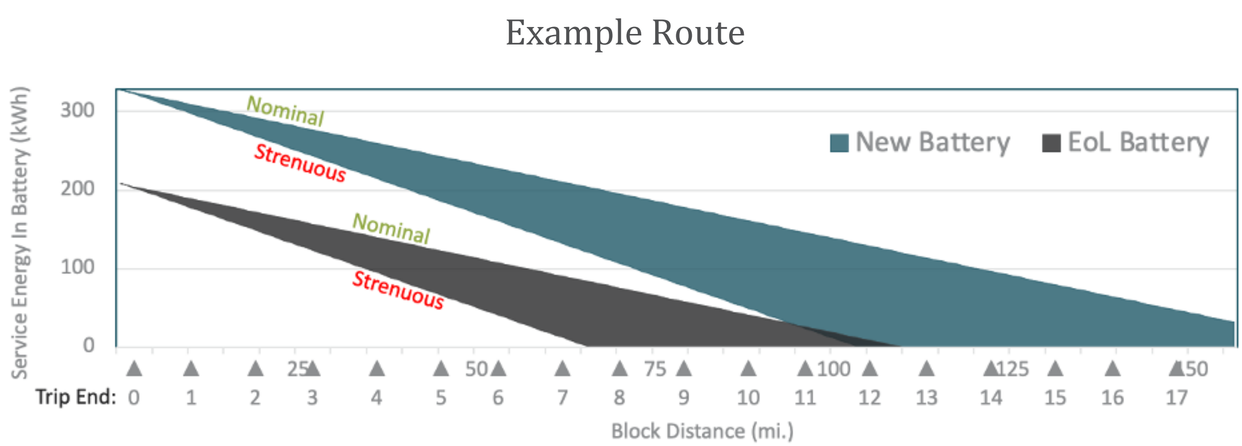

Figure 2 - Example Route Block Analysis

Figure 2 shows the range of remaining BEB battery energy (y-axis) on an example route. The blue and black areas show the range of estimated energy remaining between the nominal and strenuous load conditions for a new and an old battery, respectively. The point at which these areas cross the x-axis is the point at which there is no battery energy remaining. These colored areas shown represent the spectrum of expected operating conditions throughout the bus life to aid in service planning. The triangles under the graph denote trips within a block.

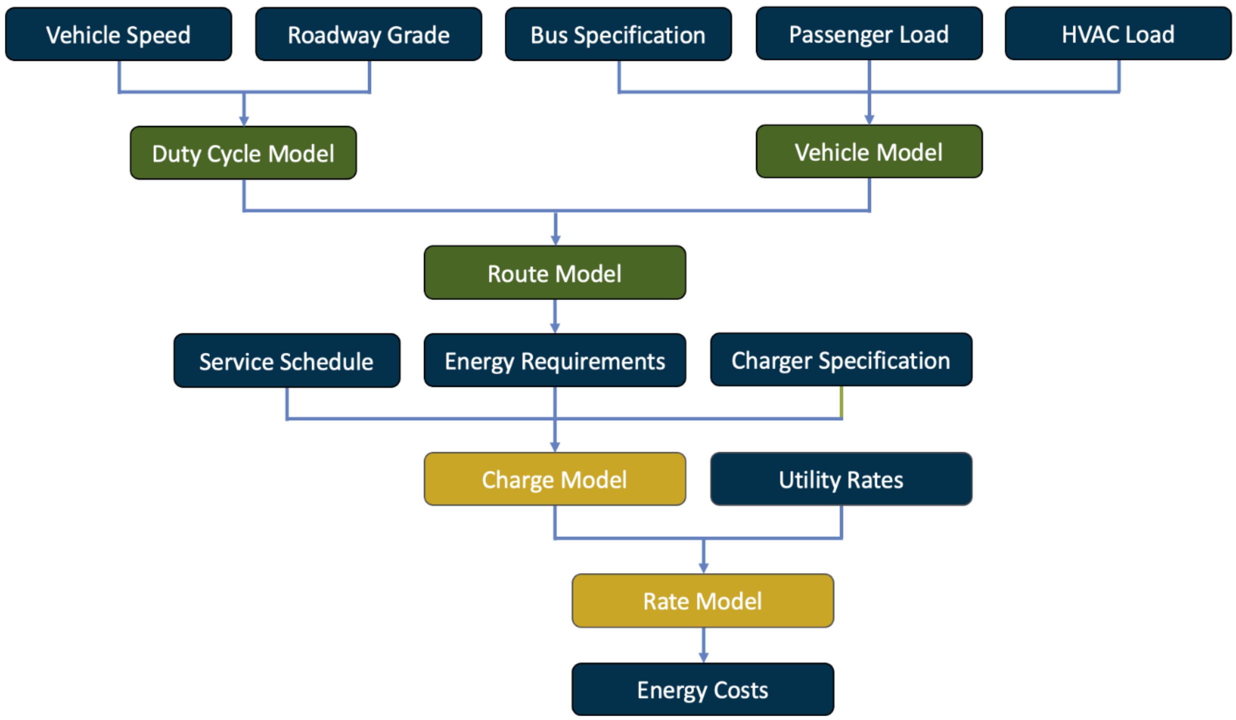

Figure 3 - CTE Modeling Methodology

Assumptions

CTE uses a set of assumptions related to battery capacity to guide the service assessment. The assumptions for the service assessment are as follows:

As of 2024, batteries for 35' battery electric buses have a nameplate capacity of 450 kWh with a usable capacity of 347 kWh. As of 2024, batteries for 60' electric buses have a nameplate capacity of 598 kWh with a usable capacity of 460 kWh. The assumed usable battery capacity for BEBs is 77% of the nameplate capacity, which is the amount advertised by the OEM. CTE assumes a 69% nameplate capacity to estimate feasibility to account for battery degradation by the end of life. A five percent improvement in battery capacity is assumed to expand every two years. In addition, CTE assumed the use of an all-electric heater in efficiency estimates.

The BEB modeling was completed using strenuous conditions with HVAC loads designated at 30°F with estimated auxiliary loads between 12-18 kW. CTE assumed nominal conditions were represented by HVAC loads designated at 61°F with estimated auxiliary loads between 3-5 kW.

For this study, CTE assumes that Mountain Line will maintain service to similar destinations within the region and therefore the blocks maintain a similar distribution of distance, relative speeds, and elevation changes throughout the transition period. This core assumption affects energy use estimates and block feasibility in each year.

Block Feasibility Results by Bus Type

The **BLOCK ANALYSIS** uses the strenuous energy required to complete each block and compares it to bus energy storage capacities. It considers what length bus is assigned to each block. Energy storage growth assumed five percent improvement in battery capacity every two years which determines the timeline for when routes and blocks become achievable for BEBs. This information is used to inform ZEB procurement projections in the Fleet Assessment. Overall, the block analysis helps to determine when, or if, a full transition to ZEBs may be feasible and when there are requirements for supplemental energy solutions. Results from this analysis are also used to determine the specific energy requirements and develop the estimated costs to operate the ZEBs in the Fuel Assessment. **Figure 4** and

Table *4* provide the results from the block analysis for BEBs in selected years (every two years from 2024-2040) by bus size (35' vs. 60').

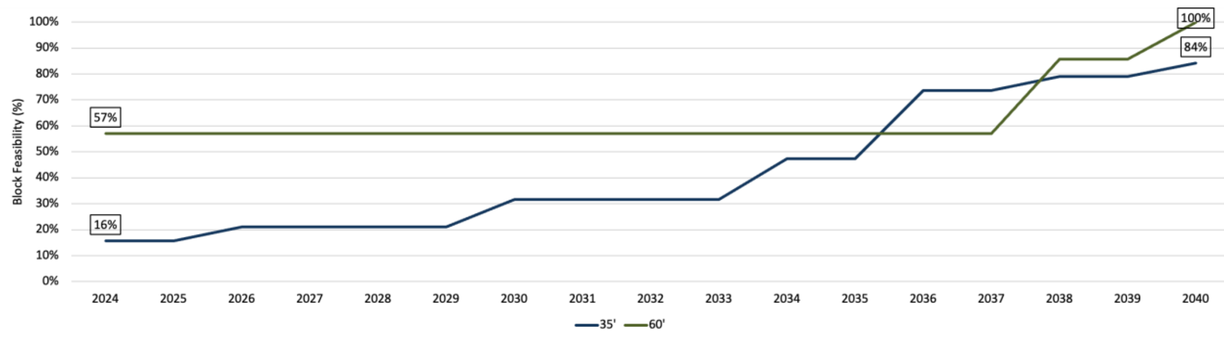

Figure 4 - BEB Block Feasibility Percentage by Year (2024-2040)

Table 4 - BEB Block Feasibility Percentage by Year

Bus Size [ft]	Block Quantity	Max. Block Distance (mi)	% Feasible in 2024	% Feasible in 2026	% Feasible in 2028	% Feasible in 2030	% Feasible in 2032	% Feasible in 2034	% Feasible in 2036	% Feasible in 2038	% Feasible in 2040
35'	7	256	29%	21%	21%	32%	32%	47%	74%	79%	84%
60'	19	170	57%	57%	57%	57%	57%	57%	57%	86%	100%

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

Figure 5 and

Table 5 show the 35’ BEB feasibility for existing blocks in the transition timeline. Blocks run with 35’ buses are compared to today’s 35’ BEB energy storage capacities. The preliminary results show an 84% feasibility rate in 2040 with 16 out of 19 blocks feasible.

Figure 5 - 35’ BEB Block Feasibility Projection

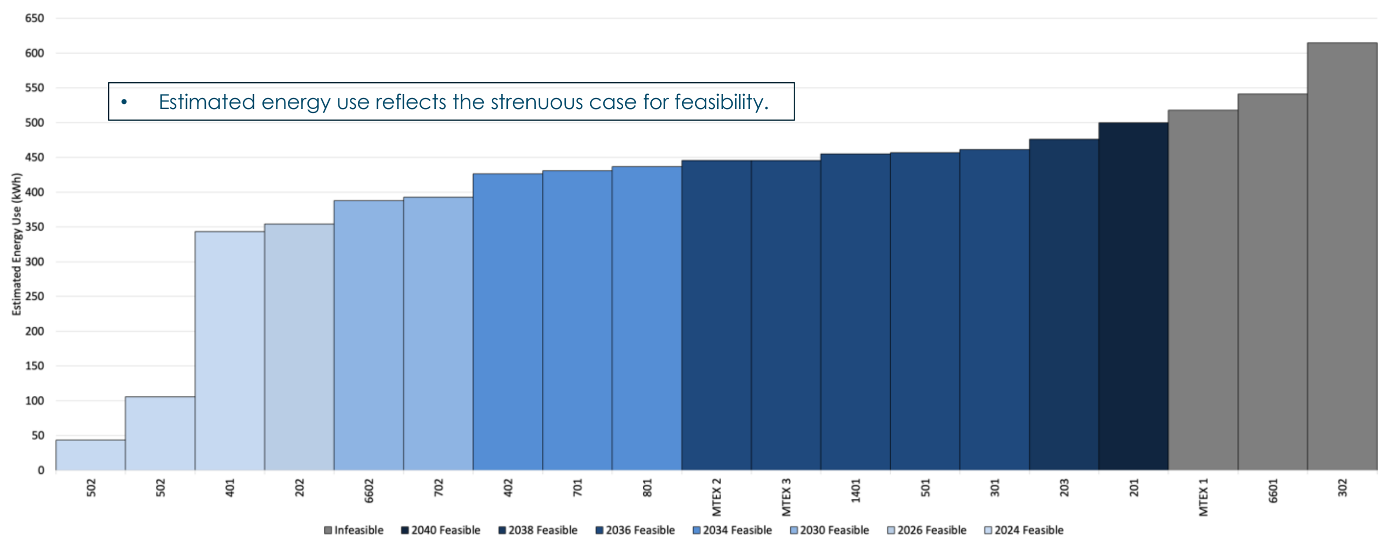

Table 5 - 35' BEB Block Feasibility Projection (2024-2040)

Bus Size [ft]	Block Quantity	Max Block Distance (mi)	% Feasible in 2024	% Feasible in 2026	% Feasible in 2028	% Feasible in 2030	% Feasible in 2032	% Feasible in 2034	% Feasible in 2036	% Feasible in 2038	% Feasible in 2040	Infeasible Blocks
35'	19	256	29%	21%	21%	32%	32%	47%	74%	79%	84%	3

Table 6 below shows the additional energy needs on 35' BEBs to make the 3 infeasible blocks feasible. 350kW is assumed for average BEB higher power opportunity charging power. Average charging power may vary depending on OEM and battery size.

Table 6 - Additional Energy Needs: 35' BEB

Blocks Infeasible with Overnight Charged BEB in 2040	Estimated Additional 2040 Energy Need (kWh)	Estimated Duration with 350kW Higher Power Opportunity Charging (h:mm)
MTEX1	59	0:11
6601	82	0:16
302	156	0:31

Figure 6 and **Table 7** show the 60’ BEB feasibility for existing blocks in the transition timeline. Blocks run with 60’ buses are compared to today’s 60’ BEB energy storage capacities. The preliminary results show a 100% feasibility rate in 2040 with 7 out of 7 blocks feasible.

Figure 6 - 40’ BEB Block Feasibility Projection

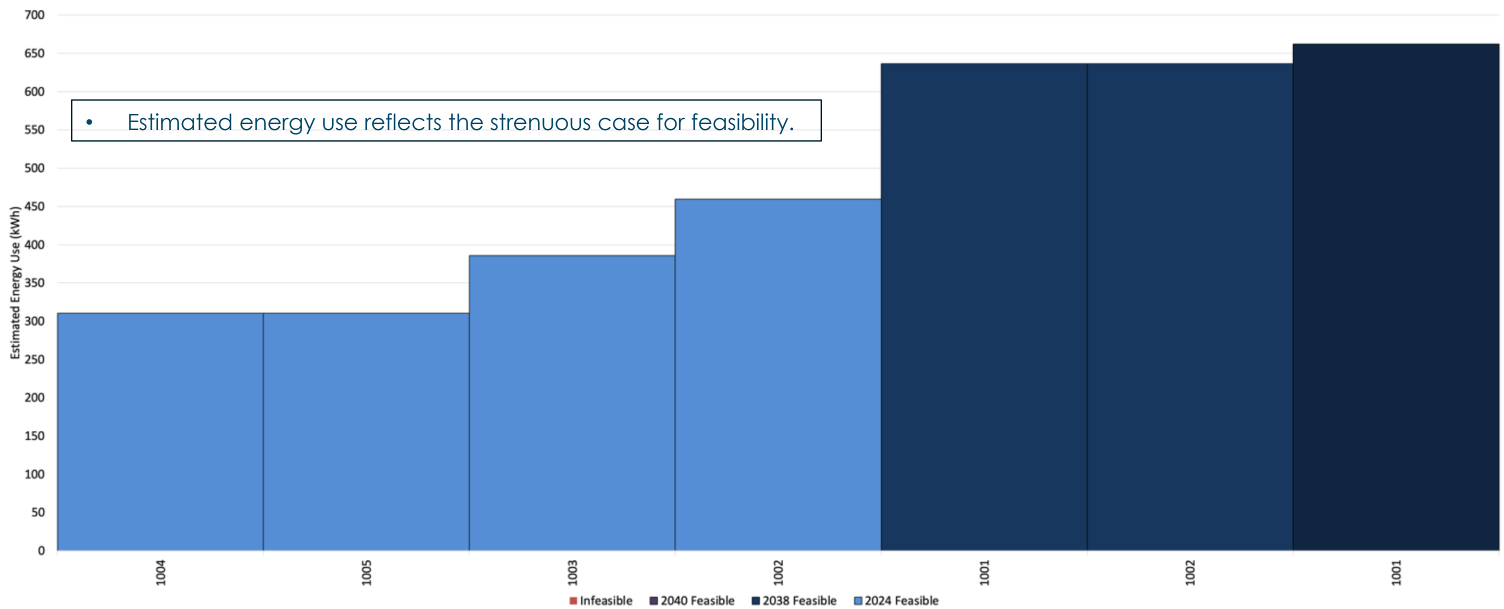

Table 7 - 40' BEB Block Feasibility Projection (2024-2040)

Bus Size [ft]	Block Quantity	Max Block Distance (mi)	% Feasible in 2024	% Feasible in 2026	% Feasible in 2028	% Feasible in 2030	% Feasible in 2032	% Feasible in 2034	% Feasible in 2036	% Feasible in 2038	% Feasible in 2040	Infeasible Blocks
60’	7	170	57%	57%	57%	57%	57%	57%	57%	86%	100%	0

Summary

Overnight charged (plug-in) BEBs cannot complete all current Mountain Line blocks by study end (2040) under current assumptions. 35’ vehicles achieve 84% of all assigned blocks by 2040, while 60’ vehicles achieve 100% of all assigned blocks by 2040.

With the addition of on route chargers (pantographs), BEBs can complete all current Mountain Line blocks by study end (2040) under current assumptions. Three of the 35’ BEB blocks would require an estimated 11-31 minutes of on-route charging throughout the service day to increase the 35’ block feasibility to 100% by 2040.

Fleet Assessment

The goal of the **FLEET ASSESSMENT** is to determine what type of ZEB technology solutions are required to transition an entire fleet to zero-emission vehicles. Results from the Service Assessment are integrated with Mountain Line's current fleet replacement plan and purchase schedule to produce two main outputs:

1) A projected bus replacement timeline through the end of the transition period

and

2) The total capital costs of those replacements.

Throughout the assessment, the projected bus procurement plan is referred to as the transition period.

For this effort, the Service Assessment was used to inform the percentage of buses that could be transitioned to ZEBs each year during the transition. This analysis included an outline of the expected fleet structure and capital costs expected over the transition period for each scenarios explored.

Assumptions

CTE uses a set of assumptions related to vehicle prices to guide the fleet assessment. The assumptions for the fleet assessment are as follows:

- CTE considers depot-charging as plug-in charging, and on-route charging as pantograph charging in this analysis. Mountain Line currently supports existing BEBs with one 450 kW pantograph charger and one 50kW mobile plug-in charger at the Kaspar Drive bus depot.
    - There are lower-powered pantograph chargers (example: ABB's 50-150 kW) designed for depot use and suitable for overnight charging. There are high-powered (300 kW+) pantograph chargers specifically intended for on-route charging. Mountain Line to decide how to move forward with approach to charging scenarios. Utilizing pantograph chargers for a full fleet may come with logistic challenges.
- Procurement cost assumptions per vehicle type are shown in **Table 8** with the following assumptions applied:
    - Annual inflation of 4% applied through 2026, and 2% applied through the remainder of the period
    - Additional $50K was added to bus price for pantograph rails

    - Procurement cost does not include any battery warranty costs in this study; estimated $75k additional cost
- Known Procurements:
    - 4 x BEBs - 5353-5350 (2026)
- Vehicle useable lifetime of 15 years for buses
    - 2008 vehicles 5384-5385 will be rehabilitated and add 10 years to service life, for a total service life of 25 years. These are the two diesel hybrids identified to stay in the fleet until 2041.
- Starting year reflects first year of service, not order year
- Battery capacity improvement assumption of 5% battery improvement every two years
- Current capacities based on current market availability

Table 8 - Fleet Procurement Cost Assumptions

Vehicle	Cost	Source
Diesel-Hybrid 35'	$800,000	Mountain Line Bus Costs (2023)
Diesel-Hybrid 60'	$970,850	Mountain Line Bus Costs (2017)
Electric 35'	$1,500,000	Mountain Line Bus Costs (2026)
Electric 60'	$1,635,128	Market Average

Procurement Timeline

Figure 7, Figure 8, and **Figure 9** show the overall procurement phase-in of buses during the transition period for each of the scenarios: Baseline, BEB Depot (Plug-in) Only, and BEB Depot (Plug-in) and On-Route (Pantograph) Charged. This timeline is inclusive of the vehicles that will need to be procured once they reach their end-of-life. The lifespan of a full-sized BEB is assumed to be 15 years based on Mountain Line data. Calendar years represent when replacement enter service.

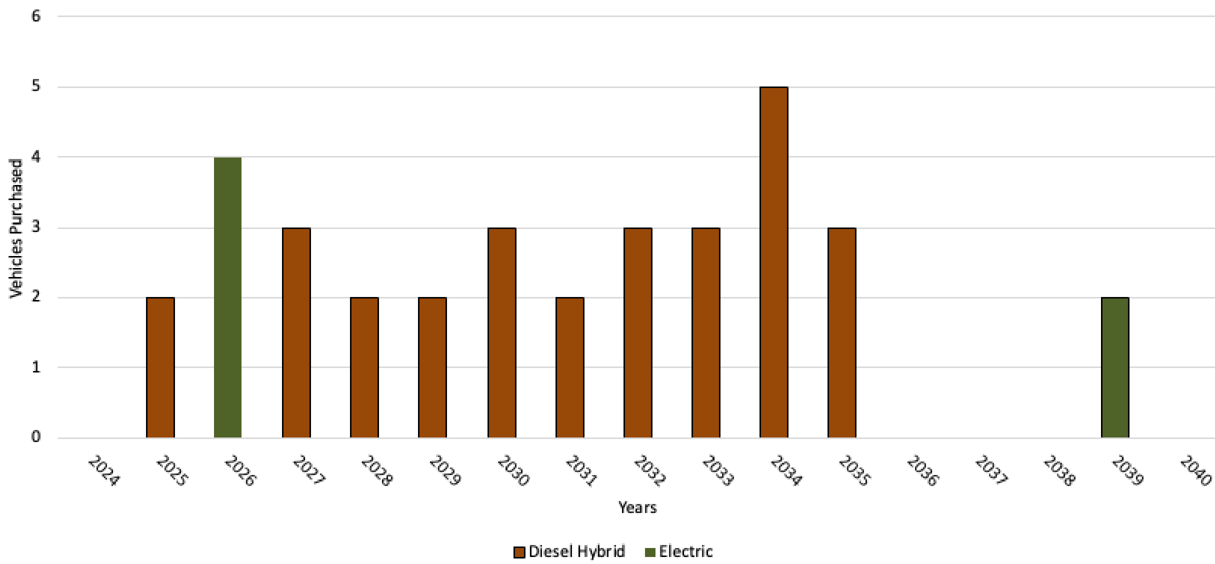

Figure 7 - Procurement Phase-In: Baseline Scenario

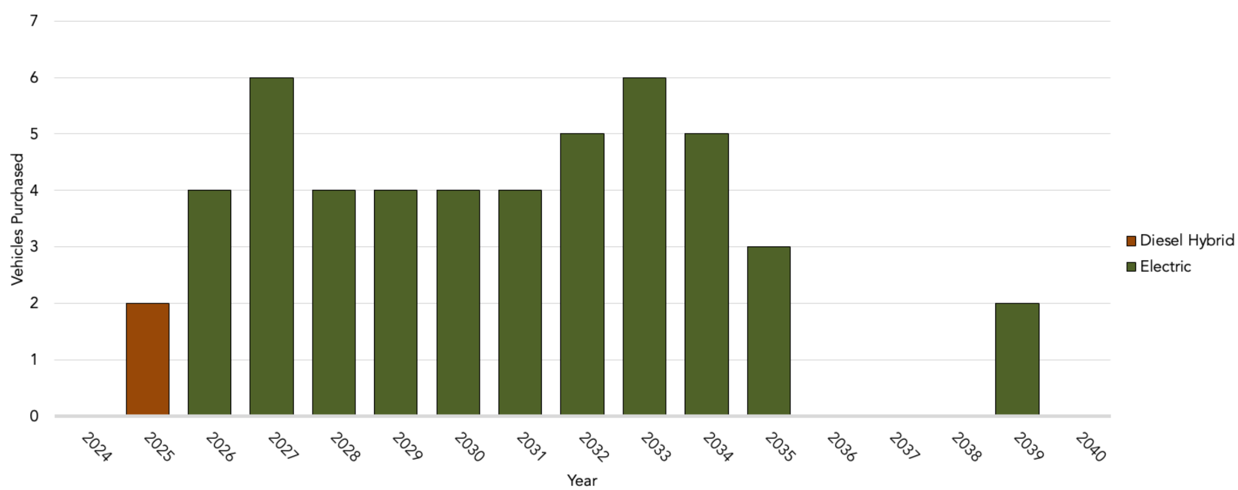

Figure 8 - Procurement Phase-In: BEB Depot (Plug-in) Only Scenario

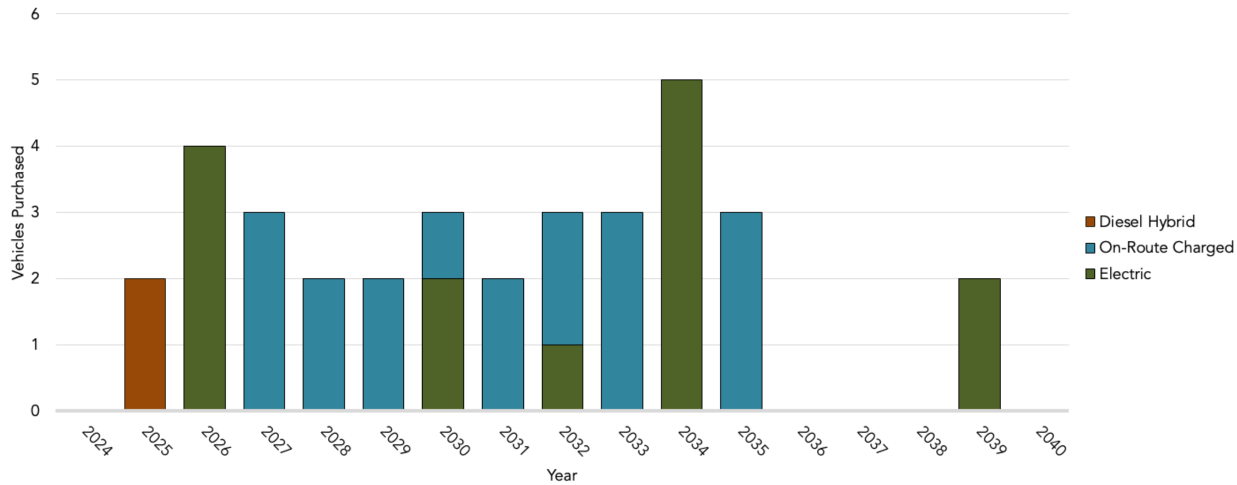

Figure 9 - Procurement Phase-In: BEB Depot (Plug-In) and On-Route (Pantograph) Charged Scenario

Vehicle Composition

Baseline

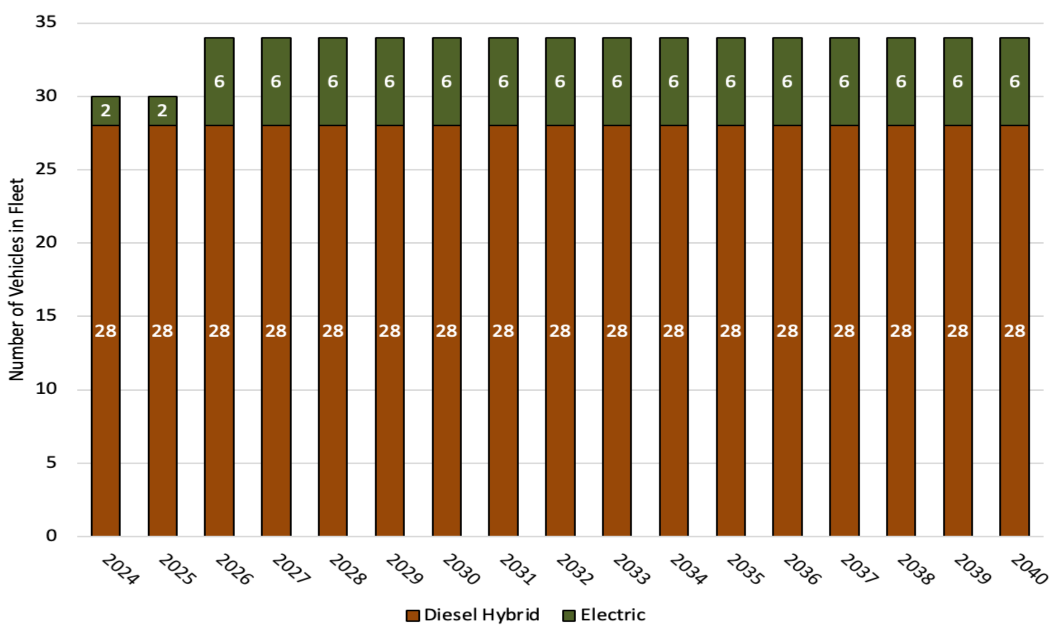

Figure 10 shows the vehicle composition of the Baseline scenario throughout the transition period. The Mountain Line fleet is 18% ZEB by 2040 with 28 diesel-hybrid and 6 electric vehicles.

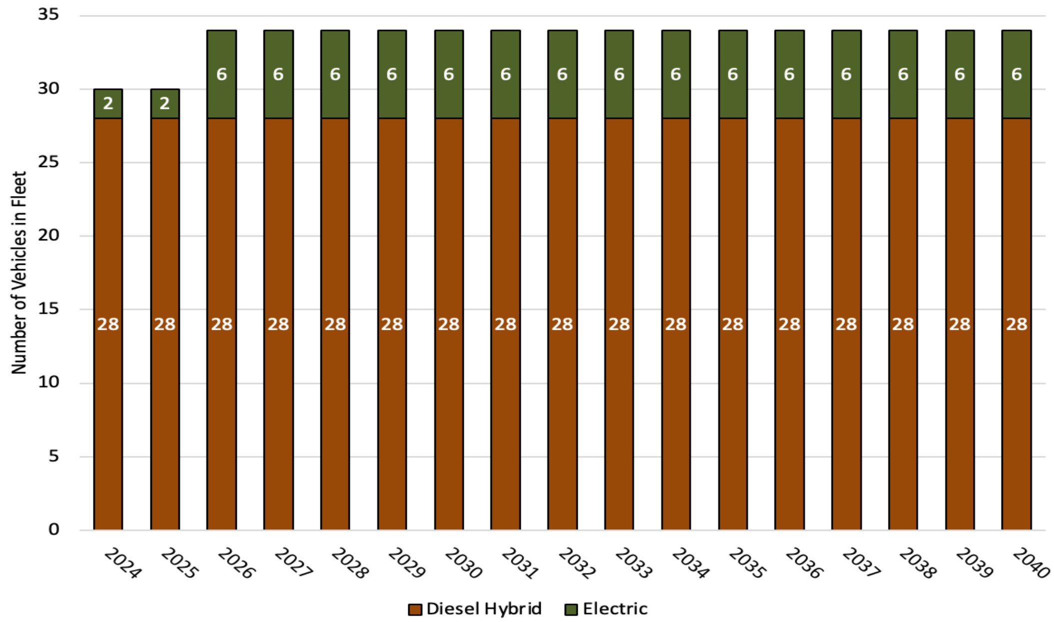

Figure 10 - Fleet Composition: Baseline Scenario

BEB Depot (Plug-in) Only

Figure 11 shows the vehicle composition of the BEB Depot (Plug-in) Only scenario throughout the transition period. The Mountain Line fleet is 96% ZEB by 2040 with 47 electric and 2 diesel hybrids (that will be rehabilitated). This assumes a 15-vehicle expansion. A 15-year service life assumption would assume the final two diesel hybrid vehicles wouldn't be replaced until 2041.

The fleet would be 35% ZEB without expansion and 49% ZEB with limited expansion.

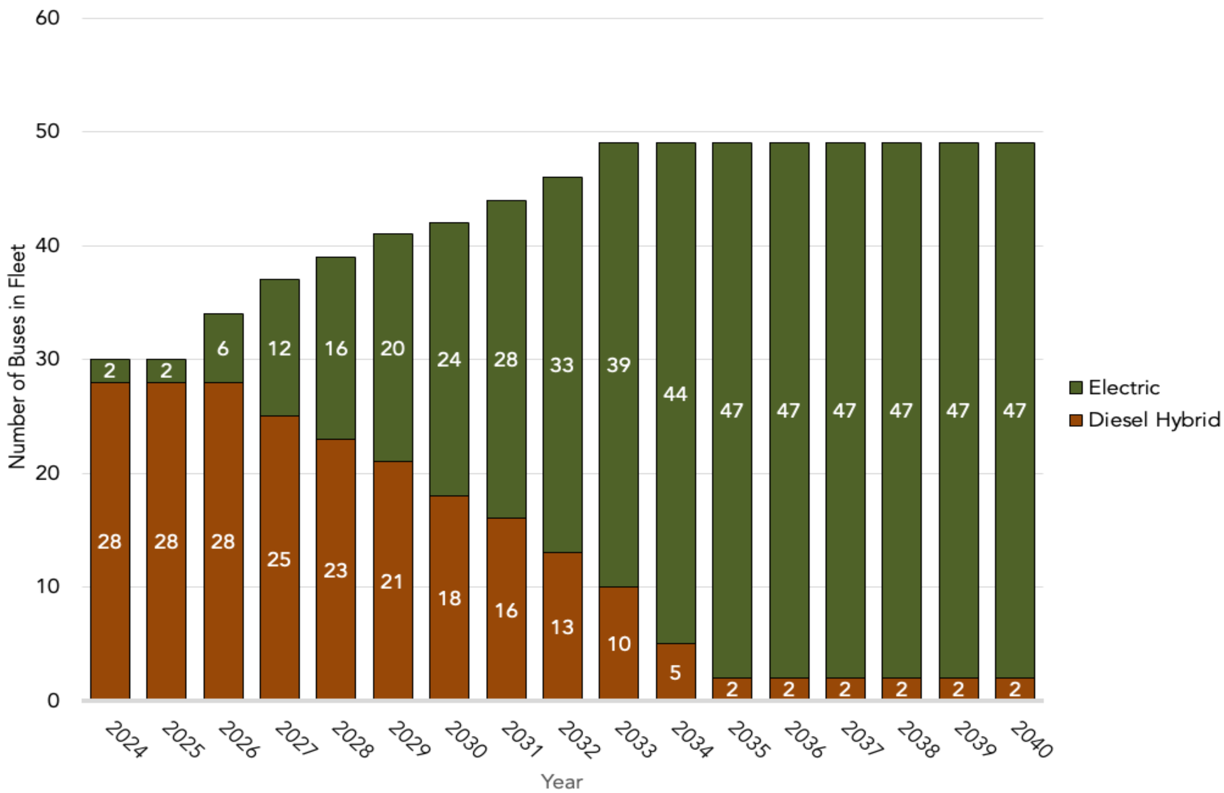

Figure 11 - Fleet Composition: BEB Depot (Plug-In) Only Scenario

BEB Depot (Plug-In) and On Route (Pantograph) Charged

Figure 12 shows the vehicle composition of the BEB Depot (Plug-In) and On Route (Pantograph) Charged scenario throughout the transition period. The Mountain Line fleet is 94% ZEB by 2040 with 14 depot-charged electric, 18 on-route charged electric, and 2 diesel hybrid vehicles. A 15-year service life assumption would assume the final two diesel hybrid vehicles that will be rehabilitated wouldn't be replaced until 2041.

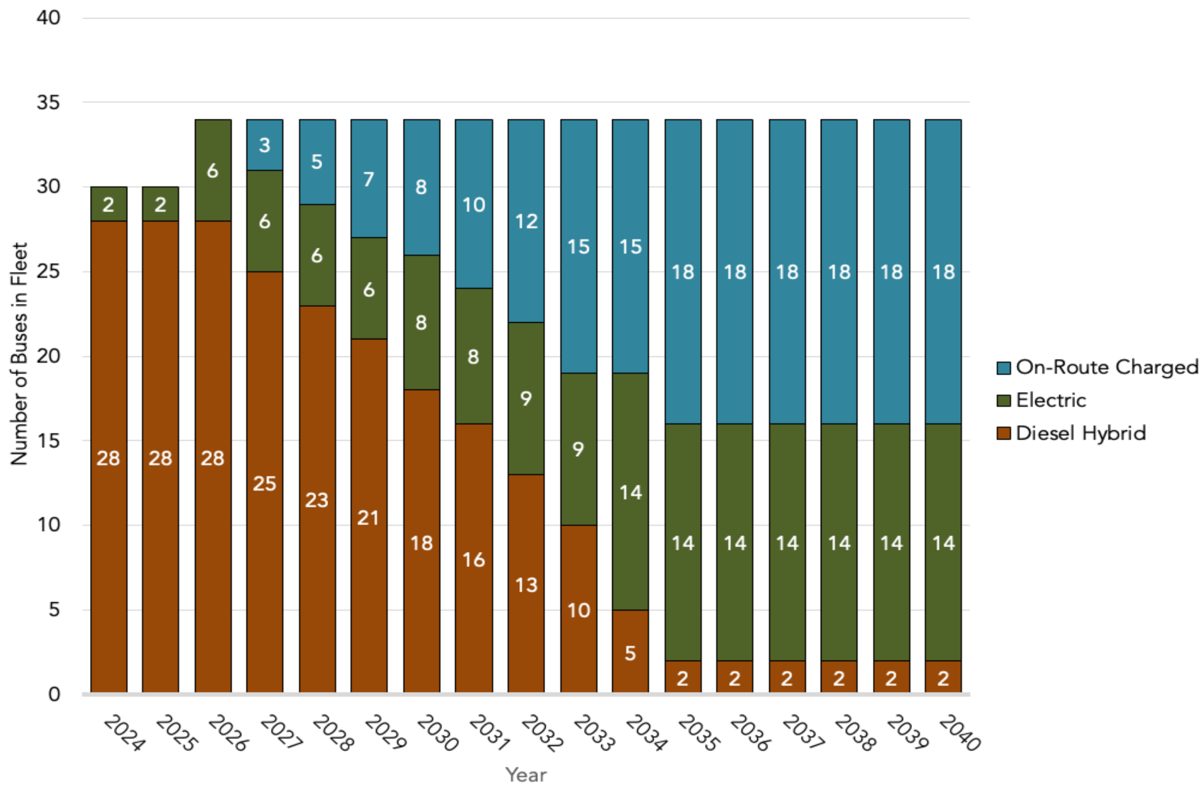

Figure 12 - Fleet Composition: BEB Depot (Plug-In) and On Route (Pantograph) Charged Scenario

Annual Fleet Costs

Baseline

Figure 13 shows the annual fleet costs by fuel type in the Baseline scenario throughout the transition period. The total expenditures from 2024 to 2040 equals $38.7 million. The Baseline Scenario assumes Mountain Line's current fleet of diesel hybrids will remain consistent and is used as a means for comparing incremental capital and operating costs of various ZEB scenarios.

Mountain Line's Baseline fleet consists of two Electric 35', 22 35' diesel hybrid and six 60' diesel hybrid buses. There are significant costs associated with infrastructure procurement for BEB charging, but because the infrastructure for the existing fleet is already in place, the Baseline Scenario assumes no new infrastructure costs. This scenario estimates an 18% ZEB fleet by 2040.

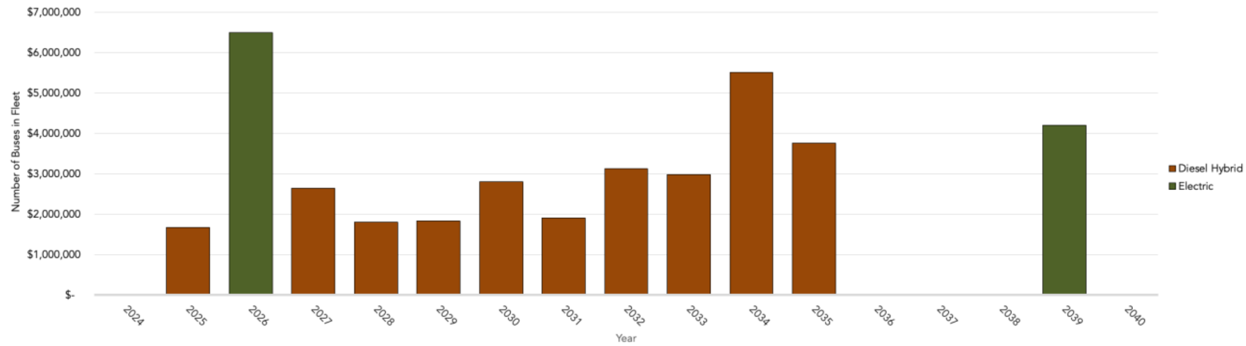

Figure 13 - Annual Fleet Costs: Baseline Scenario

BEB Depot (Plug-in) Only

Figure 14 shows the annual fleet costs by fuel type in the BEB Depot (Plug-in) Only Charged scenario throughout the transition period. The total expenditures from 2024 to 2040 equals $86.8 million.

The BEB Depot (Plug-in) Only Charged Scenario was developed to model an option with a fleet consisting entirely of battery electric buses that can meet existing service range requirements. Fleets consisting of depot-charged BEBs may not be able to meet the range requirements of present routes and would require additional time to return to the depot to mid-day charge or implement on-route charging. According to CTE's modeling, 84% of Mountain Line's blocks are achievable with 35' BEB by 2040, and 100% of Mountain Line's blocks are achievable with 60' BEBs by 2040. A shortcoming of a BEB only fleet is that it may be less resilient than a mixed fuel or internal combustion engine (ICE) fleet since interruptions to the power supply could jeopardize the operability of the fleet. This hurdle can be mitigated by installing back-up power supplies and planning contingencies.

The Battery Electric Bus (BEB) Depot (Plug-in) Only Scenario assumes the following:

- 1:1 replacement with BEBs for blocks where technology meets service requirements with depot (plug-in) charging
- 2:1 replacement with BEBs for blocks that are not achievable on a single charge (plug-in)
    - Final fleet count will be 49 vehicles.
        - By 2040, 35' block feasibility will require an expansion of 3 vehicles to support 3 infeasible blocks.
            - CTE added additional vehicles as soon as possible (3 x 2027) to increase ZEB % timeline.

        - By 2040, 60’ block feasibility does not require additional 60’ buses with overnight charging.
    - Kaspar Headquarters Master Plan phase two shows future capacity for 52 buses (10 60-foot buses & 42 35-foot buses). 4 buses are on order in 2025, plus Prop 488 expansion is projected to add 11 35-foot buses, for a total of 45 buses in the future fleet (6 60-foot buses & 39 35-foot buses). There is future bus storage space available for an additional 4 x 60’ buses & 3 x 35’ buses. However, Mountain Line prefers not to use all unassigned bus spaces available with BEB 2:1 replacement as the facility expansion is meant to fulfill all known and unforeseen growth needs to 2042.
- 1:1 replacement of spare vehicles with BEBs

The BEB Depot Plug In scenario assumed a fleet expansion of 15 BEBs to meet block requirements and estimates a 96% ZEB fleet by 2040 with 47 BEBs and 2 diesel hybrid buses. Based off a 15-year lifetime, the two-remaining diesel-hybrids would get replaced in 2041.

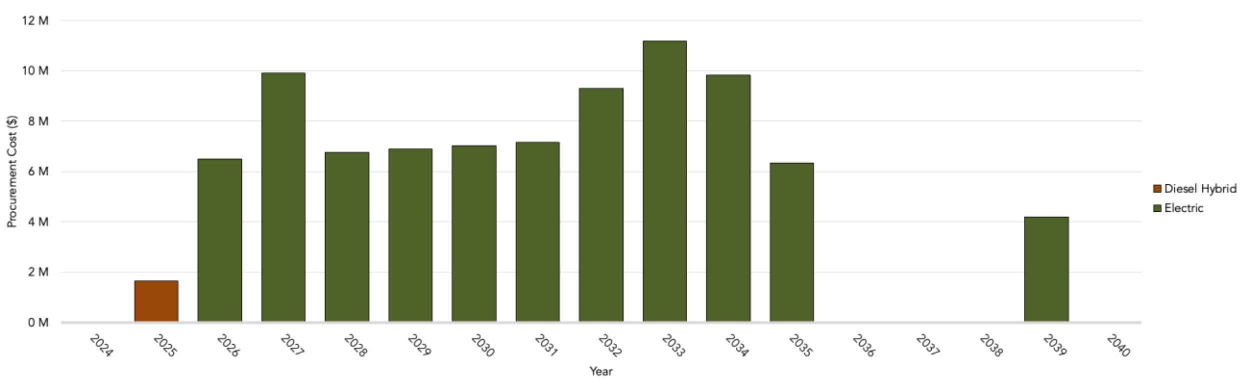

Figure 14 - Annual Fleet Costs: BEB Depot (Plug-in) Only Scenario

BEB Depot (Plug-In) and On Route (Pantograph) Charged

Figure 15 shows the annual fleet costs by fuel type in the BEB Depot (Plug-In) and On Route (Pantograph) Charged scenario throughout the transition period. The total expenditures from 2024 to 2040 equals $61.5 million.

The BEB Depot (Plug-In) and On Route (Pantograph) Charged Scenario was developed to mitigate the gaps in feasibility, as the Feasibility Assessment determined that the range of market average BEBs would not be sufficient to meet all Mountain Line's service requirements with just overnight, depot-charging. On-route charging allows Mountain Line to meet all their service needs. In 2025, Mountain Line can only complete three of the 19 35ft blocks (502, 401, and 6602) under strenuous conditions with the two electric buses in service today due to battery capacity (340 and 440 kW). Mountain Line should continue to track the number of blocks achievable on a single charge to determine the remaining support needed with on-route charging.

In 2040, 16 of the 19 service blocks are achievable under strenuous conditions, and three of the 35ft blocks (MTEX 1, 6601, and 302) would require an estimated 11-31 minutes of on-route charging throughout the service day.

BEB Depot (Plug-In) and On Route (Pantograph) Charged Scenario assumes 1:1 replacement with BEBs utilizing on-route charging for every block and topping off at the depot overnight.

Mountain Line Downtown Connection Center (DCC) currently has the capacity for two fast charging, pantograph on-route chargers. The soonest installation of these chargers is 2028 but could be in 2030 or later, depending on progress of the Rio de Flag flood mitigation project. **CTE did not assume these chargers exist in this analysis.** In addition, the team is shifting a lot of depot charging to Kaspar Drive headquarters to maximize Mountain Line Kaspar Master Plan which can accommodate up to 52 buses. However, this transition plan only considers the current 34 vehicle fleet of buses. Mountain Line has not yet determined where the charging will take place and plans to change bus routes in the next 10 years, which may open new opportunities for on-route charging. This ZEB plan only focuses on the current fleet and service.

This scenario estimates a 94% ZEB fleet by 2040 with 32 BEBs (14 BEBs charged at the depot only and 18 BEBs charged via on-route pantographs) and 2 diesel hybrid buses. Based off a 15-year lifetime, the two-remaining rehabilitated diesel-hybrids would get replaced in 2041.

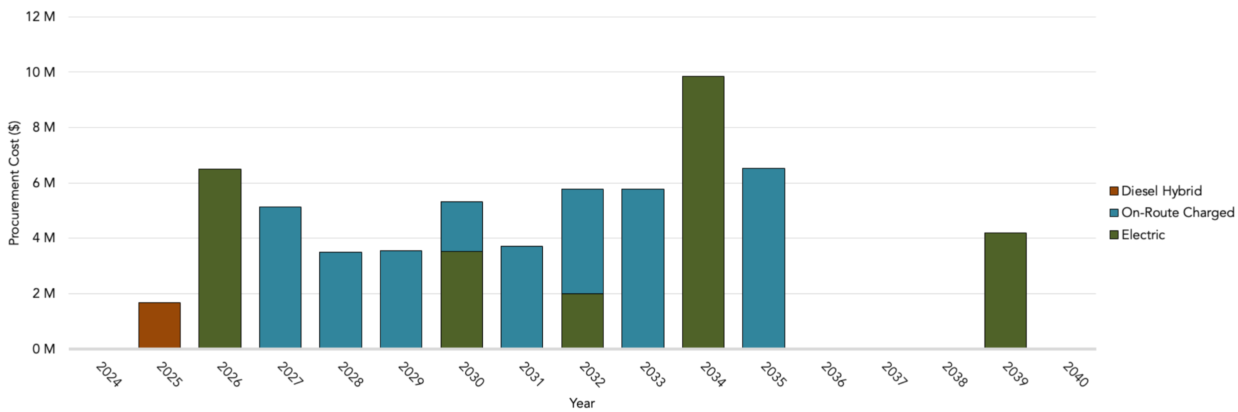

Figure 15 - Annual Fleet Costs: BEB Depot (Plug-In) and On Route (Pantograph) Charged Scenario

Summary

Figure 16 and **Table 9** compare the cumulative costs and percentage of ZEBs in the fleet over the transition timeline of 2024-2040 for each scenario. The BEB Depot (Plug-in) Only scenario includes a bus expansion and is comprised of 96% ZEBs by 2040 and costs $86.8 million over the transition period. Under the Depot (Plug-in) and On Route (Pantograph) Charged scenario, the Mountain Line fleet is comprised of 94% ZEBs by 2040 and costs $61.5 million over the transition period. These compare to the baseline cost of $38.2 million which results in an 18% ZE fleet by 2040.

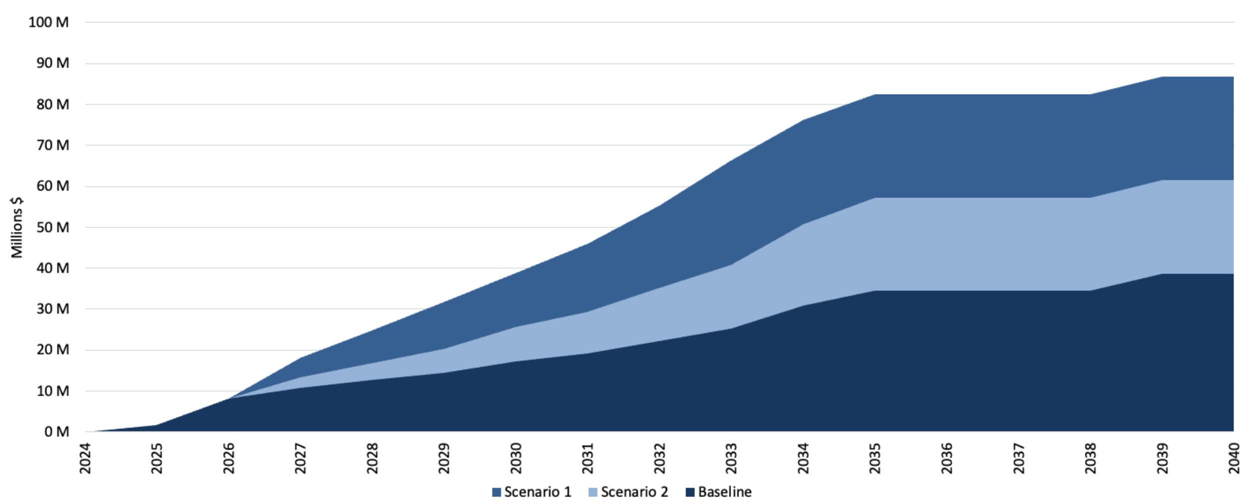

Figure 16 - Cumulative Fleet Cost by Scenario

Table 9 - Cumulative Fleet Costs by Scenario

Costs	Baseline	Scenario 1 BEB Depot Only (plug-in) Expansion	Scenario 2 BEB Depot (plug-in) & On-Route (pantograph)
Cumulative ($)	38.2M	86.8M	61.5M
Incremental over Baseline ($)	-	48M	22.7M
% ZEB Fleet by 2040	18%	96%	94%

Fuel Assessment

The **Fuel Assessment** estimates fuel consumption and costs for each of the technologies: diesel and electric studied in the relevant scenario. Using ZEB performance data from the route simulation, CTE analyzed expected bus performance on each block in Mountain Line's service catalog to calculate the daily fuel required for that block's completion. CTE completed this analysis for each of the two zero-emission fleet transition scenarios and the baseline scenario. The analysis produced estimates of the fuel costs for each projected fleet composition through the transition period.

Assumptions

The following assumptions have been made for vehicle fuel use and efficiency projections through 2040. Annual mileage and fuel use for all vehicles are expected to remain constant, as provided by Mountain Line.

In the case of BEBs, fuel use is determined based on CTE's efficiency assumptions, measured in kilowatt-hours per mile, and assumes an 80% charger efficiency, reflecting typical losses during the charging process. These assumptions provide a basis for evaluating fuel consumption and vehicle efficiency over the projected period. **Table 10** and **Table 11** outline the assumptions used to estimate fuel cost. All fuel costs are escalated using EIA's 2022 Annual Energy Outlook 2024-2050 average annual change. The fuel assessment also includes charger maintenance costs to reflect total cost of charging operation. Depot charger maintenance is estimated at $3,000/yr/charger (2:1 vehicle: charger ratio) and pantograph charger maintenance cost is estimated at $6,000/yr/charger (4:1 vehicle: charger ratio). Mountain Line has the option to switch to Time of Use rates, but experience challenges avoiding demand at this time. Original Baseline Analysis (2020) electric costs included demand charges. The current analysis does not. Total costs include Flagstaff, Arizona's State Sales Tax (5.6%), County Sales Tax (1.3%), City Sales Tax (2.28%), Regulatory Assessment (0.2122%) and Franchise Fee (2%.)

BEB Depot (Plug-in) Only Scenario assumes depot charger (plug-in) count increases as fleet increases, whereas BEB Depot (Plug-in) and On Route (Pantograph) Charged Scenario assumes Mountain Line will transition to necessary on-route only use for pantographs beginning in 2027. Analysis also does not include Mountain Line's Heliox mobile charger.

Table 10 - BEB Fuel Cost Assumptions- Utility Rate Schedule

Arizona Public Service – Large General		
Charge	**Cost**	**Unit**
Customer Accounts Charge	$2.597	Daily
Meter Reading	$0.010	Daily
Billing	$0.032	Daily
Self-Contained Metering	$0.668	Daily
Transmission	$2.870	kW
Generation	$6.458	kW
Secondary (First 100kW)	20.094	kW
Secondary (All Additional)	10.917	kW
System Benefits	$0.00361	kWh
Generation (Summer: May-Oct)	$0.05280	kWh
Generation (Winter: Nov-Apr)	$0.03439	kWh
Renewable Energy (REAC-1)	$0.007100 (capped at $355 for Large)	kWh
Demand Side Management (DSMAC-1)	$0.883	kW
Court Resolution (CRS-1)	$0.001480	kWh

Table 11 – Diesel Fuel Cost Assumptions

Fuel Type	Cost per Unit	Source
Diesel	$3.04	Mountain Line FY25 Average cost/gallon

Analysis Results

Baseline

Figure 17 shows the annual fuel cost by bus type over the course of the transition period for the Baseline scenario. The total expenditures from 2024-2040 equals $13.2M total ($12.5 million from diesel hybrid vehicles, $699K from electric vehicles).

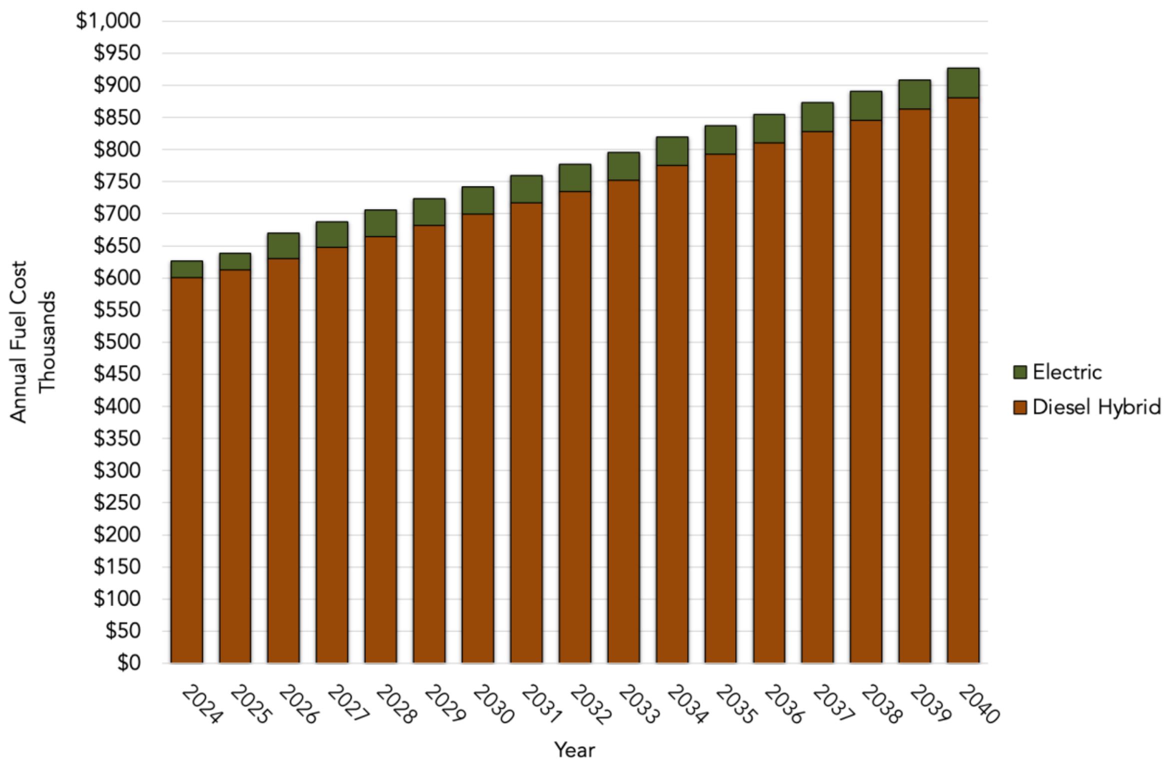

Figure 17 - Annual Fuel Cost: Baseline Scenario

BEB Depot (Plug-in) Only

Figure 19 shows the infrastructure needs over the course of the transition period for the BEB Depot (Plug-in) Only scenario. The graph does not show existing pantographs. By 2040, the fleet will be compromised of 47 BEBs which will require 24 depot-chargers and 48 dispensers.

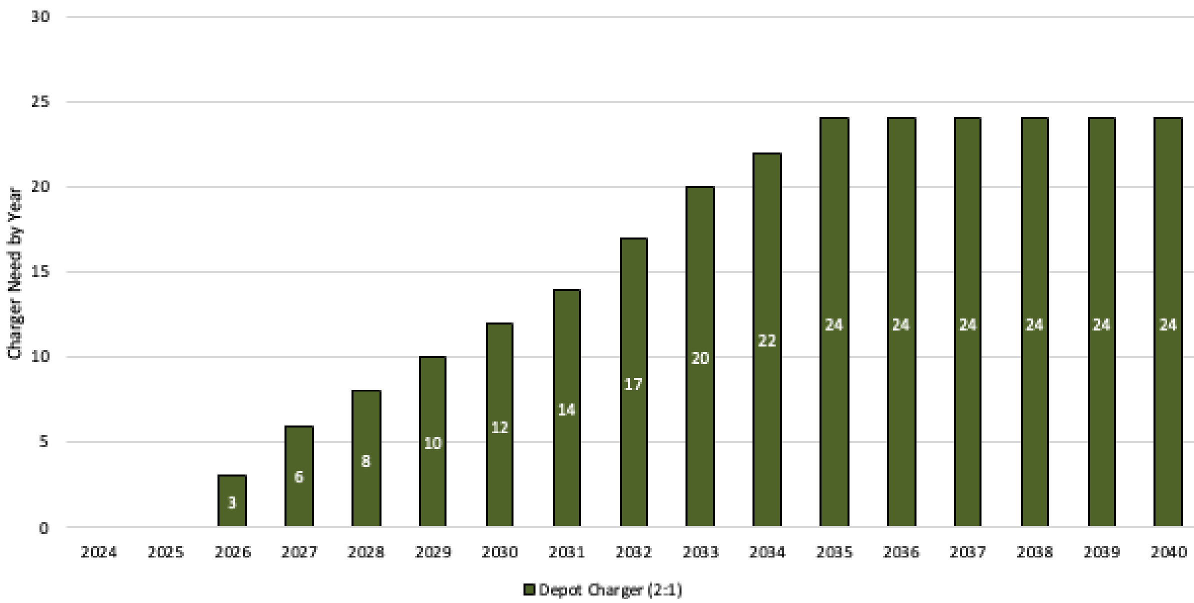

Figure 18 - Annual Fuel Cost: BEB Depot (Plug-In) Only Scenario

Error! Reference source not found. shows the annual fuel cost by bus type over the course o f the transition period for the BEB Depot (Plug-in) Only scenario. The total expenditures from 2024-2040 equals $10.9M total ($5.3 million from diesel hybrid vehicles and $5.6 million from electric vehicles).

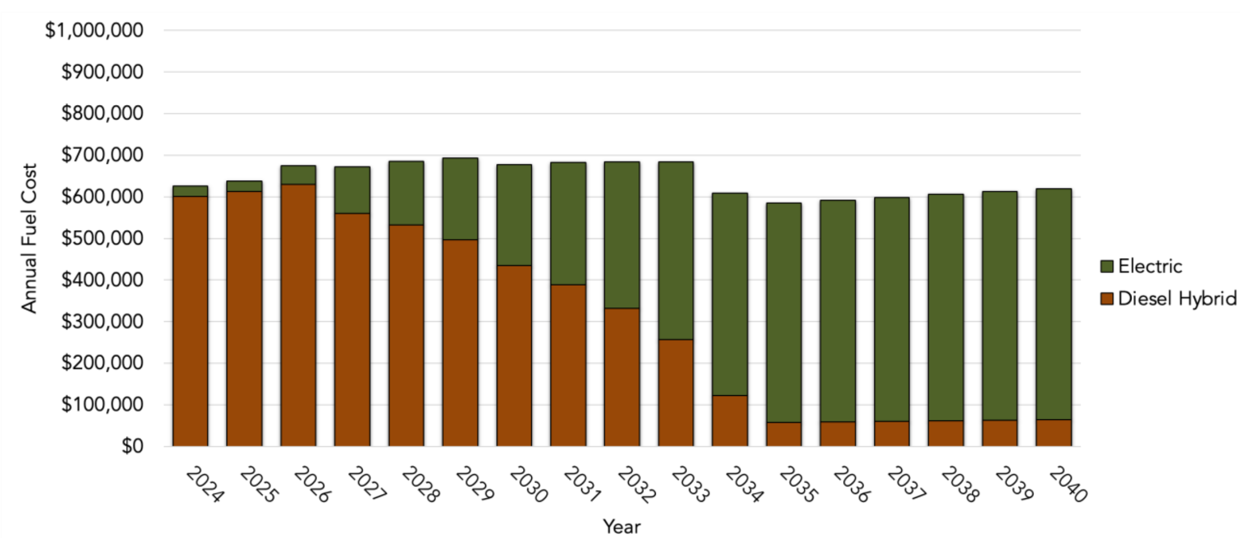

Figure 19 - Fueling Infrastructure Needs BEB Depot (Plug-in) Only

BEB Depot (Plug-in) and On Route (Pantograph) Charged

Figure 20 shows the infrastructure needs over the course of the transition period for the BEB Depot (Plug-in) and On Route (Pantograph) Charged scenario. The graph does not show existing pantograph or the mobile charger at the Kaspar Drive bus depot. By 2040, the fleet will be compromised of 32 BEBs which will require 21 chargers (5 pantograph on-route chargers and 16 plug-in depot chargers) and 32 dispensers. Mountain Line may require further analysis to determine feasibility of implementation based on space and location constraints.

Figure 21 shows the annual fuel cost by bus type over the course of the transition period for the BEB Depot (Plug-in) and On-Route (Pantograph) Charged scenario. The total expenditures from 2024-2040 equals $8.5M total ($5.3 million from diesel hybrid vehicles, $1.2 million from electric vehicles, and an additional $962K for on-route charged electric vehicles).

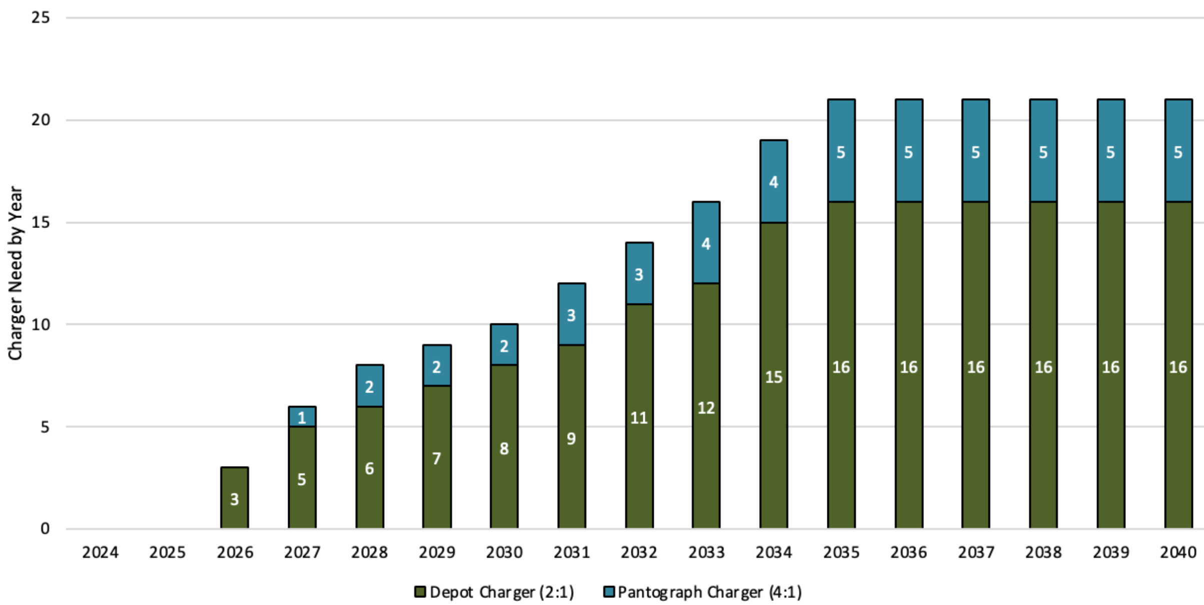

Figure 20 - Fueling Infrastructure Needs BEB Depot (Plug-In) and On Route (Pantograph) Scenario

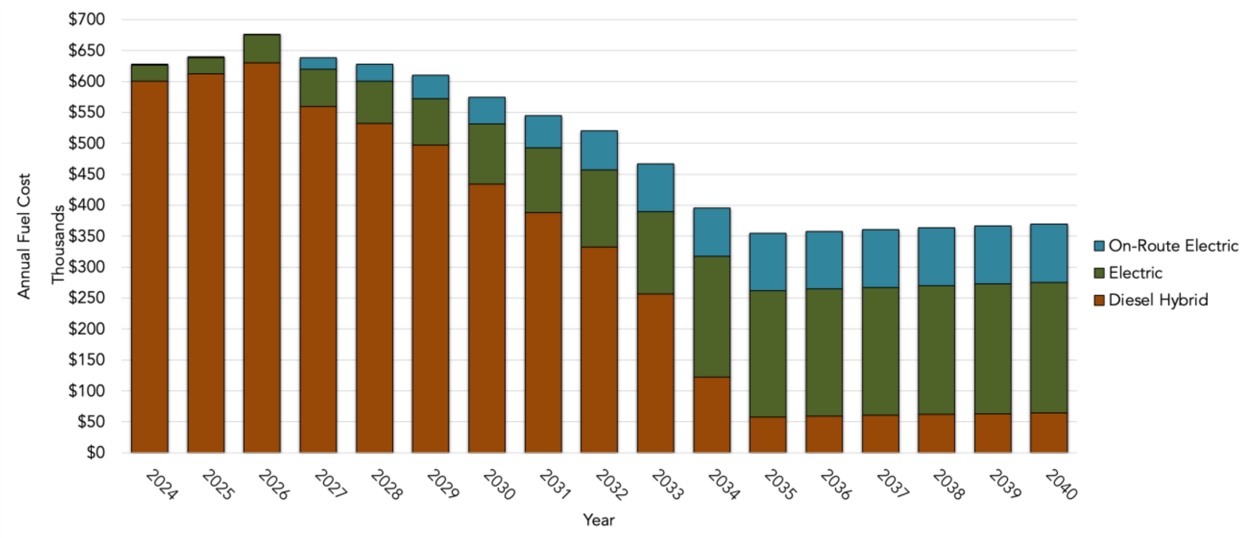

Figure 21 - Annual Fuel Cost: BEB and On-Route Charged Scenario

Summary

When comparing vehicle options for fuel cost versus capabilities, there are a few tradeoffs to consider. **Figure 22** and **Table 12** show the cumulative fuel costs throughout the transition timeline by scenario. The Baseline scenario has a projected cumulative cost of $13.2M, the BEB Depot (Plug-in) Only scenario has a projected fuel cost of $11M, and the BEB Depot (Plug-in) and On-Route (Pantograph) Charged scenario has a projected cost of $8.5M over the transition timeline.

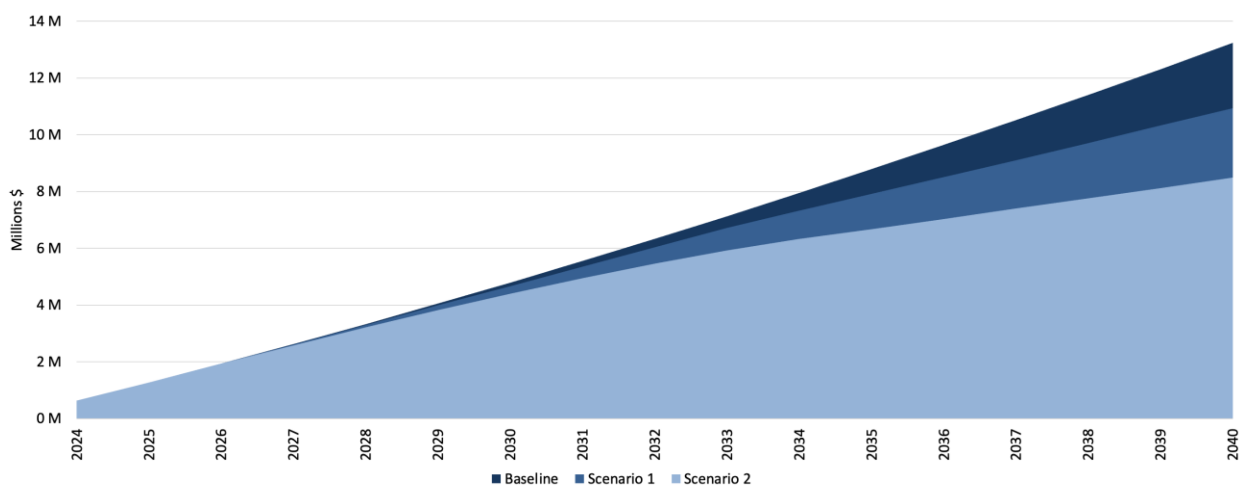

Figure 22 - Cumulative Fuel Costs by Scenario (2024-2040)

Table 12 - Cumulative Fuel Costs by Scenario

Costs	Baseline	Scenario 1 (BEB Depot Only)	Scenario 2 (BEB Depot & On-Route)
Cumulative ($)	13.2M	11M	8.5M
Incremental over Baseline ($)	-	-2.3	-4.7M
% ZEB Fleet by 2040	18%	100%	100%

Facilities Assessment

The FACILITIES ASSESSMENT determines the scale of fueling infrastructure (charging stations for BEBs) that is needed to meet the projected energy use for each scenario. It is informed by the Fleet and Fuel Assessments. Facilities costs are estimated based on the assessed infrastructure requirements for the given fleet and the selected fueling technology. The information in this section is organized according to the fueling technology explored in this transition plan: depot-charging and on-route charging.

Assumptions

The following terms are used when discussing chargers and charging infrastructure:

- **Charging Station:** Self-contained unit that connects to grid, converts electricity from AC to DC, and outputs power to bus through dispenser.
- **Power Cabinet:** Structure to hold power conversion hardware. Connects to multiple dispensers.
- **Dispenser:** Cord that carries DC power from power conversion hardware to bus's charge inlet.

The charging infrastructure for the project will include the purchase and installation of 180kW depot plug-in chargers and dispensers, as well as 350 kW on-route pantograph chargers. The depot-charging ratio is set at 2 dispensers for every 1 charger, while the pantograph-charging ratio will be 4 buses per 1 charger.

Analysis Results

Baseline

The Baseline scenario assumes 2 BEBs in service from 2024-2025 and 6 BEBs in service from 2026-2040. **Figure 23** shows the annual energy use associated with the BEBs in the fleet. This scenario assumes that in 2040, Mountain Line will operate 6 BEBs and 1 pantograph which will result in a 2040 total demand of 450 kw (450 kw* 1 charger) and a 2040 annual energy of 162,600 kWh.

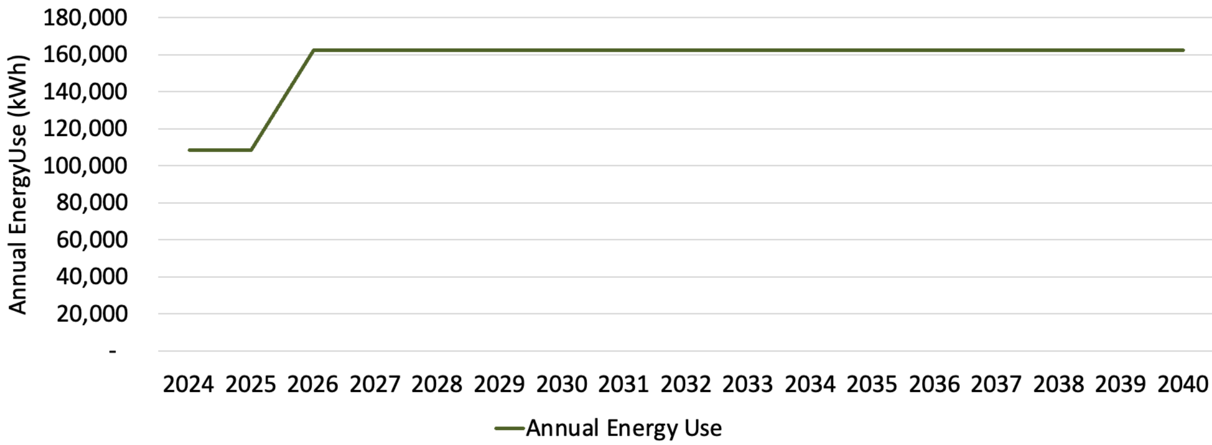

Figure 23 - Annual Energy Usage Baseline Scenario

BEB Depot (Plug-in) Only

The BEB Depot (Plug-in) Only scenario assumes Mountain Line will transition their fleet to 47 BEBs by 2040. This scenario does not consider on-route charging.

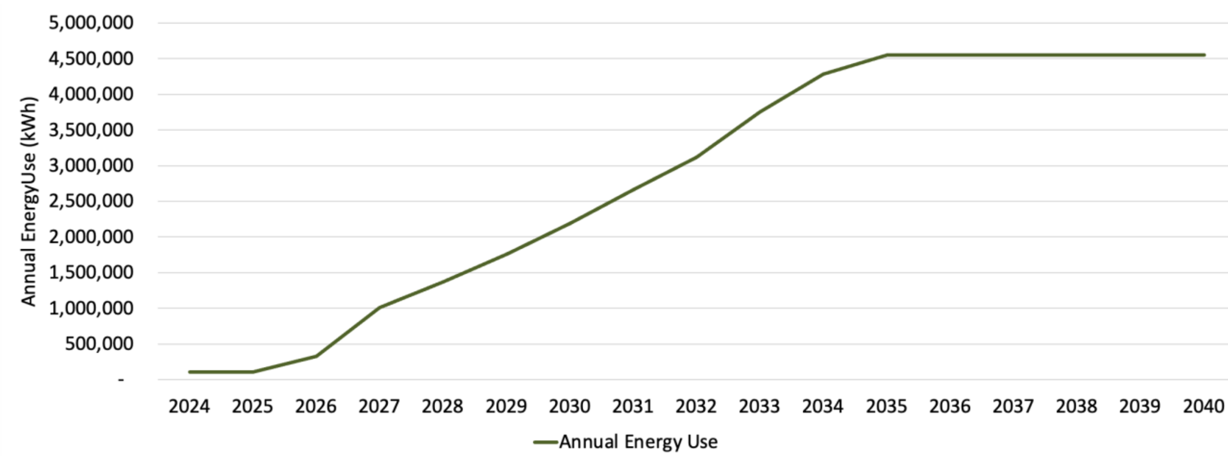

Figure 24 shows the annual energy use associated with the BEBs in the fleet. This scenario assumes that by 2040, Mountain Line will have purchased 24 depot chargers (48 dispensers) which will result in a 2040 total demand of 4320 kw (180 kw* 24 chargers) and a 2040 annual energy of 4.6MWh.

Figure 25 shows the number of chargers added by year and the number of BEBs in Mountain Line's fleet throughout the transition timeline.

BEB infrastructure upgrades require comprehensive planning and often require additional power upgrades. Mountain Line should coordinate with their utility to ensure the infrastructure meets growing demand.

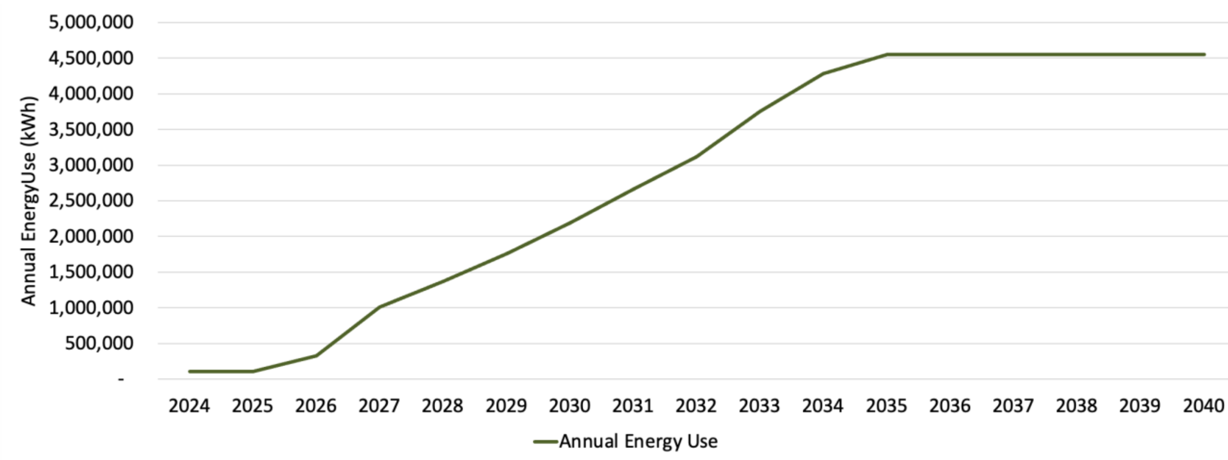

Figure 24 - Annual Energy Usage: BEB Depot (Plug-in) Only Scenario

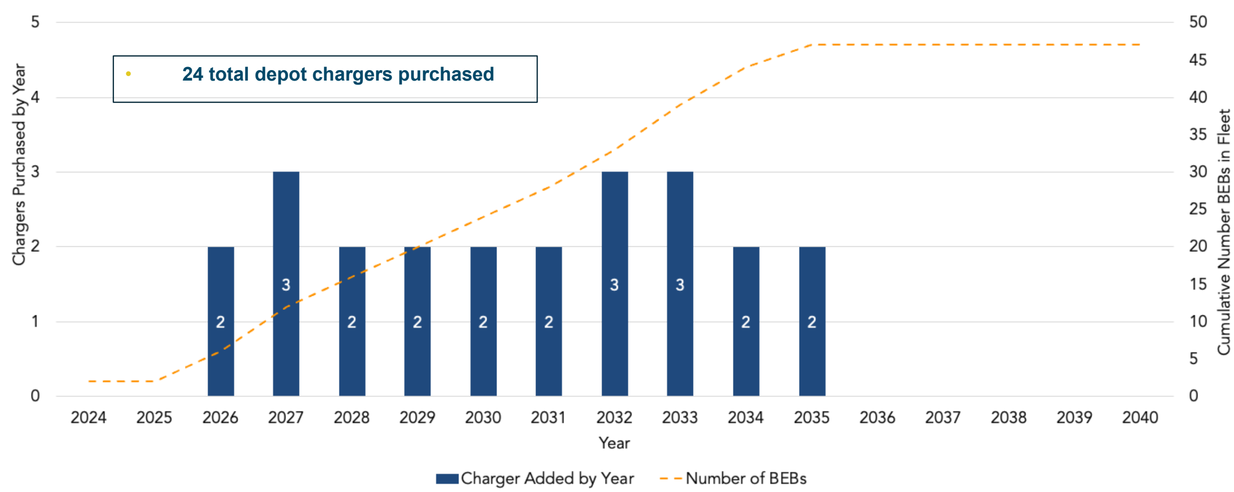

Figure 25- Annual Infrastructure Purchases BEB Depot (Plug-in) Only Scenario

BEB Depot (Plug-in) and On Route (Pantograph) Charged

The BEB Depot (Plug-in) and On Route (Pantograph) Charged scenario assumes Mountain Line will transition their fleet to 32 BEBs by 2040. **Figure 26** shows the annual energy use associated with the BEBs in the fleet. This scenario assumes that by 2040, Mountain Line will have purchased 21 chargers (5 pantograph chargers and 16 depot chargers) along with 32 dispensers which will result in a 2040 total demand of 5,130 kw [(450 kw* 5 pantograph chargers) + (180 kW*16 depot chargers) and a 2040 annual energy of 1.3MWh.

Figure 27 shows the number of chargers (depot and pantograph) added by year and the number of BEBs in Mountain Line's fleet throughout the transition timeline.

BEB infrastructure upgrades require comprehensive planning and often require additional power upgrades. Mountain Line should coordinate with their utility to ensure the infrastructure meets growing demand.

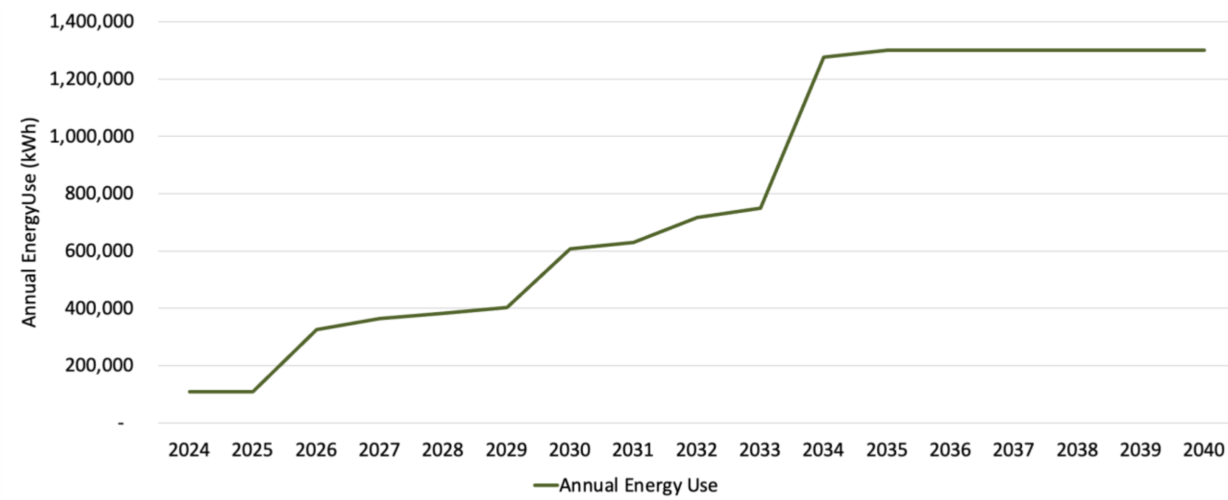

Figure 26 - Annual Energy Usage: BEB Depot (Plug-in) and ORC (Pantograph) Scenario

- **16 total depot chargers (plug-in) purchased**
- **5 on-route chargers (pantograph) purchased**

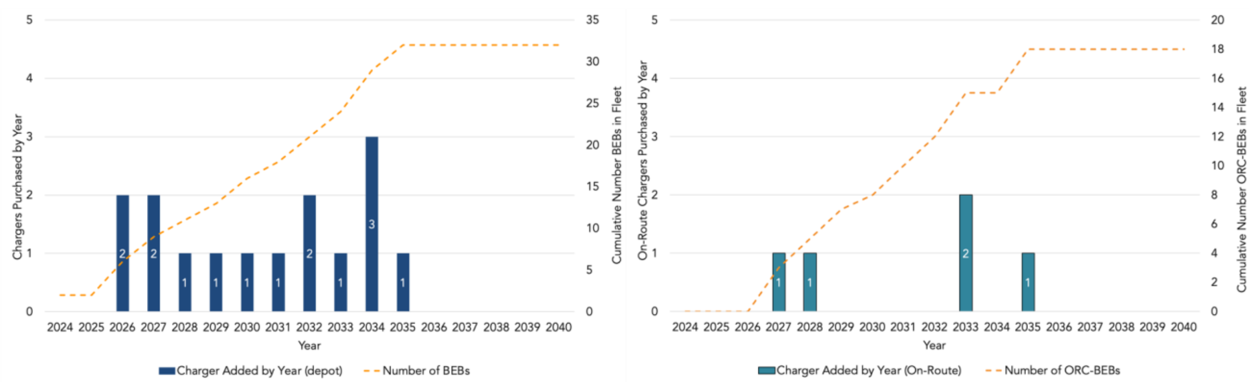

Figure 27- Annual Infrastructure Purchases BEB Depot (Plug-in) and ORC (Pantograph) Scenario

CTE does not transition vehicles based off block assignment, but rather on annual block feasibility (%) as vehicles are ready to be replaced. Deployment of BEBs on certain blocks, and thus charger location, is ultimately up to Mountain Line. However, CTE has provided the following estimates of where chargers may be recommended based off block feasibility data received from Mountain Line. **Table 13** and **Table 14** displays the number of chargers (depot plug in and on route pantograph) purchased in each year throughout the transition at each location.

15 weekday blocks would require on-route (pantograph) charging in 2026: 9 of the On-Route-Charged service will occur at the Downtown Connection Center (DCC) and 6 of the On-Route-Charged Service will occur at the Mall Connection Center (MCC). The current DCC assumption is that only two pantograph chargers can be accommodated due to Rio de Flag flood mitigation constrains. It was determined that with the current service structure and number of blocks that utilize DCC but not MCC, three pantograph chargers are needed at the DCC. This may not be an issue as 47% of blocks are anticipated to be achievable in 2034, and 74% by 2036 with advances in bus battery capacity. Mountain Line will need to monitor as the situation draws closer.

CTE split annual On-Route Charged-vehicles according to 60%/40% ratio, to estimate chargers needed at each location.

Table 13 - Charger Purchases each Year Downtown Connection Center (DCC)

DCC	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
ORC-BEB Count	2	3	4	5	6	7	9	9	11	11	11	11	11	11	11
ORC Purchases	1						1		1						3

Table 14 - Charger Purchases each Year Mall Connection Center (MCC)

MCC	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Total
ORC-BEB Count	1	2	3	3	4	5	6	6	7	7	7	7	7	7	7
ORC Purchases		1					1								2

Conclusions and Recommendations

Zero-emission buses offer a wide range of benefits not only for the agencies deploying them but also for the communities they serve. There are significant environmental benefits associated with the transition to ZEB technology. Widespread adoption of zero-emission bus technology has the potential to greatly reduce greenhouse gas (GHG) emissions resulting from the transportation sector. Through the reduction of tailpipe emissions, ZEBs benefit the environment by delivering better air quality and health benefits to the passengers and neighboring areas which tend to be disproportionately low-income and historically disadvantaged communities. Additionally, the total cost of ownership for a ZEB fleet has the potential to be equal to or less than a fleet of ICE vehicles. ZEBs are also significantly quieter than traditional vehicles which can help with noise reduction.

Mountain Line is a great example of an agency motivated to move to ZEBs without any mandates or staff well-versed in ZEB technology. To get a better understanding of the obstacles and requirements involved with the switch to zero-emission, Mountain Line has proactively worked to develop a ZEB transition plan to act as a blueprint for ZEB long-term fleet and facilities management.

ZEB technologies are in a period of rapid development. While the technologies have been proven in many pilot deployments, they are not yet matured to the point where they can easily replace current ICE technologies on a large scale. BEBs require significant investment in facilities and infrastructure and may require changes to service and operations to manage their range constraints. FCEBs can provide an operational equivalent to ICE buses, but the cost of buses, fueling infrastructure, and fuel remain a significant barrier to mass adoption. Despite the challenges associated with ZEB technology, Mountain Line has the opportunity to implement environmentally friendly policies and reduce its carbon footprint.

Summary of Scenario Options

The approach for this transition plan is based on the analysis of two ZEB technology scenarios compared to a baseline scenario. The baseline scenario is reflective of Mountain Line's current diesel hybrid bus fleet. The two potential transition scenarios include a BEB Depot (Plug-in) Only scenario of battery electric buses charged at the depot and a BEB Depot (Plug-in) and On Route (Pantograph) Charged scenario of battery electric buses charged at the depot and on route.

Recommendations

Given these considerations, the recommendations for Mountain Line are as follows:

1) **Select a preferred scenario to refine and remain proactive with ZEB deployment grants:** This Transition Plan was developed to present Mountain Line with options for transitioning to a fully zero-emission fleet. The Plan will put forth Mountain Line's vision for a ZEB Transition and will act as a living document to help the agency plan out grant funding requirements. As a greater proportion of Mountain Line's fleet converts to ZEB technology, auxiliary equipment, hardware, and software will be needed to ensure a successful fleet transition. Mountain Line should continue to remain proactive in the purchase and deployment of ZEBs and their associated systems by taking advantage of various grant and incentive programs.
2) **Monitor local and regional developments:** In the zero-emission technology sector, developments at the local level can have the ability to catapult the industry forward. When local bus OEMs or fuel providers enter the zero-emission market, it can spark technological innovation and cost reduction. Neighboring transit agencies can also work together through group purchasing agreements and lobbying efforts to reduce purchase costs or increase funding opportunities.
3) **Evaluate requirements for workforce and stakeholders:** Understand the impacts that the ZEB transition will have on key stakeholders and changes to accommodate workforce development. Evaluate the tradeoffs for various alternatives to reduce the risk for stakeholders at all levels for hurricanes, tropical storms, power outages, equipment failure, and fuel disruptions, and allow Mountain Line to meet all first responder requirements.
4) **Match the individual bus technology to the individual route and blocks:** Mountain Line should consider the strengths of given ZEB technologies and focus those technologies on routes and blocks that take advantage of their efficiencies and minimize the impact of the constraints related to the respective technologies. These technologies cannot follow a one-size-fits-all approach from either a performance or cost perspective. Matching the present technology to the present service levels will be a critical best practice.

The transition to ZEB technologies represents a fundamental paradigm shift in bus procurement, operation, maintenance, and infrastructure. It is only through a continual process of deployment with specific goals for advancement that the industry can achieve the goal of economically sustainable, zero-emission public transit.

Appendix B – Mountain Line Block Energy Needs by Bus Size

Weekday Estimated Block Energy			
Block	Vehicle Class	Distance (mi)	Strenuous Energy (kWh)
502	35'	18	43
502	35'	44	106
401	35'	143	343
202	35'	148	354
6602	35'	162	388
702	35'	164	393
402	35'	178	426
701	35'	180	431
801	35'	182	437
1401	35'	190	455
501	35'	190	457
301	35'	192	461
203	35'	198	476
201	35'	208	500
6601	35'	225	541
302	35'	256	615
1004	60'	80	310
1005	60'	80	311
1003	60'	99	386
1002	60'	118	459
1001	60'	163	637
1002	60'	163	637
1001	60'	170	662

Weekend Estimated Block Energy			
Block	Vehicle Class	Distance (mi)	Strenuous Energy (kWh)
202 SA	35'	73	175
1001 SA	60'	131	510
1002 SA	60'	131	510
401 SA	35'	150	360
501 SA	35'	165	397
201 SA	35'	170	409
1401 SA	35'	174	416
701 SA	35'	177	424
6601 SA	35'	186	446
301 SA	35'	227	544
MTEX 1	35'	216	518
MTEX 2	35'	186	446
MTEX 3	35'	186	446