LANE TRANSIT DISTRICT

FLEET PROCUREMENT PLAN

PHASE II

TASK 4: FINAL FLEET PROCUREMENT PLAN

April 2023

Final

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ACRONYMS AND TERMS

Acronym/Term	Description
AC Transit	Alameda-Contra Costa Transit District
ADA	Americans with Disabilities Act
AFC	Alternative Fuels Corridor
BEB	Battery-electric bus
BEV	Battery-electric vehicle
BIL	Bipartisan Infrastructure Law
BRT	Bus rapid transit
CMAQ	Congestion Mitigation and Air Quality
CMS	Charge management system
CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalent
CRP	Carbon Reduction Program
DC	Direct current
DGE	Diesel Gallon Equivalent
ENC	ElDorado National-California
EPA	U.S. Environmental Protection Agency
FCEB	Fuel-cell electric bus
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
GHG	Greenhouse Gas
GVWR	Gross vehicle weight rating
H2Hubs	Clean Hydrogen Hubs
HVAC	Heating, ventilation, and air conditioning
ICEV	Internal Combustion Engine Vehicle
Kg	kilogram
kW	Kilowatt
kWh	Kilowatt-hour
LTD	Lane Transit District
NEVI	National Electric Vehicle Infrastructure
NO_X	Nitrogen oxides
O&M	Operations and maintenance
OCTA	Orange County Transportation Authority
OEM	Original equipment manufacturer
Plan	Lane Transit District's 15-Year Fleet Procurement Plan
PRISM	A proprietary tool developed by WSP to assess fleet lifecycle costs
RNG	Renewable Natural Gas
RNP	Renewable propane
R99	Renewable diesel
SARTA	Stark Area Regional Transit Authority
SMR	Steam methane reformation
USDOT	U.S. Department of Transportation

1 INTRODUCTION

1.1 BACKGROUND AND APPROACH

In 2020, Lane Transit District (LTD) adopted the Climate Action Policy Statement and Fleet Procurement Goals, which commit to three general goals for LTD's fleet: 1) retire and replace 25 vehicles in the existing fleet with battery-electric buses (BEBs) by 2023, 2) reduce tailpipe emissions by 75 percent by 2030 and eliminate fossil fuel vehicles by 2035, and 3) perform a deliberate exploration of emerging technology and fuels.

To accomplish these goals, LTD launched a two-phased project that will result in the development of a 15-Year Fleet Procurement Plan (Plan). Phase I of the project focused on exploring the fuel and technology options available. Phase 2 then focused on refining the assessment and developing the Plan. The Plan aims to establish the framework of implementable actions that need to be taken to transition LTD's fleet to cleaner fuel and technologies.

Concluded in February 2022, Phase 1 of the project assessed different fuels and technologies in the context of LTD's Triple-Bottom-Line Approach to Sustainability, which focuses on a fuel/technology's impact on operations, social equity and environment, and finances. The final outputs of Phase 1 are the Transit and Paratransit Fleets' *Selection of Priority Fuels/Technologies Reports*, which provided preliminary lists of priority fuels and technologies to be further explored in Phase 2.[1]

In Phase 2, in-depth fleet-wide lifecycle emission and cost appraisals (through 2040) were conducted for each priority fuel/technology scenario.[2] The emission analysis calculated the greenhouse gas (GHG) and tailpipe emissions reductions from the transition for each fuel/technology scenario. Meanwhile, the lifecycle cost analysis was conducted by using the PRISM Model, which provided a comprehensive assessment of the capital, operating and maintenance (O&M), disposal, and environmental costs of each fuel/technology scenario. As the final output of the project, this 15-year Procurement Plan summarizes findings from previous analyses and provides implementation considerations for LTD's fleets transitions.

1.2 FINDINGS

Table 1-1 lists the priority fuel/technology scenarios explored in Phase 2 for both transit and paratransit fleets. The analyses were done in comparison to the baseline scenarios that reflect the fuels and technologies currently used by LTD.

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[1] Refer to Appendix A for Phase I – Transit and Paratransit Fleets Selection of Priority Fuels/Technologies Reports

[2] Refer to Appendix C for Phase II - Priority Fuel/Technology Scenario Report

Table 1-1. Fuel/Technology Scenarios

Service	Existing (Baseline) Fuel/Technology	Priority Fuel/Technology Scenarios
Transit	R99 Renewable Diesel	Renewable Natural Gas
		Battery-electric
		Hydrogen
Paratransit	E10 Gasoline	Renewable Propane
		Battery-electric

Source: WSP, LTD

The results from emissions and lifecycle cost analyses showed that each fuel/technology scenario has different advantages and disadvantages. From the cost perspective, existing fuels and technologies have the lowest capital costs but produce the most emissions. For the transit fleet, renewable natural gas (RNG) has the lowest overall lifecycle costs due to the lower O&M costs. Meanwhile, more nascent zero-emission (ZE) technologies, especially battery-electric vehicles (BEVs), produce the lowest emissions but have significantly higher lifecycle costs due to the higher capital and O&M costs. Table 1-2 summarizes the findings from the emissions and lifecycle cost analyses.

Table 1-2. Findings from Emissions and Lifecycle Cost Analyses

Indicators	Transit Fleet				Paratransit Fleet		
	Renewable Diesel	RNG	Battery-Electric	Hydrogen	E10 Gasoline	Renewable Propane	Battery-Electric
Lowest GHG Emissions			V				V
Lowest Tailpipe Air Pollutants			V	V			V
Lowest Capital Costs	V				V		
Lowest O&M Costs		V			V		
Lowest Lifecycle Costs		V			V		

Source: WSP, LTD

It is important to note that the analyses were based on empirical numbers observed by peer agencies operating similar technologies. Newer ZE fuels and technologies currently have higher costs. However, with the increasing policy support and rapid technology development, the costs are expected to decrease in the future. Moreover, the production of all fuels is forecasted to become greener, which will provide additional emissions reductions. Thus, LTD needs to periodically reassess the analyses to make an informed decision on future fuel and technology use.

Based on the findings, all fuel/technology scenarios were deemed feasible to be adopted by LTD in the future, depending on the priority given to the different aspects of each fuel and technology. Thus, all three future fuel/technology scenarios for the transit fleet (RNG, battery-electric, and hydrogen) and two future fuel/technology scenarios for the paratransit fleet (renewable propane [RNP] and battery-electric) are elaborated in this Procurement Plan.

1.3 REPORT STRUCTURE

This report is organized into five main sections. The first section, Introduction, provides an overview of the project's background and approach, findings from the previous phase and analyses, and the report's structure. The second section, Existing Conditions, provides an overview of the existing facility, fleet, and service provided by the transit and paratransit fleets. The third and fourth sections, Transit Fleet Procurement Plan and Paratransit Fleet Procurement Plan, respectively, present the technology overview, transition schedule, emissions, lifecycle costs, and transition considerations for the baseline fuel/ technology and each priority fuel/technology scenario. Finally, the Summary and Next Steps section summarizes the pathways for both transit and paratransit fleets and outlines the next steps in the transition process.

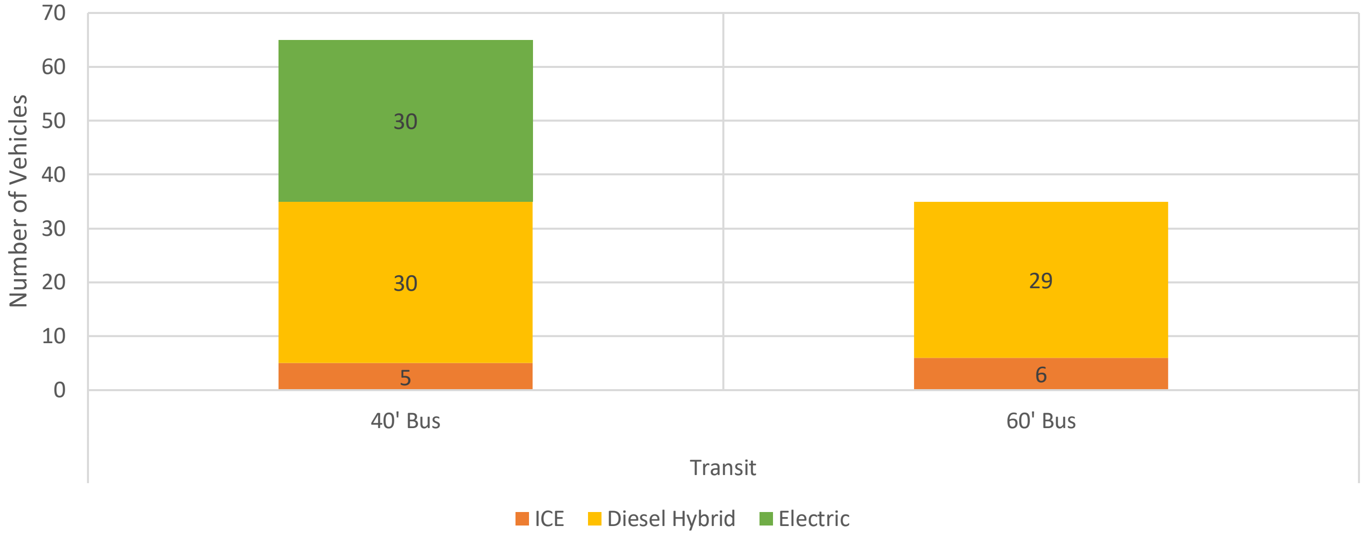
2 EXISTING CONDITIONS

2.1 TRANSIT FLEET

LTD operates fixed-route and bus rapid transit service on 31 routes with a 100-bus fleet. The fleet consists of sixty-four 40-foot buses and thirty-six 60-foot articulated buses, 22 of which are dedicated for LTD's Emerald Express bus rapid transit service. Based on LTD's vehicles' miles traveled and age, the average annual miles traveled is approximately 47,500 miles for a 40-foot bus and 44,800 miles for a 60-foot bus.

LTD has already taken the first step toward meeting its Climate Action Policy Statement and Fleet Procurement Goals by placing its first 11 BEBs in service in June 2021. The first 11 BEBs are New Flyer XE40s, with a 388 kilowatt-hour (kWh) capacity and are charged by 150 kilowatt (kW) chargers. Nineteen longer-range BEBs are being procured and will be delivered in 2022, bringing the total BEB fleet to 30 vehicles, surpassing the Board's Climate Action Policy Statement and Fleet Procurement Goals of procuring 25 BEBs by 2023. Figure 2-1 illustrates LTD's expected transit fleet inventory in 2022, including the 30 new BEBs.

Figure 2-1. Transit Fleet Inventory 2022



Source: LTD (August 2022)

Currently, the majority of the vehicles (59 percent) are diesel hybrid buses. Additionally, 11 percent are diesel vehicles fueled by R99 renewable diesel (99 percent renewable diesel/1 percent fossil diesel). The vehicles are fueled on site at the transit fleet facility (Figure 2-2).

Figure 2-2. LTD Transit Fleet Facility

Source: Google Earth (2022)

2.2 PARATRANSIT FLEET

LTD's Americans with Disability Act (ADA)–compliant paratransit service, RideSource, is an origin-to-destination transportation solution for people unable to use a fixed-route bus due to a disability, as mandated by the ADA in 1990. The service operates within approximately 3/4 mile of bus routes in the Eugene/Springfield metropolitan area and is available during the same hours as fixed-route service. Besides the ADA paratransit service, RideSource also offers transportation services for residents who are eligible under Medicaid and the Oregon Health Plan. These services are mainly provided through an external fleet, such as taxis or other for-hire vehicles, operated by a partner agency, separate from the LTD-owned vehicles.

RideSource is operated with a total of 53 vehicles, which includes 47 cutaway shuttle buses and six modified vans (Figure 2-3). All of LTD's paratransit vehicles are fueled by E10 gasoline at a local gas station. While RideSource vehicles are owned by LTD, they are operated and maintained by a contracted service provider at the LTD-owned Garfield Facility (Figure 2-4). The average annual miles traveled for each active vehicle varies between 15,300 to 25,600 miles for cutaway and 10,900 to 21,900 miles for modified van.[3]

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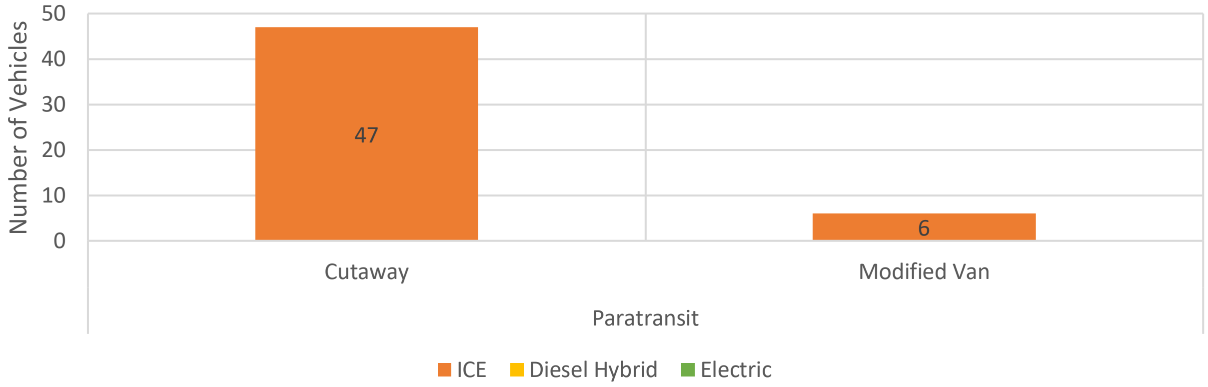
[3] Calculated from latest odometer reading from LTD Agency Quarterly Report Q3 FY 2021-2022

Figure 2-3. Paratransit Fleet Inventory 2022



Source: LTD (August 2022)

Figure 2-4. LTD Paratransit Fleet Facility

Source: Google Earth (2022)

3 TRANSIT FLEET PROCUREMENT PLAN

After considering LTD's Triple-Bottom-Line Approach to Sustainability and in-depth emissions and lifecycle cost analyses, three priority fuel/technology scenarios are deemed feasible to be adopted by LTD's transit fleet: RNG, battery-electric, and hydrogen. This chapter discusses the transition schedule, emissions, lifecycle costs, and transition considerations of each fuel/technology scenario in comparison to the baseline scenario of R99 renewable diesel fuel/technology.

3.1 BASELINE SCENARIO: R99 RENEWABLE DIESEL

3.1.1 TECHNOLOGY OVERVIEW

In September 2020, LTD transitioned from conventional B5 ultra-low sulfur diesel (95 percent fossil diesel/5 percent biodiesel) to R99 renewable diesel (99 percent renewable diesel/1 percent fossil diesel).

It is important to note that renewable diesel is not the same as biodiesel. Despite using the same renewable feedstock such as plant and animal waste, the two fuels have different production processes. The process to create biodiesel is called transesterification, which produces fuel that contains oxygen atoms, making it chemically distinct from regular diesel. Renewable diesel, on the other hand, is produced from a process called hydrotreating that produces a fuel chemically identical to regular diesel. Due to their identical properties, renewable diesel can run on conventional diesel engine without any upgrades or retrofitting. Meanwhile, only approved vehicle models can run on high-content biodiesel. R99 renewable diesel, though more expensive, emits fewer lifecycle GHGs than conventional diesel fuel.

VEHICLE AVAILABILITY

R99 renewable diesel can be used in conventional diesel buses. Thus, by using this fuel, LTD has the option to keep operating and procuring the same vehicles that are currently in the fleet. Currently, LTD is operating 40-foot Gillig diesel buses and 60-foot New Flyer diesel buses. The major original equipment manufacturers (OEMs) for 40-foot diesel buses are Gillig, New Flyer, NOVA Bus, and ElDorado National-California (ENC). Meanwhile, 60-foot diesel buses are available from New Flyer and NOVA Bus. Note that the industry is currently experiencing industry-wide supply chain disruptions that increase the lead time for vehicles and parts procurements.

FUEL AVAILABILITY

R99 renewable diesel is produced in the United States or imported from Asia.[4] As of 2020, there were five commercial renewable diesel plants with a combined capacity of 550 million gallons, and one facility

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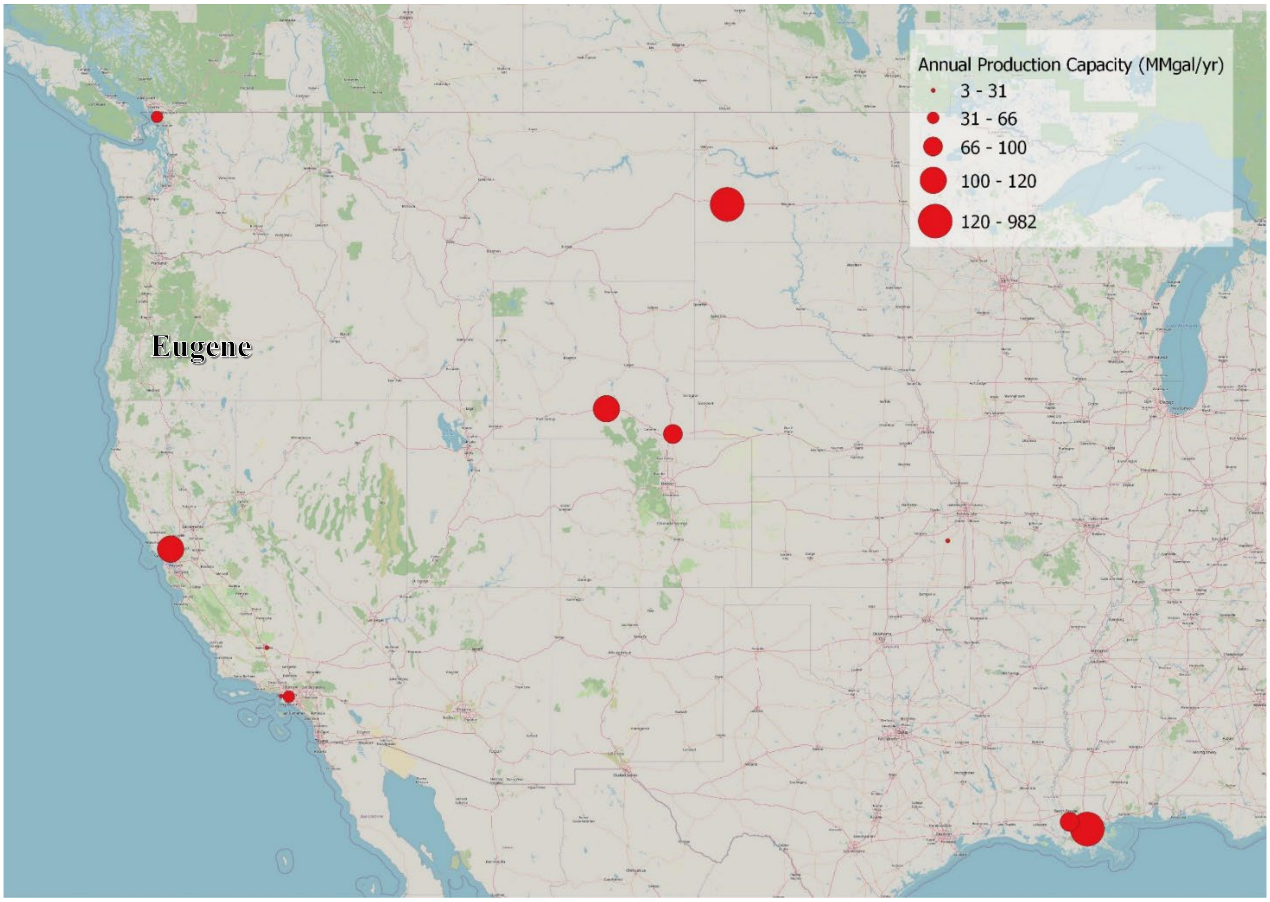
[4] Alternative Fuels Data Center. *Renewable Hydrocarbon Biofuels.* https://afdc.energy.gov/fuels/emerging_hydrocarbon.html

producing both renewable diesel and sustainable aviation fuel with a capacity of 42 million gallons. Production is expected to grow in the near term, with two billion gallons of additional capacity from six plants currently under construction and three existing plants under expansion. Figure 3-1 illustrates the production capacity of U.S. renewable diesel plants in January 2022. The closest plants to Eugene are approximately 400 miles north in Blaine, Washington, and 500 miles south in Rodeo, California.

Nearly all domestically produced and imported renewable diesel is used in California due to economic benefits under the Low Carbon Fuel Standard. As of February 2022, LTD procures its R99 renewable diesel based on monthly bid cycles. Commonly, only a single fuel supplier can meet this request. The fuel is produced in Asia, shipped to Portland, and trucked to Eugene.

Figure 3-1. Transit Fleet - Renewable Diesel Plants 2022



Source: U.S. Energy Information Administration (2022)

3.1.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS AND CONSTRUCTION SCHEDULE

Currently, the majority of LTD transit vehicles are diesel hybrid vehicles or internal combustion engine vehicles (ICEVs) fueled by R99 renewable diesel. These vehicles are fueled on site at the transit fleet facility. Therefore, the transit facility is equipped with the required fueling infrastructure and will not need further improvements for future fleet in this baseline R99 renewable diesel scenario. Infrastructure replacement and maintenance might be needed, but it will not affect the vehicle procurement schedule.

VEHICLE PROCUREMENT SCHEDULE

LTD currently has a transit fleet procurement plan spanning through 2031. Using LTD's vehicle useful life assumptions,[5] the plan was extrapolated through 2040. In the baseline R99 renewable diesel scenario, LTD will replace all current diesel hybrid buses with new R99 renewable diesel buses and keep the 30 BEBs in the fleet. Several vehicles may need to be operated past their useful lives to more evenly distribute the number of vehicles procured annually. This scenario's procurement plan serves as the baseline for the procurement schedules of the other priority fuel/technology scenarios included in this report.

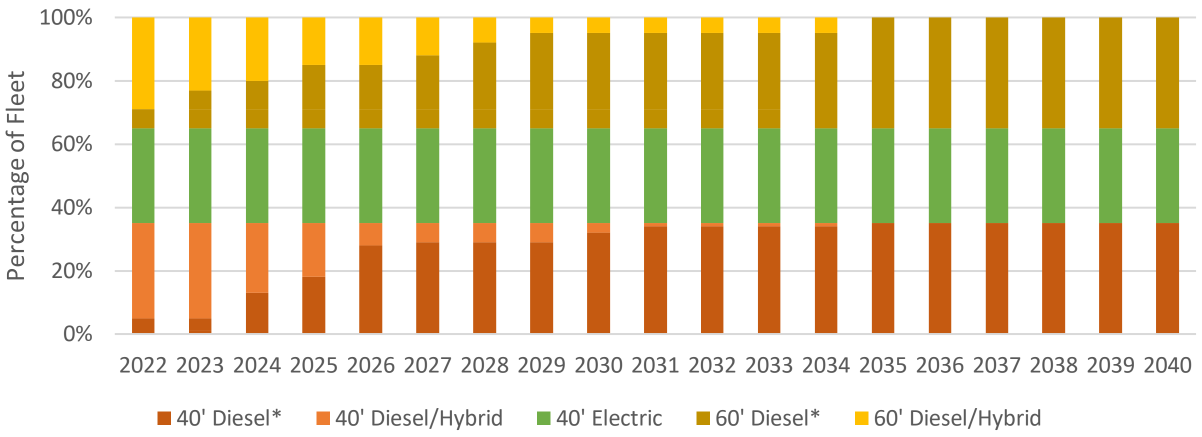
Table 3-1 details the baseline procurement schedule, showing the number of new vehicles that will be delivered each year. Figure 3-2 illustrates the baseline transit fleet inventory by year, fuel type, and vehicle type, including the existing 30 BEBs.

Table 3-1. Transit Fleet – Baseline Procurement Schedule

Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
40' Diesel*	0	4	9	5	10	1	0	0	3	2	0	0	0	1	0	12	6	10	1
40' Electric	19	0	0	0	0	0	0	0	0	0	0	11	6	6	7	0	0	0	0
60' Diesel*	0	6	3	5	0	3	4	3	0	0	0	0	6	5	0	6	8	0	3
Total	19	10	12	10	10	4	4	3	3	2	0	11	12	12	7	18	14	10	4

Source: LTD, WSP
*All diesel buses use R99 renewable diesel fuel

Figure 3-2. Transit Fleet – Baseline Inventory



Source: LTD Long Range Fleet Replacement Plan, WSP
*All diesel buses use R99 renewable diesel fuel

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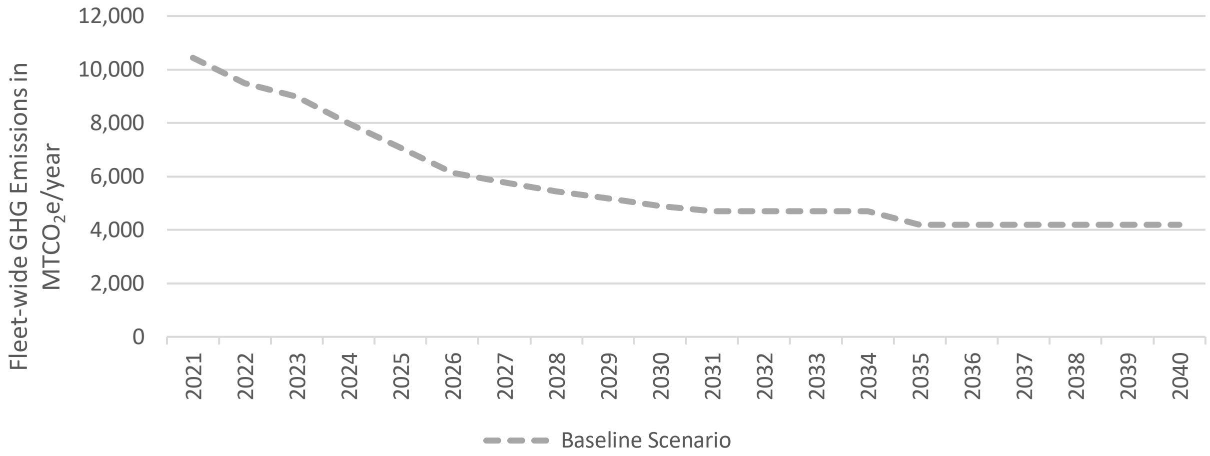
[5] Diesel Bus: 14 years, Diesel/Hybrid: 13 years, BEB: 12 years

3.1.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the baseline R99 renewable diesel scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation. The baseline scenario results in a 60 percent decrease in annual GHG emissions in 2040 as compared to 2021 conditions (Figure 3-3). R99 renewable diesel buses are expected to be cleaner than the current diesel hybrid buses which will result in immediate emissions reductions as the diesel hybrid buses are retired and replaced by new R99 renewable diesel buses.

The annual lifecycle GHG emissions (carbon dioxide equivalent; CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory and procurement schedule and estimated duty cycles (mileage). The number does not include emissions from vehicle components production.

Figure 3-3. Transit Fleet - Baseline Annual GHG Emissions



Source: WSP

3.1.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet/technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[6]

Based on the analysis, the lifecycle costs of the baseline R99 renewable diesel scenario is $664 million or approximately $5.15 per mile (Table 3-2). Total capital costs for the baseline R99 renewable diesel scenario are $271 million and mostly consist of new vehicle costs. Current transit facility is equipped with sufficient fueling infrastructure, which will not need further upgrades except for parts replacement. Meanwhile, the total O&M costs are $359 million. If only considering the cash costs (capital, O&M, and disposal costs), the baseline R99 renewable diesel scenario has total cash costs of $628 million or $4.87 per mile. The total environmental costs are $36 million. This scenario has relatively low capital and O&M

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[6] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

costs but high environmental costs. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components and the supporting fueling infrastructure.

Table 3-2. Transit Fleet – Baseline 2022-2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline Scenario
Cash Costs		
Capital Costs	Vehicle Purchase Price	$260.6
	Modifications and Contingency	$1.4
	Charging/Fueling Infrastructure	$8.6
	Total Capital Costs	*$270.7*
O&M Costs	Vehicle Maintenance	$174.6
	Vehicle Tires	$27.0
	Vehicle Fuel Costs	$143.9
	Charging/Fueling Infrastructure	$8.1
	Incremental Training Costs	$5.4
	Total O&M Costs	$359.0
Disposal Costs	Battery Disposal	$0.0
	Bus Disposal	-$1.8
	Total Disposal Costs	-$1.8
	Total Cash Costs	**$627.9**
	Total Cash Cost per Mile	**$4.87**
Non-Cash Costs		
Environmental Costs	Emissions - Tailpipe	$9.6
	Emissions - Refining/Utility	$13.8
	Noise	$12.7
	Total Environmental Costs	*$36.1*
	Total Cash and Non-Cash Cost	**$664.0**
	Total Cash and Non-Cash Cost per Mile	**$5.15**

Source: WSP PRISM Tool

3.1.5 IMPLEMENTATION CONSIDERATIONS

In conclusion, the baseline R99 renewable diesel scenario has relatively low capital and lifecycle costs but high environmental costs. LTD will need to consider the trade-off of both aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects that should be considered, as described below.

OPERATIONAL IMPACT

Considering that R99 renewable diesel is LTD's existing fuel/technology, it is expected that this scenario will have minimum impact on LTD's daily operation.

FUEL AVAILABILITY

As discussed in section 3.1.1, R99 renewable diesel is currently still in limited production. LTD will need to rely on a small number of suppliers, which comes with risks in the event of disruptions. If a disruption occurs, the service can still operate by using conventional diesel that is widely available, but with higher GHG emissions. R99 renewable diesel production is expected to grow in the next several years.

POLICY SUPPORT AND FUNDING AVAILABILITY

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. R99 renewable diesel could be considered a low-emission fuel; however, several alternative fuel funding sources do not include R99 renewable diesel in the requirements. There are currently no specific incentives available at the state level for low-emission transit buses.

There are several incentives and funding sources at the federal level that could fund R99 renewable diesel buses, including:

- Federal Transit Administration (FTA) Low or No Emission Vehicle Program (part of the Bipartisan Infrastructure Law; BIL): May be used for the purchase or lease of low-emission transit buses and related equipment, as well as construction of supporting facilities
- Congestion Mitigation and Air Quality (CMAQ) Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure
- Carbon Reduction Program (CRP): Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- U.S. Department of Transportation (USDOT) Rebuilding American Infrastructure with Sustainability and Equity (RAISE) competitive grant program

3.2 SCENARIO 1: RENEWABLE NATURAL GAS FLEET

3.2.1 TECHNOLOGY OVERVIEW

Natural gas is an odorless, gaseous mixture of hydrocarbons, predominantly made up of methane (CH_4). It is mainly used in electric power production but has been proven to be a reliable alternative fuel to power natural gas vehicles in the form of compressed natural gas (CNG) or liquefied natural gas. The vast majority of CNG in the United States is derived from fossils and, therefore, considered a fossil fuel.

Renewable natural gas (RNG) sourced from biomass is available as a cleaner alternative and can be used interchangeably with CNG to power natural gas vehicles.[7] RNG is produced by purifying biogas from organic materials, such as waste from landfills and livestock, through thermochemical processes. RNG is

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[7] U.S. Department of Energy: Office of Energy Efficiency & Renewable Energy.2020. *Natural Gas Vehicle Basics.* https://afdc.energy.gov/files/u/publication/natural_gas_basics.pdf

chemically identical to conventional CNG with similar amounts of tailpipe emissions. However, RNG will significantly reduce the upstream GHG emissions from fuel production.

As a vehicle fuel, RNG is stored onboard in a compressed gaseous state at a pressure of up to 3,600 pounds per square inch. Natural gas vehicles have a slightly shorter range than diesel buses—between 350 and 400 miles on a full tank.

Natural gas vehicles will need to undergo periodic inspection to ensure the condition of the fuel tanks. The fuel tank will need to be inspected in a qualified service facility every three years or 36,000 miles, whichever comes first.

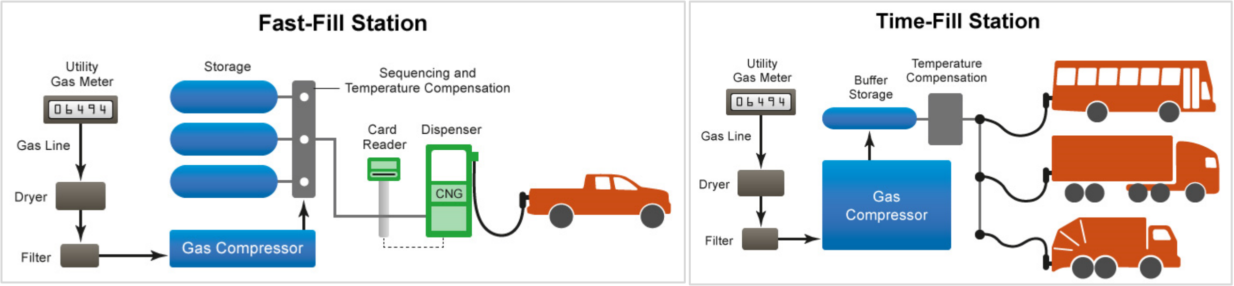
FUELING INFRASTRUCTURE

There are two configurations available for RNG fueling stations (Figure 3-4):

- **Fast-fill stations** fill vehicles rapidly using larger compression equipment and high-pressure gas-storage systems. Generally, this configuration is more suitable for retail charging stations where a high volume of vehicles need to fill up quickly. The fuel is stored in storage vessels at a high service pressure (4,300 pounds per square inch), so the dispenser can quickly deliver the fuel to the vehicle. The fueling time is comparable to that of conventional diesel buses.

- **Time-fill stations** fuel vehicles automatically overnight, taking advantage of smaller, less expensive compression equipment. Fueling time depends on the number of vehicles, compressor size, and amount of buffer storage. This configuration is primarily used by fleets and is more suitable for large vehicles that refuel at a central location every night. In this configuration, CNG is delivered at low pressure to a compressor on site. Vehicles generally are filled directly from the compressor without the need for high-pressure storage vessels. In general, time-fill stations are designed specifically for the intended use. Thus, further analysis and design efforts will be needed to assess the most suitable solution for LTD’s RNG fueling station.

Figure 3-4. Transit Fleet – RNG Fueling Configuration



Source: Alternative Fuels Data Center

VEHICLE AVAILABILITY

There are several OEMs that offer 40-foot and 60-foot CNG transit buses and have been proven reliable by peer agencies. Forty-foot CNG buses are available from ENC, Gillig, New Flyer, and NOVA Bus. Meanwhile, only New Flyer currently offers 60-foot CNG buses. As noted above, the industry is currently experiencing industry-wide supply chain disruptions, which increase the lead time for vehicles and parts procurements.

Several light-duty and medium-duty vehicles are available for retrofit by a qualified system retrofitter or vehicle modifier. However, such retrofit is not available for the 40-foot transit buses or 60-foot articulated buses operated by LTD.

Fuel Availability

RNG is produced domestically and can be distributed by using the existing natural gas pipeline distribution system. RNG production is available from various producers locally and nationally. Early coordination with the utility provider will be needed to understand the utility provider’s specific policy for RNG distribution.

3.2.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS

RNG is lighter than air and will therefore rise to the ceiling of the maintenance facility and quickly dissipate in the event of leakage. The natural gas could potentially ignite if it achieves the required level of concentration and encounters an ignition source. In most cases, natural gas will dissipate before achieving an ignitable concentration level. However, proper mitigation measurements still need to be installed to protect against fire and explosion.

Although some of the means of protection for RNG are similar to those used for liquid fuels (ventilation and elimination of ignition sources), the types and placement of the equipment are different because of the gaseous nature of the fuel and its properties. Additionally, specific safeguard measures, such as methane detection and an alarm system, might be needed to alert personnel about dangerous natural gas concentrations. The primary documents to follow for implementing safety measures are the National Fire Protection Association's publication NFPA 30A – Code for Motor Fuel Dispensing Facilities and Repair Garages and the appropriate sections of the International Fire Code. However, codes and ordinances vary widely by jurisdiction; thus, early interaction with local authorities is strongly encouraged to ensure that the appropriate codes are followed.[8]

LTD will need to install new RNG fueling stations on site. Early contact with the local utility provider (NW Natural) will be needed to ensure that the transit fleet facility can receive piped natural gas. The utility provider will determine whether the appropriate level of gas pressure is available at the site, ensure that the gas quality and moisture content are appropriate, and assess whether the existing gas service (if any) can support the future required gas flow.

The required fueling infrastructure will depend on the fueling configuration. Fast-fill stations will require a compressor, high-pressure storage vessels, and dispensers. Time-fill stations, on the other hand, generally only need a compressor and a buffer storage.

CONSTRUCTION SCHEDULE

The future fuel/technology vehicles should only be delivered once the maintenance facility is upgraded to accommodate RNG and the new fueling station. The design procurement phase of the whole facility

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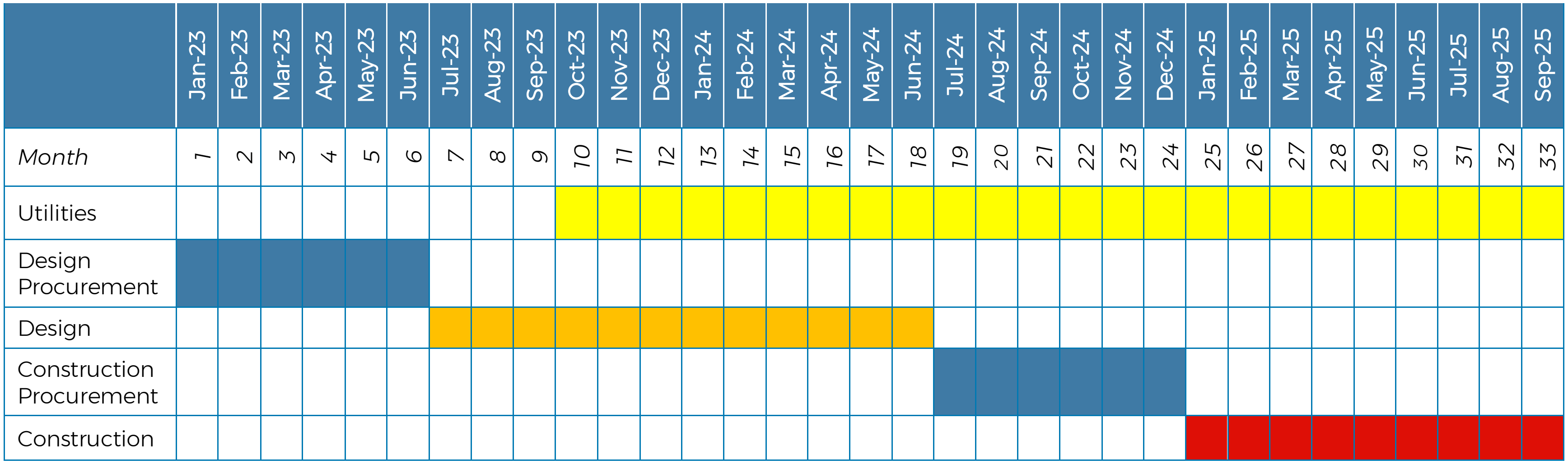
[8] National Renewable Energy Laboratory (NREL) provides a summary of natural gas-related codes and citations which can be accessed at https://afdc.energy.gov/files/pdfs/48611.pdf. However, local authority will make the final decision on which codes to follow

improvement is assumed to occur between January and June 2023, followed by 12 months of design. Utility coordination and construction procurement phases will occur simultaneously with the design phase. Construction for RNG is assumed to take nine months, beginning in January 2025 and concluding in September 2025. Based on the proposed schedule, the transit facility will be ready to accept future RNG vehicles in 2025. Figure 3-5 illustrates the construction timeline for the fleet.

Figure 3-5. Transit Fleet – RNG Scenario Proposed Construction Schedule



	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25
Month	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*
Utilities										🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Design Procurement	🟦	🟦	🟦	🟦	🟦	🟦																											
Design							🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧															
Construction Procurement																			🟦	🟦	🟦	🟦	🟦	🟦									
Construction																									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥

Source: WSP

VEHICLE PROCUREMENT SCHEDULE

Based on the assumed schedule, facility upgrades for RNG fueling will be completed in 2025. Therefore, any vehicles delivered during the construction process, between 2023 and 2025, are assumed to be R99 renewable diesel vehicles. Any vehicles delivered in 2025 and beyond are assumed to be RNG vehicles. The existing 30 BEBs are assumed to remain in the fleet, and no fleet expansion is expected. Considering that the average vehicle lead time is approximately 18 months, LTD will need to start the procurement process in fiscal year 2023 to have vehicles delivered in 2025. Table 3-3 details the proposed procurement schedule.

Table 3-3. Transit Fleet – RNG Scenario Proposed Procurement Schedule

Vehicle Type	2022	2023	2024	2025*	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
40' Diesel*	0	4	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' Electric	19	0	0	0	0	0	0	0	0	0	0	11	6	6	7	0	0	0	0
60' Diesel*	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' RNG Bus	0	0	0	5	10	1	0	0	3	2	0	0	0	1	0	4	9	5	10
60' RNG Bus	0	0	0	5	0	3	4	3	0	0	0	0	6	5	0	6	3	5	0
Total	19	10	12	10	10	4	4	3	3	2	0	11	12	12	7	10	12	10	10

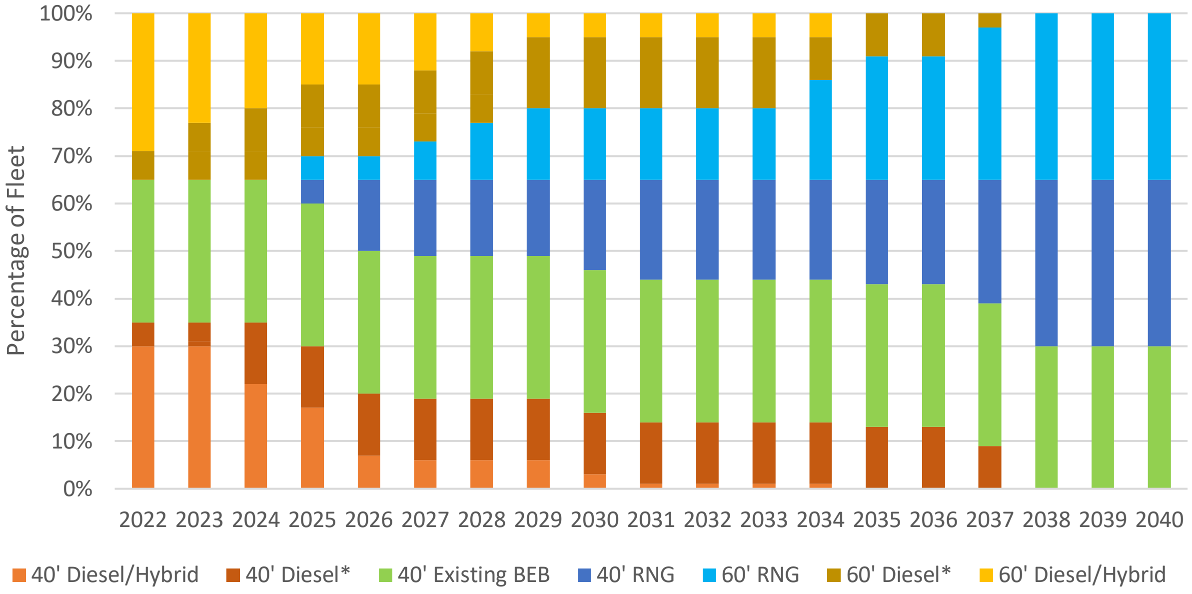
Source: WSP, LTD

* All diesel buses use R99 renewable diesel fuel

The schedule is developed with the assumption that vehicles will be replaced at end of useful life. The current R99 renewable diesel buses and future RNG buses are expected to have 14 years of useful life, the existing hybrid diesel buses are assumed to have 13 years useful life, and the existing BEBs are assumed to have 12 years of useful life. Several vehicles may need to be operated past their useful life to more evenly distribute the number of vehicles procured annually.

Figure 3-6 illustrates the future vehicle inventory. Based on the current assumed vehicle useful life, the R99 renewable diesel vehicles will be fully replaced by 2038. Note that the minimum useful life required by the FTA for heavy-duty buses is 12 years or 500,000 miles. Therefore, if LTD wants to achieve the goal of eliminating fossil fuel by 2035 while staying in compliance with FTA requirements, any R99 renewable diesel vehicles procured in 2023 need to be retired in 12 years, while vehicles procured in 2024 will need to achieve 500,000 miles by 2035.

Figure 3-6. Transit Fleet – RNG Scenario Future Vehicle Inventory



Source: LTD, WSP

* All diesel buses use R99 renewable diesel fuel

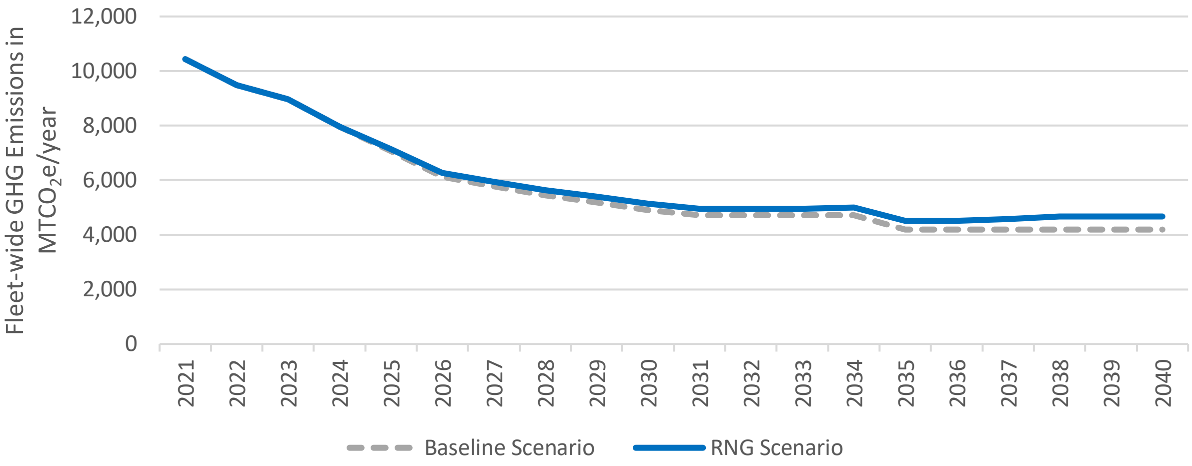
3.2.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the RNG scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation. The transition to RNG buses results in a 55 percent decrease of lifecycle GHG emissions in 2040 compared to 2021, which is 5% percent less effective than the reduction achieved by the baseline R99 renewable diesel scenario (Figure 3-7).

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory and procurement schedule and estimated duty cycles (mileage). The RNG and baseline scenarios have the same emissions profile until 2024. Then they start to diverge after the transition to the RNG fleet begins in 2025. The number does not include emissions from vehicle components production.

Moreover, the RNG scenario will result in significant nitrogen oxides (NO_X) and volatile organic compound (VOC) emission reductions, as compared to the baseline. However, RNG has considerably more carbon monoxide (CO) emissions.

Figure 3-7. Transit Fleet – RNG Scenario Annual GHG Emissions



Source: WSP

3.2.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[9]

Based on the analysis, transitioning to a full RNG fleet has the lowest lifecycle cost due to the lower O&M cost compared to the baseline R99 renewable diesel scenario. The total lifecycle cost of the RNG fuel/technology scenario is approximately $624 million or $4.96 per mile, 9 percent ($40 million) lower than the baseline R99 renewable diesel scenario (Table 3-4). The RNG fuel/technology scenario is the only future fuel/technology option with lifecycle costs lower than the existing fuel.

In terms of capital costs, RNG has higher total costs than the baseline scenario due to the higher vehicle costs and the infrastructure costs of building new RNG fueling stations and retrofitting the maintenance facility. The RNG fuel/technology scenario total capital cost is 12 percent ($32 million) higher than the baseline scenario.

However, RNG has lower total O&M costs than the baseline R99 renewable diesel scenario due to significantly lower fuel costs. Higher training and fueling infrastructure maintenance costs are expected, especially considering that the technology will be newly adopted by LTD. However, the costs will be offset by the savings from lower vehicle maintenance costs and fuel costs. Therefore, the RNG fuel/technology scenario total O&M cost is 19 percent lower ($68 million) than the baseline R99 renewable diesel scenario.

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[9] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

The total cash cost (capital, O&M, and disposal costs) of the RNG fuel/technology scenario is 6 percent ($36 million) lower than the baseline scenario, with a total of $592 million, or $4.71 per mile.

When combining both GHG and local air pollutants, the total environmental costs of the RNG fuel/ technology scenario are slightly better than the baseline R99 renewable diesel vehicles due to the lower tailpipe emissions. The environmental costs of the scenario are 10 percent ($4 million) lower than the baseline R99 renewable diesel scenario. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components and the supporting fueling infrastructure.

Table 3-4. Transit Fleet – RNG Scenario 2022–2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline	RNG
Cash Costs			
Capital Costs	Vehicle Purchase Price	$260.6	$285.0
	Modifications and Contingency	$1.4	$1.6
	Charging/Fueling Infrastructure	$8.6	$16.1
	Total Capital Costs	*$270.7*	*$302.7*
O&M Costs	Vehicle Maintenance	$174.6	$149.9
	Vehicle Tires	$27.0	$26.1
	Vehicle Fuel Costs	$143.9	$52.9
	Charging/Fueling Infrastructure	$8.1	$45.4
	Incremental Training Costs	$5.4	$16.2
	Total O&M Costs	$359.0	$290.6
Disposal Costs	Battery Disposal	$0.0	$0.0
	Bus Disposal	-$1.8	-$1.7
	Total Disposal Costs	-$1.8	-$1.7
Total Cash Costs		$627.9	$591.5
Total Cash Cost per Mile		$4.87	$4.71
Non-Cash Costs			
Environmental Costs	Emissions - Tailpipe	$9.6	$5.6
	Emissions - Refining/Utility	$13.8	$14.6
	Noise	$12.7	$12.3
	Total Environmental Costs	*$36.1*	*$32.4*
Total Cash and Non-Cash Cost		$664.0	$623.9
Total Cash and Non-Cash Cost per Mile		$5.15	$4.96

Source: WSP PRISM Model

O&M = operations and maintenance; RNG = renewable natural gas; YOE = year of expenditure

3.2.5 IMPLEMENTATION CONSIDERATIONS

In conclusion, the RNG scenario has the lowest lifecycle costs and reduces the majority of tailpipe emissions. However, it has higher lifecycle GHG emissions compared to the baseline scenario. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects that should be considered, as described below.

VEHICLE RANGE

Natural gas vehicles have a range between 350 and 400 miles, which is sufficient for most service. However, this is less than the range of conventional diesel buses, so service planners need to keep this in mind when planning the service blocks.

FUELING TIME

Especially if choosing the time-fill fueling configuration, LTD will need to ensure that all buses will have enough time to refuel overnight.

POLICY SUPPORT AND FUNDING

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. Natural gas is generally considered a low emission alternative fuel and is eligible for alternative fuel funding. There are currently no specific incentives available at the state level for low emissions transit buses.

There are several incentives and funding sources at the federal level that can potentially fund RNG buses, including:

- FTA Low or No Emission Vehicle Program (part of the BIL): May be used for the purchase or lease of low emission or ZE transit buses and related equipment, as well as the construction of supporting facilities
- CMAQ Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure
- CRP: Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- USDOT RAISE competitive grant program
- Alternative Fuel Excise Tax Credit: $0.50 per diesel gallon equivalent (DGE) tax credit for fuel that is used to operate vehicles

There are several other programs that do not apply to transit vehicles or depot fueling infrastructure, but indicate a strong push toward the adoption of alternative fuels, such as the Federal Highway Administration (FHWA)’s designated National Alternative Fuels Corridor (AFC) grant and National Electric Vehicle Infrastructure (NEVI) formula funding programs. Both programs, especially the AFC grant, aim to establish interconnected networks of public alternative fueling corridors, including natural gas fueling stations.

RENEWABLE NATURAL GAS DISTRIBUTION

RNG is chemically identical to conventional natural gas. Therefore, once injected into the pipeline, there is no difference between RNG and CNG. The fuel costs paid by LTD will ensure that the required amount of RNG is being produced. However, the produced RNG then will be mixed and distributed with conventional CNG to the LTD facility through the distribution pipeline.

3.3 SCENARIO 2: BATTERY-ELECTRIC BUS FLEET

3.3.1 TECHNOLOGY OVERVIEW

BEBs use on-board batteries to store and distribute energy to power an electric motor and other on-board systems. Today's market-available BEBs come with on-board battery packs with capacities of 300 to 700+ kWh of energy storage and can achieve 125 to 200 miles on a single charge. Battery technology is continually advancing, both in efficiency and size; for instance, Proterra recently announced a 738 kWh battery to be produced in 2023 that is projected to support an estimated vehicle range of 300 miles.

Batteries are heavy and less energy dense than other forms of transit fuel. With existing technologies, adding battery capacity to increase vehicle range above 200 miles often comes at a cost of reducing passenger capacity to meet gross vehicle weight rating (GVWR) restrictions. Vehicle energy consumption rates are typically measured as kWh per mile, and route and operating characteristics such as hills; driver behavior and heating, ventilation, and air conditioning (HVAC) load can all affect energy consumption rates and thus reduce vehicle range.

CHARGING INFRASTRUCTURE

Similar to many other battery-powered products, BEBs must be charged for a period of time to be operational. The successful deployment of a BEB fleet requires a comprehensive understanding of the various charging systems available. The three most common charging systems—plug-in, pantograph, and inductive—each serve a specific function and are subject to their respective limitations. Table 3-5 covers some of the pros and cons of each technology, and Figure 3-8 shows examples.

Table 3-5. Transit Fleet – Charging Technology Pros and Cons Overview

Charging Technology	Pros	Cons
Plug-In	– Compatible with multiple bus OEMs. – Charging cabinets can be remotely located overhead or away from the immediate bus parking areas.	– Has limited output capacity (not appropriate for on-route charging) – Requires personnel to manually plug the charger into the bus, introducing possibility of user error
Pantograph	– Requires minimal operator interaction to begin or end the charging process – Appropriate for depot and on-route charging – Can deliver higher power for faster charging if connected to a higher-power charging cabinet	– Has more moving parts – Costs more than plug-in dispensers – Requires adequate space under existing enclosed garage roof structures or new overhead frame support structures at exterior bus parking areas
Inductive	– Requires no mechanical moving parts, reducing maintenance requirements and costs – Requires minimal or no operator interaction during charging process – Induction systems can support shared charging ratios of up to 1:4 (chargers to dispensers/vehicles).	– Most expensive of the three technologies – There is no standard for inductive charging for heavy duty vehicles. Currently, all inductive charging systems are proprietary and there is no interoperability across OEMs' equipment.

Source: WSP USA, Inc.

Figure 3-8. Transit Fleet – BEB Charging Methods

Plug-in

Pantograph

Inductive

Source: YorkMix, ABB (formerly ASEA Brown Boveri), and Long Beach Transit (left to right)

Each charging type will have various charge rate and configuration options. The power rate, charger configuration, and BEB battery capacity will affect charging time. For example, a 150 kW direct current (DC) charger with 1:2 configuration (one charger cabinet and two dispensers) will be able to charge two buses at 75 kW rate concurrently (depending on each charger model specification). Thus, a BEB with 525 kWh battery capacity will need approximately 3.5 hours to fully charge, assuming a 150 kW charge rate, or 7 hours assuming 75 kW charge rate.

VEHICLE AVAILABILITY

Technological advances over the past 20 years have made BEBs a viable and desirable alternative to traditional diesel-fueled buses. There are a variety of bus OEMs that produce BEBs in the United States, with many new OEMs joining the market (Arrival, Van Hool, etc.). As noted above, the industry is currently experiencing industry-wide supply chain disruptions, which increase the lead time for vehicles and parts procurements. Table 3-6 summarizes the available BEBs on the market that best align (based on length and vehicle type) with LTD’s existing fleet. BYD is currently not available for federal funding due to the National Defense Authorization Act.[10]

Table 3-6. Transit Fleet – Available BEBs in the U.S. Market

Manufacturer	Length	Capacity (kWh)
BYD	40 feet	313–352
	60 feet	578
GreenPower	40 feet	400
Gillig	40 feet	444

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[10] Federal Transit Administration. *FAQ Regarding Section 7613 of the National Defense Authorization Act for FY20.* https://www.transit.dot.gov/funding/procurement/frequently-asked-questions-regarding-section-7613-national-defense

Manufacturer	Length	Capacity (kWh)
New Flyer	40 feet	350/440/525
	60 feet	525
NOVA Bus	40 feet	564
Proterra	40 feet	675

Source: WSP
BEB = battery-electric bus; kWh = kilowatt hours

FUEL AVAILABILITY

Electricity is generally available as long as the power grid and the facility have enough electrical capacity and are equipped with infrastructure to support the required load. If any upgrades are needed, the timeline will vary depending on the scale of the upgrades. Ideally, the BEB delivery will happen after the electricity and charging stations are available on site. Depending on the utility provider, it might be possible to gradually bring power to the site. Considering that the solution will be site specific, continuous coordination with the utility provider is strongly encouraged to ensure seamless transition to a full BEB fleet.

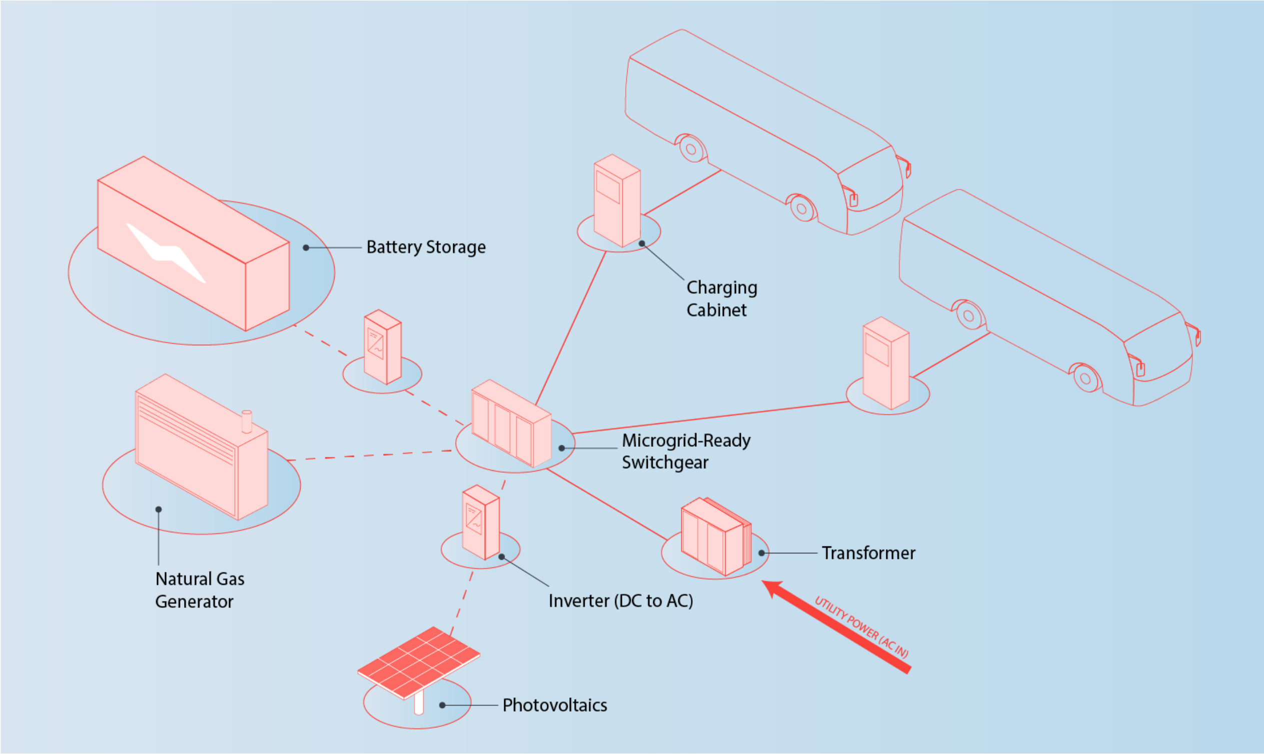
3.3.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS

Overnight depot charging ensures that vehicles have a full state of charge for morning pullout. However, depot charging requires significant amounts of power. To accommodate its existing 30 BEBs, LTD has performed upgrades to the facility's utility service, including upgrading the transformers and switchgears. Further utility assessment will be needed to estimate the required upgrade for a full 100-BEB transit fleet. An in-depth design process will also be needed to ensure the bus facility can efficiently accommodate the required number of chargers. A phased approach is recommended, in which sites are prepared for electrification in alignment with regular procurement cycles that convert the fleet to BEBs.

Figure 3-9 illustrates the various components of a BEV charging system. The needed infrastructure and equipment include: charging cabinet(s), which dispense power and, in most cases convert, power from alternating to direct current; transformer(s), which step down electricity to a safe and suitable limit; and switchgear(s), which allow for the isolation of power. Other components can also be considered, such as battery storage, photovoltaics (solar panels), and backup generators.

Figure 3-9. Transit Fleet – Battery-Electric Scenario Typical Charging System



Source: WSP

CONSTRUCTION SCHEDULE

BEBs should only be delivered once the maintenance facility is upgraded to accommodate the charging stations. The design procurement phase of the whole facility improvement is assumed to occur between January and June 2023, followed by 12 months of design. Utility coordination and construction procurement phases will occur simultaneously with the design phase. Construction for a BEB fleet is assumed to be completed in two phases, with the first phase completed in September 2025 and the second concluded in March 2026. Based on the proposed schedule, the transit facility will be ready to accept BEB vehicles in 2025. BEB delivery can start once the phase 1 construction is completed in September 2025.

The construction timeline for the battery-electric scenario reflects a conservative schedule; the phases may be streamlined considering that LTD has previous experience in retrofitting the transit facility to accommodate the existing BEBs. Moreover, LTD has upgraded the utility equipment and installed chargers to anticipate the existing 30 BEBs. Depending on the actual chargers usage and the available capacity of the equipment, several more BEBs may be accommodated without needing any significant upgrade. More in-depth analysis will be needed to assess the required upgrade for a full BEB fleet. Figure 3-10 illustrates the construction timeline for the fleet.

Figure 3-10. Transit Fleet – Battery-Electric Scenario Proposed Construction Schedule

	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26
Month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Utilities										🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨						
Design Procurement	🟦	🟦	🟦	🟦	🟦	🟦																																	
Design							🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧																					
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Construction Phase I																									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
Construction Phase II																																		🟥	🟥	🟥	🟥	🟥	🟥

Source: WSP

VEHICLE PROCUREMENT SCHEDULE

Based on the assumed schedule, BEB vehicle delivery can start in 2025. Therefore, any vehicles delivered during the construction process, between 2023 and 2025, are assumed to be R99 renewable diesel vehicles. Any vehicles delivered in 2025 and beyond are assumed to be BEBs. Considering that the average vehicle lead time is approximately 18 months, LTD will need to start the procurement process in fiscal year 2023 to have vehicles delivered in 2025.

Table 3-7 details the proposed procurement schedule. The schedule is developed with the assumption that vehicles will be replaced at end of useful life. The current R99 renewable diesel buses are expected to have 14 years useful life, the existing hybrid diesel buses are assumed to have 13 years useful life, and BEBs are assumed to have 12 years of useful life. Several vehicles may need to be operated past their useful life to more evenly distribute the number of vehicles procured annually.

Figure 3-11 illustrates the future transit fleet inventory for the battery-electric scenario. Based on the current assumed vehicle useful life, the R99 renewable diesel vehicles will be fully replaced by 2038. Note that the minimum useful life required by the FTA for heavy-duty buses is 12 years or 500,000 miles. Therefore, if LTD wants to achieve the goal of eliminating fossil fuel by 2035 while staying in compliance with FTA requirements, any R99 renewable diesel vehicles procured in 2023 need to be retired in 12 years, while vehicles procured in 2024 will need to achieve 500,000 miles by 2035.

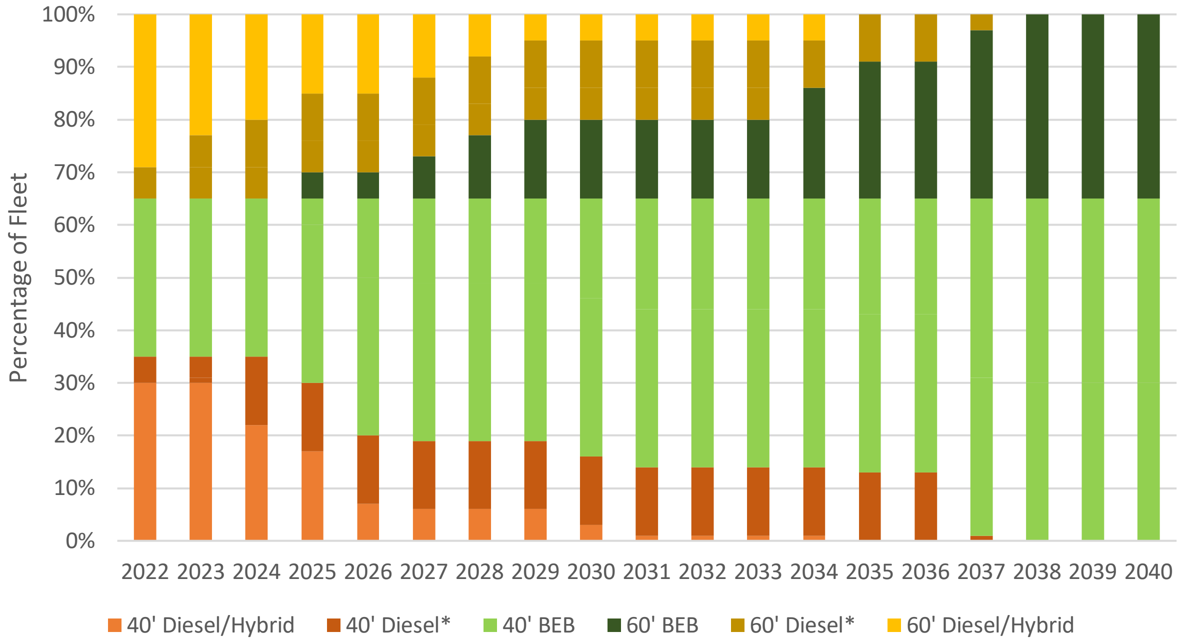
Table 3-7. Transit Fleet – Battery-Electric Scenario Proposed Procurement Schedule

Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
40' Diesel*	0	4	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' Electric	19	0	0	0	0	0	0	0	0	0	0	11	6	6	7	0	0	0	0
60' Diesel*	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' BEB	0	0	0	5	10	1	0	0	3	2	0	0	0	1	0	12	6	10	1
60' BEB	0	0	0	5	0	3	4	3	0	0	0	0	6	5	0	6	8	0	7
Total	19	10	12	10	10	4	4	3	3	2	0	11	12	12	7	18	14	10	8

Source: WSP, LTD

*All diesel buses use R99 renewable diesel fuel

Figure 3-11. Transit Fleet – Battery-Electric Scenario Future Vehicle Inventory



Source: LTD, WSP

* All diesel buses use R99 renewable diesel fuel

3.3.3 EMISSIONS

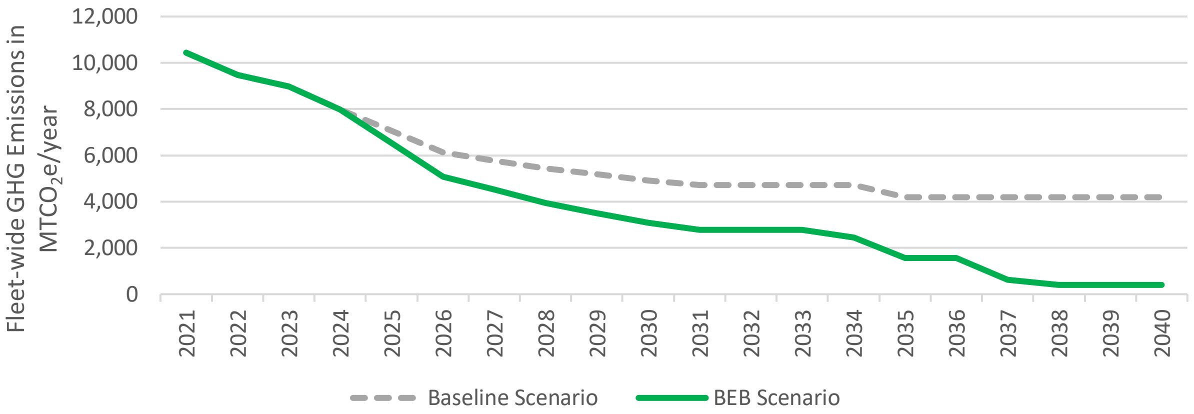
The lifecycle GHG emissions for all fuel/technology scenarios, including the battery-electric scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation.

The battery-electric scenario provides the greatest reduction in lifecycle GHG emissions and is the only future fuel/technology option with lower GHG emissions than the baseline R99 renewable diesel scenario. The estimated reduction from the battery-electric scenario in 2040 is 96 percent as compared to 2021 emissions, which is an additional 36 percent reduction as compared to the baseline R99 renewable diesel scenario (Figure 3-12). The lifecycle GHG emissions for battery-electric technology are exclusively from the upstream electricity generation.

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory, procurement schedule, and estimated duty cycles (mileage). The battery-electric and baseline scenarios have the same emissions profile until 2024. Then, they start to diverge after the transition to a full battery-electric fleet begins in 2025. Throughout the years, the battery-electric scenario constantly reduces more GHG emissions annually compared to the baseline R99 renewable diesel scenario.

BEBs do not produce tailpipe emissions, but particulate emissions from brake and tire wear would occur. No other tailpipe local air pollutants would be emitted from the transit fleet by 2040 in the battery-electric scenario.

Figure 3-12. Transit Fleet – Battery-Electric Scenario Annual GHG Emissions



Source: WSP

Upstream GHG emissions from vehicles and batteries productions were not evaluated as part of this analysis. The emissions will greatly vary depending on the source of raw materials and the production process used by the vehicle component OEMs. There is currently no standardized method to estimate these emissions.

The quantification of project-level GHG emissions from the battery lifecycle is an ongoing area of research. It is estimated that the full lifecycle emissions of a battery electric passenger vehicle are less than those of an internal combustion engine passenger vehicle.[11] The battery manufacturing process will add a new emissions component compared to traditional ICEVs. However, the overall lifecycle emissions of BEBs will be lower due to the lower emissions from electricity production and the zero tailpipe emissions. More studies are needed to determine if the same conclusion is true for different battery chemistries and vehicle types, especially when considering the larger battery requirements for medium- and heavy-duty vehicles such as buses and cutaways.

3.3.4 LIFECYCLE COSTS

Lifecycle cost analyses capture the total costs of transitioning the transit fleet to future fleet/technology. They assess direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[12]

Based on the analysis, the lifecycle costs of transitioning to a full battery-electric fleet are higher than the baseline R99 renewable diesel scenario due to the higher capital and O&M costs. The lifecycle costs of the battery-electric scenario are 33 percent ($220 million) higher than the baseline scenario (Table 3-8). The lifecycle costs are approximately $884 million or $6.68 per mile.

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[11] IEA. 2021. *Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle.* IEA. Paris. https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle

[12] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

The primary difference between battery-electric fuel/technology scenario and other options is the capital costs. Standard vehicle prices for diesel buses are considerably lower than for BEBs. Furthermore, LTD will need to install new charging stations, upgrade the utility infrastructure (if needed), and retrofit the maintenance facility to accommodate the new infrastructure. Thus, the total capital cost for the battery-electric fuel/technology scenario is approximately $441 million, 63 percent ($170 million) higher than the baseline scenario.

In terms of overall O&M costs, the battery-electric scenario has a total cost of $426 million, 17 percent higher than the baseline scenario. For battery-electric technology, the savings from the lower energy price in comparison to diesel is more than offset by the higher maintenance costs. Current data from peer agencies show that BEBs require higher vehicle maintenance than diesel buses throughout the first 10 years of operation, the extent of operational information currently available. Note that the analysis was based on empirical data from peer transit agencies that operate BEBs. These agencies were the first adopters and might be operating earlier versions of BEBs. O&M costs are highly dependent on factors that are continually evolving as BEBs continue to be deployed in transit service. More operational benefits may be experienced in the coming years as the technology improves.

If only considering the cash costs (capital, O&M, and disposal costs), the battery-electric scenario has 38 percent ($239 million) higher costs than the baseline R99 renewable diesel scenario. The total lifecycle cash cost is $867 million or $6.55 per mile.

When combining both GHG and local air pollutants, the battery-electric scenario will have the least environmental costs due to lower upstream emissions, virtually zero tailpipe emissions, and fewer noise impacts. A minimal amount of local air pollutants is still produced from brake and tire wear. The total non-cash environmental cost of battery-electric scenario is $17 million, 52 percent ($19 million) lower than the baseline R99 renewable diesel scenario. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components or the supporting charging and utility infrastructure.

Table 3-8. Transit Fleet – Battery-Electric Scenario 2022–2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline	Battery-Electric
Cash Costs			
Capital Costs	Vehicle Purchase Price	$260.6	$409.7
	Modifications and Contingency	$1.4	$2.5
	Charging/Fueling Infrastructure	$8.6	$29.2
	Total Capital Costs	*$270.7*	*$441.4*
O&M Costs	Vehicle Maintenance	$174.6	$281.2
	Vehicle Tires	$27.0	$29.7
	Vehicle Fuel Costs	$143.9	$86.5
	Charging/Fueling Infrastructure	$8.1	$12.9
	Incremental Training Costs	$5.4	$17.0
	Total O&M Costs	$359.0	$427.5
Disposal Costs	Battery Disposal	$0.0	$0.0
	Bus Disposal	-$1.8	-$1.8
	Total Disposal Costs	-$1.8	-$1.8
Total Cash Costs		$627.9	$867.1
Total Cash Cost per Mile		$4.87	$6.55
Non-Cash Costs			
Environmental Costs	Emissions - Tailpipe	$9.6	$3.4
	Emissions - Refining/Utility	$13.8	$2.8
	Noise	$12.7	$10.9
	Total Environmental Costs	*$36.1*	*$17.2*
Total Cash and Non-Cash Cost		$664.0	$884.3
Total Cash and Non-Cash Cost per Mile		$5.15	$6.68

Source: WSP PRISM Model

O&M = operations and maintenance; YOE = year of expenditure

3.3.5 IMPLEMENTATION CONSIDERATIONS

In conclusion, the battery-electric scenario has the lowest GHG and tailpipe emissions. However, it has higher lifecycle costs due to the higher capital costs and O&M costs. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects that should be considered, as described below.

VEHICLE RANGE

As discussed in section 3.3.1, current BEBs have limited battery capacity to stay in compliance with the mandated GVWR. It means that BEBs have a shorter range than conventional diesel buses. Depending on the vehicle size, the advertised range will vary from 125 to 200 miles on a single charge. Therefore, the service may need to be adjusted so it can be completed by a BEB. Another option is to prioritize deploying BEBs on the shorter service blocks while waiting for the technology and range to improve.

VEHICLE REPLACEMENT RATIO

Due to the lower range of BEBs, LTD may need to procure additional vehicles to complete the same amount of service. However, this will depend on the current peak vehicle ratio) of the fleet and the number of spare vehicles that can be utilized to cover service. For example, the longer block can be split to shorter blocks that can be completed by an additional spare vehicle while the BEB pulls in to the facility and charge midday (if possible). The charged BEB then can be used to complete another service block. This strategy will require additional pull out and may increase labor costs, but it will reduce the need for additional vehicles.

As the technology develops, it is expected that the vehicle range will improve, and the replacement ratio will be closer to the ideal 1:1. LTD will need to reassess the fleet replacement ratio as the technology matures.

BATTERY DEGRADATION AND EXTENDED WARRANTY

As a result of continued use and numerous charging instances, battery performance will degrade, which results in an even shorter range. Currently, battery packs are assumed to have six years of useful life. However, during the procurement, there will be an option to choose extended warranty that generally will guarantee 80 percent of initial battery capacity. Service planners and dispatchers need to be familiar with battery degradation to be able to adjust service accordingly.

CHARGING TIME AND CHARGE MANAGEMENT SYSTEM

The total charging time will vary depending on the charger speed, charging configuration, and BEB state of charge. LTD will need to make sure that the BEBs have enough time to charge. LTD may want to use charge management system (CMS), which is a software that can intelligently schedule charging time to minimize peak demand and utility costs while still giving enough charge for the BEBs to complete service.

RELIABILITY

Based on LTD's experience with the exiting BEBs, BEBs proved to have higher downtime due to vehicle technical problems. A similar finding was reported by the Alameda-Contra Costa Transit District (AC Transit) in the Zero Emission Transit Bus Technology Analysis Report.[13]. In general, current BEB technology is not as reliable as conventional diesel buses. However, the reliability is expected to improve as the technology matures.

TECHNOLOGY GROWTH

Several advancements in battery technology are currently being researched that aim to improve energy densities, increase lifespans, and reduce weight. Additional research is being conducted to reduce the cost and time required to manufacture these batteries, as well as increase the cycle life.

The most significant advances are in energy density improvements that result in reductions in battery weight. Anticipated breakthroughs in battery performance will address many of the limitations existing today regarding range capability, weight, life expectancy, and degradation. As an example, for a bus with a 450 kWh battery, an increase of energy density from 150 watt-hours per kilogram (Wh/kg) to 300 Wh/kg

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[13] AC Transit. 2022. Zero Emission Transit Bus Technology Analysis. https://www.actransit.org/sites/default/files/2022-06/0105-22%20Report-ZETBTA%20v3_FNL.pdf

could reduce bus battery weight by up to 3,000 pounds. This weight reduction would allow for additional kWh of battery capacity or an overall reduction in bus weight.

Specific developments underway include the following:

- Lithium-air batteries are expected to exceed the conventional lithium-ion battery's charging capacity by 10 times.
- Lithium-metal batteries have high specific energy and loading capabilities. They use a solid electrolyte instead of a liquid and are believed to have a higher energy density than lithium-ion. They are also expected to have a faster charging rate, a higher voltage, and a longer cycle life. Semi-solid lithium batteries use a liquid, rather than solid, electrolyte that prevents a gap from forming at the interface of the electrolyte and the anode-cathode separator. This ensures that access to the active material is not lost over the life of the battery.

POLICY SUPPORT AND FUNDING

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. There are currently no specific incentives available at the state level for ZE transit buses. However, the State of Oregon has adopted California Advanced Clean Trucks requirements,[14] which indicates that the state may be increasing its support of heavy-duty ZEVs.

There are several incentives and funding sources at the federal level that can potentially fund BEBs, including:

- FTA Low or No Emission Vehicle Program (part of the BIL): May be used for the purchase or lease of low-emission or ZE transit buses and related equipment, as well as the construction of supporting facilities.
- CMAQ Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure.
- CRP: Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- USDOT RAISE competitive grant program

There are other programs that do not apply to transit vehicles or depot fueling infrastructure but indicate a strong push toward the adoption of alternative fuels, such as the FHWA's designated AFC grant and NEVI formula funding programs. Both programs aim to establish interconnected networks of public EV charging corridors.

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[14] Department of Environmental Quality. 2021. *Clean Truck Rules 2021. https://www.oregon.gov/deq/rulemaking/Pages/ctr2021.aspx*

3.4 SCENARIO 3: FUEL-CELL ELECTRIC BUS FLEET

3.4.1 TECHNOLOGY OVERVIEW

Fuel-cell electric bus (FCEB) technology is an emerging ZE alternative that is gaining the attention of many agencies due to its range, maintenance, and fueling being analogous to ICEBs in many respects. As of now, only a handful of agencies are operating FCEBs, with fewer than 100 vehicles deployed across the United States. Many of these agencies, such as AC Transit, the Orange County Transportation Authority (OCTA), and the Stark Area Regional Transit Authority (SARTA), have reported high satisfaction with the technology. While the United States has been slow to adopt hydrogen, the European Union, China, and Australia have been investing heavily in hydrogen as an alternative to BEVs for some time.

An FCEB propulsion system consists of hydrogen fuel, a fuel cell, and a smaller battery pack, typically amounting to 100 kWh of storage. Hydrogen is pushed through the fuel cell, which uses a chemical membrane to separate hydrogen into electricity and water. Electricity produced in this chemical reaction is stored in the on-board batteries and used to power traction motors and other electrical systems. The output of this process is water vapor emitted from the tailpipe.

While FCEBs have zero tailpipe emissions, upstream emissions vary depending on the hydrogen production method utilized. The two methods of generating hydrogen fuel are steam methane reformation (SMR) and electrolysis, and both have off-site and on-site production options. The hydrogen gas (H_2) produced via these methods is generally categorized as either brown, gray, blue, or green, with each signifying a different degree of upstream emissions. Table 3-9 describes the emissions that result from each category.

Table 3-9. Transit Fleet – Hydrogen Fuel Production Emission Categories

Brown	Gray	Blue	Green
Produced with coal. Carbon dioxide (CO_2) is emitted into the atmosphere.	Produced with natural gas. CO_2 is emitted into the atmosphere.	Produced with natural gas. CO_2 is captured and stored.	Produced with renewable energy. No CO_2 is emitted.

Source: WSP USA, Inc.

SMR is a process that strips hydrogen atoms from natural gas. Most fuel delivery companies produce hydrogen using large-scale SMR. SMR can also be used to produce hydrogen on site using small-scale equipment sized to fit a fleet's needs, but on-site production equipment does come at high capital cost and requires more space in addition to that needed for fuel storage.

Electrolysis is a process that uses electricity to separate hydrogen atoms from water. Most electrolysis systems are at the utility scale; however, some small on-site electrolysis systems are coming onto the market. These systems require the highest upfront capital cost of any hydrogen fueling system, as well as the largest on-site footprint.

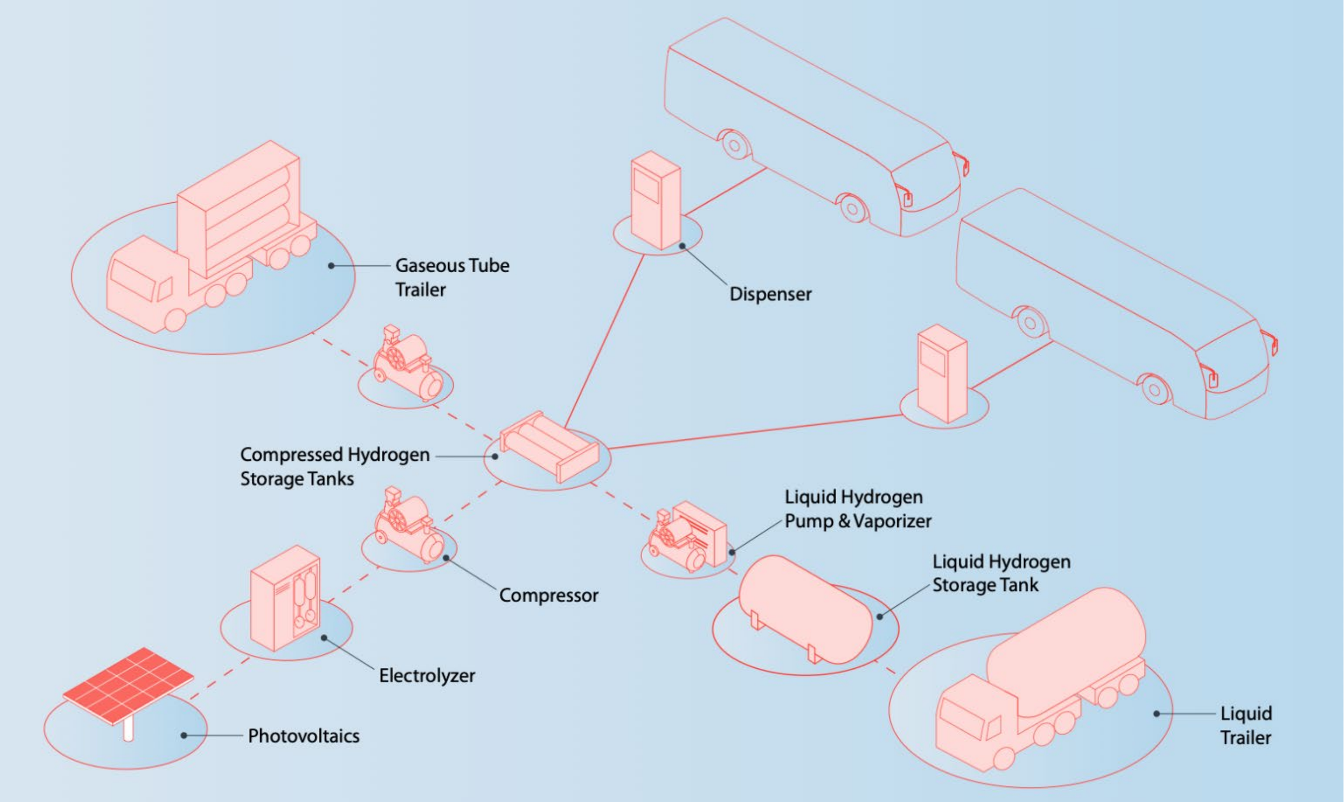
FUELING INFRASTRUCTURE

Hydrogen is lighter than air. A number of hydrogen's properties make it safer to handle than some of other fuels. For example, hydrogen is non-toxic. Moreover, its lighter-than-air property will cause it to dissipate rapidly in the event of a leak. However, it can be flammable if it reaches certain concentrations in the air. At that concentration point, it can ignite more easily than gasoline or natural gas. Therefore, adequate ventilation and leak detection systems are important to ensure a safe hydrogen fueling system.

Hydrogen gas may be delivered or produced on site and fueled at existing fueling lanes. Hydrogen fuel requires on-site storage, which occupies a large physical footprint and is required to have safety setbacks (which vary by tank size), as established by the National Fire Protection Association. These setbacks include distance restrictions for existing buildings, power lines, and other fuel storage infrastructure, as well as property lines and nearby public gathering places.

Figure 3-13 illustrates a typical FCEB fueling system. In addition to these components, safety upgrades required for maintenance bays include flame and hydrogen detection sensors, sloped roofs, and improved ventilation.

Figure 3-13. Transit Fleet – Hydrogen Fueling System



Source: WSP U

VEHICLE AVAILABILITY

There are fewer FCEBs than BEBs currently available in the U.S. market. Table 3-10 lists three available FCEB models. These vehicles are more costly than battery-electric or diesel equivalents, though prices have come down significantly in the past three years and are expected to drop further due to economies of scale. In interviews conducted by WSP with AC Transit, OCTA, and SARTA, most reported closer to 250 to 280 miles range in service.

Table 3-10. Transit Fleet – Available FCEBs in the U.S. Market

Make	Model	Estimated Range
New Flyer	40’ Low Floor	300
	60’ Articulated	300
ENC	40’ Low Floor	300

Source: WSP USA, Inc.

FUEL AVAILABILITY

Agencies interested in pursuing hydrogen technology typically commence FCEB operations with hydrogen deliveries from established national suppliers. Hydrogen delivery contracts typically include fuel storage infrastructure, and equipment maintenance amortized over the cost per kilogram (kg) of fuel.

There are two operating hydrogen plants and one future hydrogen plant within a 1,000-miles radius of Eugene (Figure 3-14). The currently operating Air Liquide and Air Products plants primarily produce grey hydrogen, with the cost varies between $9 and $10 per kg. Meanwhile, the Plug Power plant in Fresno is planned to also produces green hydrogen, with a total capacity of 30 metric tons of liquid green hydrogen daily. The cost of green hydrogen is currently higher than the other types of hydrogen, varying between $13 and $14 per kg. However, efforts to develop green hydrogen are increasing, which is predicted to lower the cost to below $2 per kg by 2040.[15]

In November 2022, Oregon and Washington submitted a Pacific Northwest regional hydrogen hubs plan to the U.S. Department of Energy as an effort to obtain the federal funding from the Clean Hydrogen Hubs (H2Hubs) program under the Infrastructure Investment and Jobs Act, to further push hydrogen adoption in the Northwest region.

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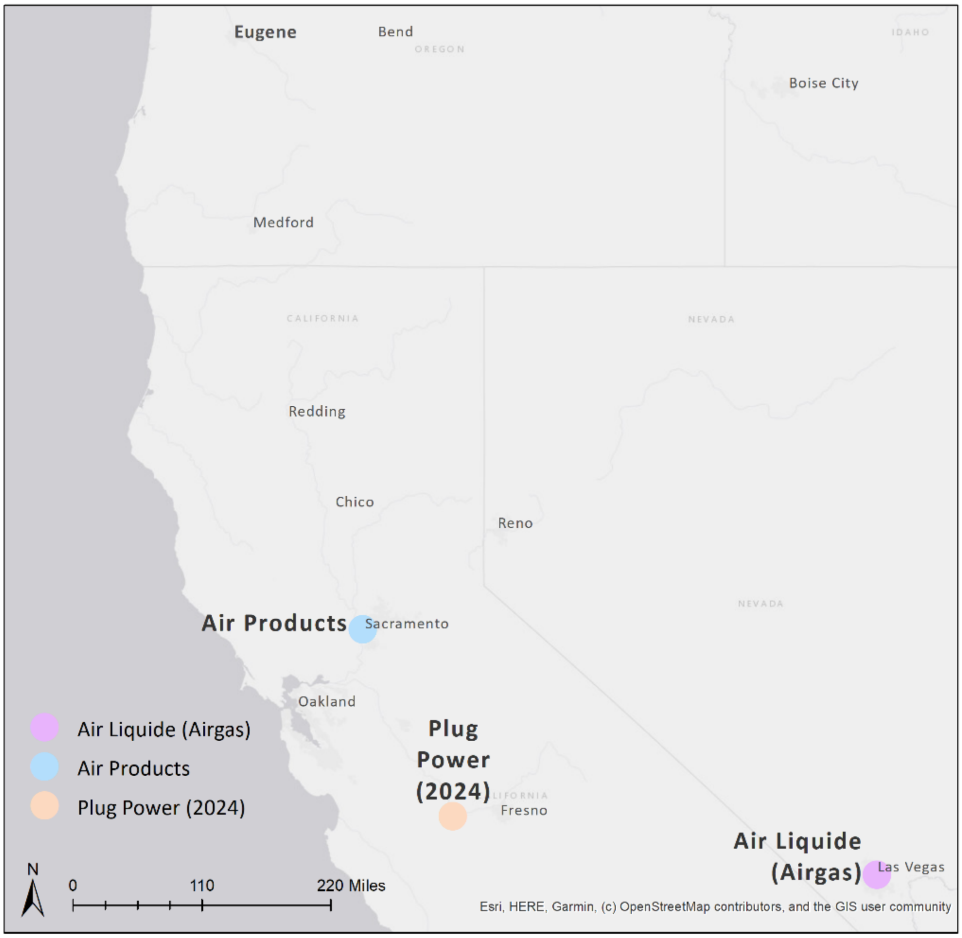
[15] Utility Dive. 2022. “Rapid development could push cost of hydrogen below $2/kg in the next 10-20 years, analysts say.” April 11. Accessed June 6, 2022. https://www.utilitydive.com/news/rapid-development-could-push-cost-of-hydrogen-below-2kg-in-the-next-10-20/621836/

Figure 3-14. Transit Fleet – Hydrogen Plant Locations



Source: Air Products, Plug Power, Air Liquide

3.4.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS

To safely accommodate hydrogen fuel, the LTD maintenance facility needs to be upgraded to accommodate lighter-than-air fuel. The National Fire Protection Association released NFPA 2: Hydrogen Technologies Code,[16] which provides fundamental safeguards for hydrogen storage and fueling infrastructure. It contains the setback requirement for hydrogen storage and other necessary safety measures that can be installed on site, such as fire walls, leakage sensors, and adequate ventilation. Installing fire wall can reduce the required setback distance. Early coordination with local authorities is strongly encouraged to ensure compliance with relevant local codes.

Assuming liquid hydrogen delivery, adequate space is needed at the facility for the hydrogen storage, vaporizer, and dispensers. The storage can be placed horizontally or vertically to reduce footprint. Figure

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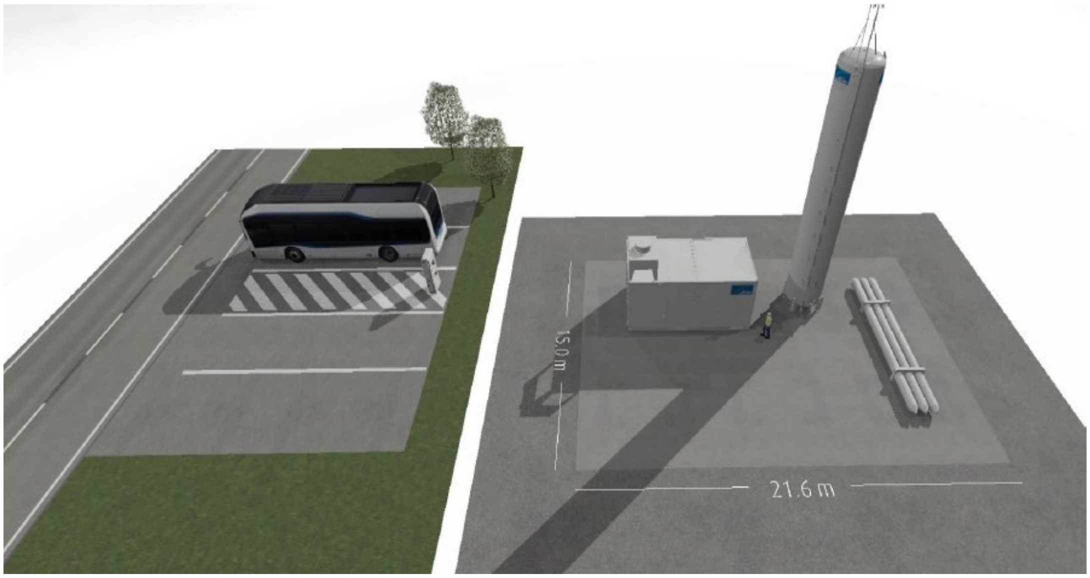
[16] NFPA. 2020. NFPA 2: Hydrogen Technologies Code. https://link.nfpa.org/free-access/publications/2/2020

3-15 provides an estimate on the footprint of a 15,000-gallon storage tank. This tank can fuel approximately 70 FCEBs and has a total footprint of 49 by 71 feet. Detailed design will be needed to accurately assess the required footprint and infrastructure upgrade (if necessary).

Figure 3-15. Transit Fleet – Hydrogen Storage System Footprint (Off-Site Delivery, 15,000 gallons)



Source: Linde

CONSTRUCTION SCHEDULE

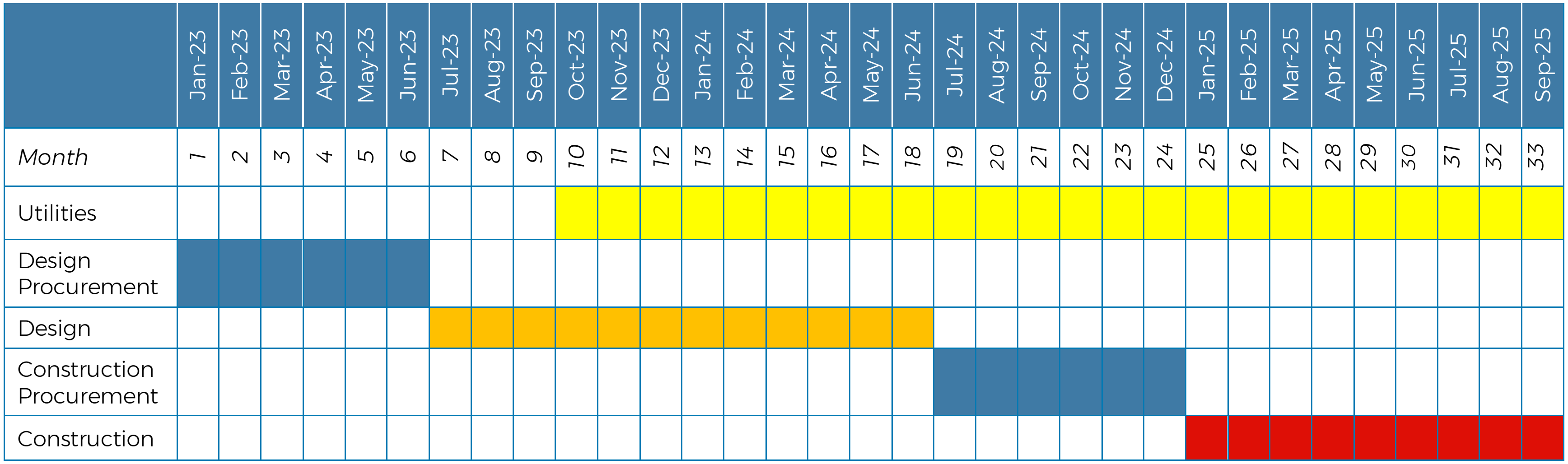
FCEB should only be delivered once the maintenance facility is upgraded to accommodate FCEB and the new fueling station. The design procurement phase of the whole facility improvement is assumed to occur between January and June 2023, followed by 12 months of design. Utility coordination and construction procurement phases will occur simultaneously with the design phase. Construction is assumed to take nine months, beginning in January 2025, and concluding in September 2025. Based on the proposed schedule, the transit facility will be ready to accept future FCEBs in 2025. Figure 3-16 illustrates the construction timeline for the fleet.

VEHICLE PROCUREMENT SCHEDULE

Based on the assumed schedule, facility upgrade for hydrogen fuel will be completed in 2025. Therefore, any vehicles delivered during the construction process, between 2023 and 2025 are assumed to be R99 renewable diesel vehicles. Any vehicles delivered in 2025 and beyond are assumed to be FCEBs. The existing 30 BEBs are assumed to remain in the fleet, and no fleet expansion is expected. Considering that the average vehicle lead time is approximately 18 months, LTD will need to start the procurement process in fiscal year 2023 to have vehicles delivered in 2025.

Table 3-11 details the proposed procurement schedule. The schedule is developed with the assumption that vehicles will be replaced at end of useful life. The existing R99 renewable diesel buses, hybrid diesel buses, and BEBs are expected to have 14 years, 13 years, and 12 years of useful life, respectively. The future FCEBs are assumed to have 12 years of useful life. Several vehicles may need to be operated past their useful life to evenly distribute the number of vehicles procured annually.

Figure 3-16. Transit Fleet – Hydrogen Scenario Proposed Construction Schedule



	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25
Month	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*
Utilities										🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨
Design Procurement	🟦	🟦	🟦	🟦	🟦	🟦																											
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Source: WSP

Table 3-11. Transit Fleet – Hydrogen Scenario Proposed Procurement Schedule

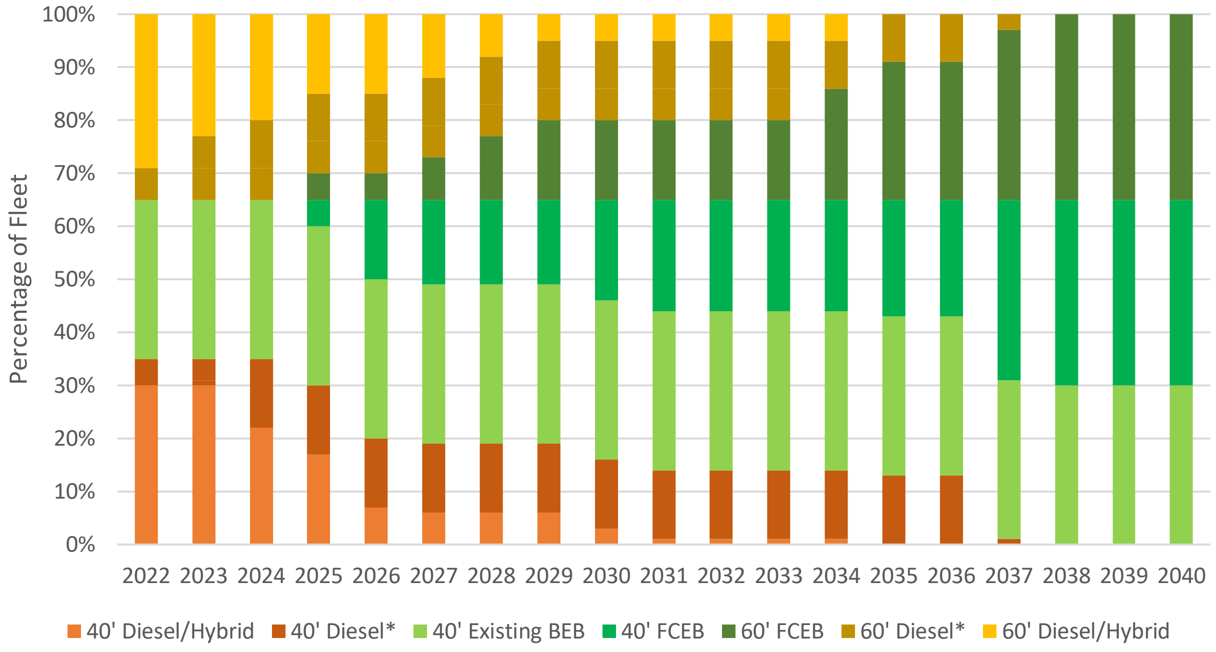
Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
40' - Diesel*	0	4	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' Electric	19	0	0	0	0	0	0	0	0	0	0	11	6	6	7	0	0	0	0
60' - Diesel*	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40' FCEB	0	0	0	5	10	1	0	0	3	2	0	0	0	1	0	12	6	10	1
60' FCEB	0	0	0	5	0	3	4	3	0	0	0	0	6	5	0	6	8	0	7
Total	19	10	12	10	10	4	4	3	3	2	0	11	12	12	7	18	14	10	8

Source: WSP, LTD

* All diesel buses use R99 renewable diesel fuel

Figure 3-17 illustrates the future vehicle inventory. Based on the current assumed vehicle useful life, all R99 renewable diesel vehicles will be replaced in 2038. Note that the minimum useful life required by the FTA for heavy-duty buses is 12 years or 500,000 miles. Therefore, if LTD wants to achieve the goal of eliminating fossil fuel by 2035 while staying in compliance with FTA requirements, any R99 renewable diesel vehicles procured in 2023 need to be retired in 12 years, while vehicles procured in 2024 will need to achieve 500,000 miles in 2035.

Figure 3-17. Transit Fleet – Hydrogen Scenario Future Vehicle Inventory



Source: LTD, WSP

* All diesel buses use R99 renewable diesel fuel

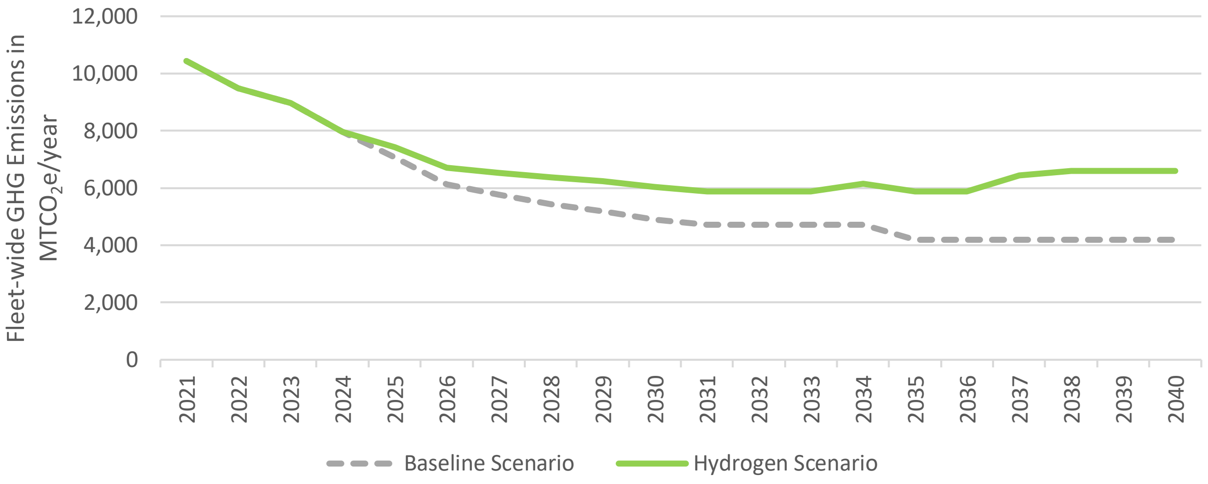
3.4.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the hydrogen scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation. However, the hydrogen scenario will result in the least emissions reduction when compared to the baseline scenario and other future fuel/technology options. The hydrogen scenario would achieve a 37 percent reduction in annual GHG emissions in 2040 compared to 2021, which is 23 percent less effective than baseline diesel scenario (Figure 3-18). The calculation was done assuming that LTD will source grey hydrogen, which is relatively more widely available and cheaper than other hydrogen types. The scenario also shows a slight emission increase in 2037–2040 as a result of the final R99 renewable diesel buses transitioning to FCEB.

Despite having no tailpipe emissions (other than brake and tire wear), hydrogen has greater lifecycle GHG emissions than the baseline R99 renewable fuel due to the emissions from the production of the hydrogen. Currently, most hydrogen is produced from natural gas via SMR, which produces carbon dioxide (CO_2). The lifecycle GHG emissions of hydrogen can further be reduced if the upstream fuel production becomes greener (i.e., hydrogen production from electrolysis).

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory,procurement schedule and estimated duty cycles (mileage). The hydrogen and baseline scenarios have the same emissions profile until 2024. Then they start to diverge after the transition to a full hydrogen fleet begins in 2025. The number does not include emissions from production of vehicle components or fuel cells.

Figure 3-18. Transit Fleet – Hydrogen Scenario Annual GHG Emissions



Source: WSP USA

3.4.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet/technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[17]

Based on the analysis, the lifecycle costs of the hydrogen scenario are higher than the baseline R99 renewable diesel scenario due to the considerably higher capital and O&M costs. The total lifecycle cost for the hydrogen scenario is 49.5 percent ($329 million) higher than the baseline scenario. The total lifecycle cost is $993 million or $7.50 per mile (Table 3-12).

The primary difference between the hydrogen scenario and the baseline scenario is the capital costs. Standard vehicle prices for diesel buses are the lowest among all fuel types, while FCEBs currently have the highest vehicle costs compared to RNG buses or BEBs. Moreover, LTD will need to retrofit the maintenance facility to accommodate gaseous fuel and install hydrogen fueling station when the baseline R99 renewable diesel scenario barely requires any facility upgrade. Thus, total capital cost for the hydrogen scenario is $543 million, 101 percent ($272 million) higher than the baseline scenario.

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[17] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

The hydrogen scenario also has higher overall O&M costs. The total O&M cost is $421 million, 19 percent higher than the baseline scenario. Current data from peer agencies show that the vehicle maintenance required for FCEBs are higher than diesel buses. Note that the analysis was based on empirical data from peer transit agencies that might be operating earlier versions of FCEBs. O&M costs are highly dependent on factors that are continually evolving as FCEBs continue to be deployed in transit service, and more operational benefits may be experienced in the coming years as the technology improves.

The total cash cost (capital, O&M, and disposal costs) of the hydrogen scenario is $962 million, 53 percent ($334 million) higher than the baseline scenario. The total cash cost is $7.27/mile.

After combining the non-cash environmental cost of GHG emissions and tailpipe air pollutants, the total environmental cost for the hydrogen scenario is $30 million, 16 percent ($6 million) lower than the baseline R99 renewable diesel scenario. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components and the supporting fueling infrastructure.

Table 3-12. Transit Fleet – Hydrogen Scenario 2022-2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline	Hydrogen
Cash Costs			
Capital Costs	Vehicle Purchase Price	$260.6	$508.4
	Modifications and Contingency	$1.4	$3.1
	Charging/Fueling Infrastructure	$8.6	$31.4
	Total Capital Costs	*$270.7*	*$542.9*
O&M Costs	Vehicle Maintenance	$174.6	$209.7
	Vehicle Tires	$27.0	$28.1
	Vehicle Fuel Costs	$143.9	$135.5
	Charging/Fueling Infrastructure	$8.1	$30.8
	Incremental Training Costs	$5.4	$17.3
	Total O&M Costs	$359.0	$421.4
Disposal Costs	Battery Disposal	$0.0	$0.0
	Bus Disposal	-$1.8	-$2.0
	Total Disposal Costs	-$1.8	-$2.0
	Total Cash Costs	**$627.9**	**$962.2**
	Total Cash Cost per Mile	**$4.87**	**$7.27**
Non-Cash Costs			
Environmental Costs	Emissions - Tailpipe	$9.6	$3.4
	Emissions - Refining/Utility	$13.8	$13.4
	Noise	$12.7	$13.5
	Total Environmental Costs	*$36.1*	*$30.4*
	Total Cash and Non-Cash Cost	**$664.0**	**$992.6**
	Total Cash and Non-Cash Cost per Mile	**$5.15**	**$7.50**

Source: WSP PRISM Model

3.4.5 IMPLEMENTATION CONSIDERATIONS

As discussed in the analysis, the hydrogen scenario has high lifecycle costs and GHG emissions. However, it has virtually no tailpipe emissions. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects that should be considered, as described below.

RANGE

FCEBs have a longer range than BEBs. The advertised range for FCEB is currently 300 to 350 miles, which is sufficient for most service. However, it is less than the range of conventional diesel buses, and service planners need to keep this in mind when planning the service blocks.

RELIABILITY

AC Transit reports that their FCEBs have lower reliability than conventional diesel buses. However, they perform slightly better than BEBs.

POLICY SUPPORT AND FUNDING

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. There are currently no specific incentives available on the state level for zero emission transit buses. However, the State of Oregon adopted California Advanced Clean Trucks requirements,[18] which indicates support toward zero-emission heavy-duty vehicles.

There are several incentives and funding sources at the federal level that can potentially fund FCEBs, including:

- FTA Low or No Emission Vehicle Program (part of the BIL): May be used for the purchase or lease of low emission or ZE transit buses and related equipment, as well as the construction of supporting facilities
- CMAQ Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure.
- CRP: Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- USDOT RAISE competitive grant program
- Alternative Fuel Excise Tax Credit: $0.50 per DGE tax credit for fuel that is used to operate vehicles
- US DOE Regional H2Hubs: This program will fund the development of regional networks of hydrogen producers, potential hydrogen consumers, and connective infrastructure located in close proximity. Oregon and Washington have submitted the regional hydrogen plan for the Pacific Northwest region.

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[18] Department of Environmental Quality. 2021. *Clean Truck Rules 2021. https://www.oregon.gov/deq/rulemaking/Pages/ctr2021.aspx*

There are also several programs that do not apply to depot fueling infrastructure but indicate a strong push toward the adoption of alternative fuels, such as the FHWA's designated AFC grant and NEVI formula funding programs. Both programs, especially the AFC grant, aim to establish interconnected networks of public alternative fueling corridors, including hydrogen fueling stations.

3.5 SUMMARY

Based on the analysis, all future fuel/technology scenarios will require upgrades to the maintenance facility. The future fuel/technology vehicle delivery can commence in 2025 once the facility is upgraded to accommodate the new fuel type and the required charging or fueling stations are installed. To achieve this timeline, the design procurement process for the facility and the vehicle procurement process need to start in 2023. Early and continuous coordination with utility providers, especially for RNG and BEB scenarios, is strongly encouraged to ensure seamless transition.

It is important to note that the minimum useful life required by FTA for heavy-duty buses is 12 years or 500,000 miles. Therefore, if LTD wants to achieve the goal of eliminating fossil fuel by 2035 while staying in compliance with FTA requirements, any R99 renewable diesel vehicles procured in 2023 need to be retired in exactly 12 years, while vehicles procured in 2024 and beyond will need to achieve 500,000 miles in 2035. If using the current assumed vehicle useful life, all R99 renewable diesel vehicles will be replaced by 2038.

Among the future fuel/technology scenarios, the battery-electric scenario is the only scenario that will provide higher GHG emissions reduction compared to the baseline R99 renewable diesel scenario. In 2040, a full BEB fleet will provide 96 percent reduction compared to 2021 level, an additional 36 percent reduction compared to the baseline scenario. The RNG fuel/technology has slightly higher lifecycle GHG emissions, while hydrogen fuel/technology, if produced from natural gas SMR, will have significantly higher upstream emissions despite the zero tailpipe emissions.

If considering local air pollutants, all future fuel/technology scenarios will considerably reduce tailpipe emissions. R99 renewable diesel is chemically similar to conventional diesel; therefore, it will only slightly improve tailpipe emissions compared to conventional diesel. RNG vehicles will significantly reduce NO_X and particulate matter pollutants, while battery-electric and hydrogen vehicles will have zero tailpipe emissions.

On the contrary, from a cost perspective, operating battery-electric and hydrogen vehicles will result in higher lifecycle costs due to the higher capital and O&M costs. The hydrogen scenario is the most costly, at 47 percent higher than the baseline scenario, followed by the battery-electric scenario, which has 30 percent higher lifecycle costs. Meanwhile, even though RNG buses have higher capital costs, the lower O&M and environmental costs reduce the overall lifecycle costs to 9 percent lower than the baseline scenario. Table 3-13 summarizes the emissions and cost findings for the transit fleet.

Table 3-13. Transit Fleet – Summary of Results

Indicators	Fuel/ Technology Scenario			
	Baseline (R99 Renewable Diesel)	Renewable Natural Gas	Battery-Electric	Hydrogen
Annual GHG emissions in 2040 compared to 2021	60% reduction	+5% from baseline	-36% from baseline	+23% from baseline
Tailpipe Air Pollutants Emissions*	Highest emissions	Significantly reducing NO$_X$ & PM	Zero emissions	Zero emissions
Environmental Costs**	$36.1	$32.4	$17.2	$30.4
Capital Costs**	$270.7	$302.7	$441.4	$542.9
Operating Costs**	$359.0	$290.6	$427.5	$421.4
Disposal Costs**	-$1.8	-$1.7	-$1.8	-$2.0
Total Lifecycle Costs**	**$664.0**	**$623.9** (-6% from baseline)	**$884.3** (+33% from baseline)	**$992.6** (+50% from baseline)
Total Costs/mile	**$5.15**	**$4.96**	**$6.68**	**$7.50**

Source: WSP

* Detailed amounts of air pollutants emissions can be found in the Excel-based Sustainability Tool

** All costs are in YOE $ Millions

LTD will need to consider other aspects besides lifecycle costs and emissions, such as impact on operations, technology development, market outlook, policy trends, and funding, before deciding on the preferred fuel/technology. Currently, there is increasing policy support and incentives toward low- and zero-emission vehicles. The higher costs of these technologies can be partially offset by the available funding. However, both ZE technologies might have significant impact on LTD's operations due to the lower reliability and the limited range of BEBs. Increases in reliability, fuel efficiency, and range are expected as the technologies improve, but currently, R99 renewable diesel and RNG fuels/technologies will have the least impact on LTD's existing operations.

4 PARATRANSIT FLEET PROCUREMENT PLAN

After considering LTD's Triple-Bottom-Line Approach to Sustainability and further emissions and lifecycle cost analyses, two future fuel/technology scenarios are deemed feasible to be adopted by LTD for the paratransit fleet: RNP and battery-electric. This chapter discusses the transition schedule, emissions, lifecycle costs, and transition considerations of each fuel/technology in comparison to the baseline scenario of E10 gasoline fuel/technology.

4.1 BASELINE SCENARIO: E10 GASOLINE VEHICLE FLEET

4.1.1 TECHNOLOGY OVERVIEW

Currently, all of LTD's paratransit vehicles are ICEVs fueled by E10 gasoline. E10 gasoline means that the fuel is a mix of 10 percent ethanol and 90 percent gasoline. Ethanol blend is used to boost octane and oxygenate the fuel to reduce air pollution. It is widely used and sold in every state in the United States. E10 does not qualify as an alternative fuel.

In the United States, 94 percent of ethanol is produced from the starch in corn grain. The majority is produced by using a "dry-milling" process, in which corn is ground into flour and fermented to produce ethanol and co-products (distiller grains and carbon dioxide). It is then transported to fueling stations and blended with gasoline.

E10 gasoline is approved to be used in any conventional, gasoline-powered vehicles without modifications.

4.1.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS AND CONSTRUCTION SCHEDULE

Currently, all of LTD's vehicles are being fueled at an off-site fueling station. Assuming there will be no changes to the fueling method, no facility upgrade is needed.

VEHICLE PROCUREMENT SCHEDULE

LTD currently has a paratransit fleet procurement plan spanning through 2029. The findings from the paratransit fleet right-sizing analysis recommended that half of the fleet be downsized from cutaways to modified minivans.[19] It was assumed that the number of vehicles delivered per year will not change, but

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[19] Refer to Appendix B – Deeper Impact Analysis Report for detailed paratransit right-sizing analysis

there will be more minivans than cutaways. Using the vehicle useful life assumptions,[20] the plan was extrapolated through 2040.

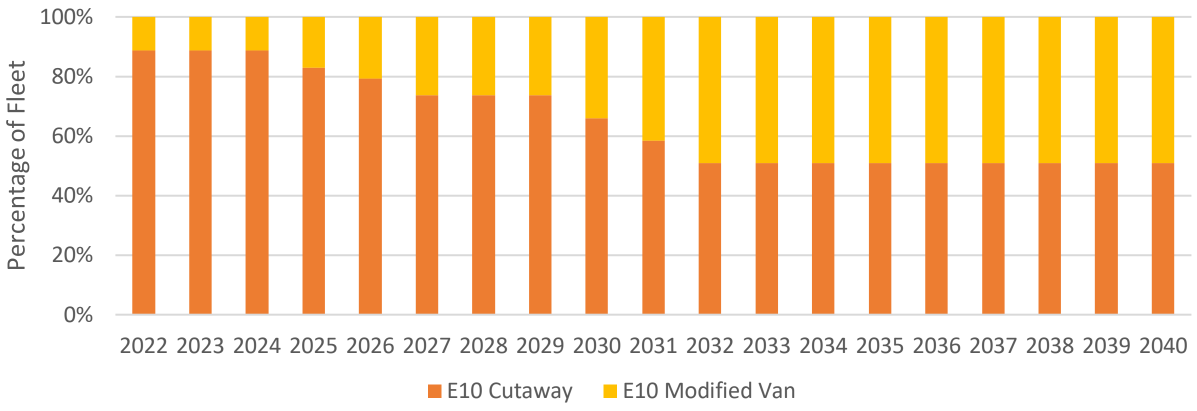
Table 4-1 details the modified procurement schedule, showing the number of new vehicles that will be delivered each year. A vehicle that is past its useful life is assumed to be replaced by a new vehicle on a one-to-one basis. The baseline procurement plan serves as the basis for the future fuel/technology scenarios' proposed procurement schedules. Figure 4-1 illustrates the baseline paratransit fleet inventory by year, fuel type, and vehicle type.

Table 4-1. Paratransit Fleet – Baseline Procurement Schedule

Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
E10 Cutaway	0	9	9	6	2	3	0	0	6	5	5	6	2	3	0	0	6	5	5
E10 Modified Van	1	1	1	4	3	5	1	1	5	5	5	3	3	4	2	2	5	5	5
Total	1	10	10	10	5	8	1	1	11	10	10	9	5	7	2	2	11	10	10

Source: LTD, WSP

Figure 4-1. Paratransit Fleet – Baseline Vehicle Inventory



Source: LTD, WSP

4.1.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the baseline E10 gasoline scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation. The baseline scenario results in a 28 percent decrease in annual GHG emissions in 2040 compared to 2021 conditions (Figure 4-2).

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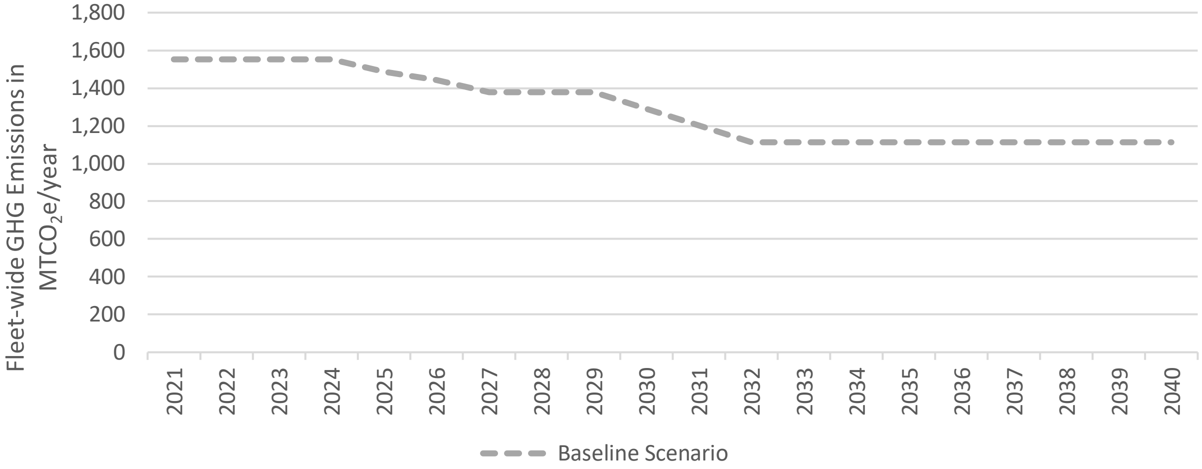
[20] Assumed useful life is eight years for cutaways and five years for modified vans.

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory and procurement schedule and estimated duty cycles (mileage). The number does not include emissions from vehicle components production.

Figure 4-2. Paratransit Fleet – Baseline Annual GHG Emissions



Source: WSP

4.1.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet/technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, disposal costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[21]

Based on the analysis, the lifecycle costs of the baseline E10 gasoline scenario is $105 million or approximately $2.11 per mile (Table 4-2). Total capital cost for the baseline E10 gasoline scenario is $32 million, which reflects the costs of new vehicles. Current vehicles are fueled off site, which will eliminate the needs for on-site facility upgrades. Meanwhile, the total O&M costs are $63 million. If only considering the cash costs (capital, O&M, and disposal costs), the baseline E10 gasoline scenario has total cash costs of $93 million or $1.86 per mile. The total environmental cost is $12 million. This scenario has relatively low capital and O&M costs but high environmental costs. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components.

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[21] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

Table 4-2. Paratransit Fleet – Baseline Scenario 2022-2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline
Cash Costs		
Capital Costs	Vehicle Purchase Price	$31.9
	Modifications and Contingency	$0.3
	Charging/Fueling Infrastructure	$0.0
	Total Capital Costs	**$32.3**
O&M Costs	Vehicle Maintenance	$52.4
	Vehicle Tires	$0.0
	Vehicle Fuel Costs	$10.8
	Charging/Fueling Infrastructure	$0.0
	Training	$0.0
	Total O&M Costs	**$63.2**
Disposal Costs	Battery Disposal	$0.0
	Bus Disposal	-$2.9
	Total Disposal Costs	*-$2.9*
	Total Cash Costs	**$92.5**
	Total Cash Cost per Mile	**$1.86**
Non-Cash Costs		
Environmental Costs	Emissions – Tailpipe	$0.9
	Emissions – Refining/Utility	$6.2
	Noise	$5.3
	Total Environmental Costs	$12.3
	Total Cash and Non-Cash Cost	**$104.8**
	Total Cash and Non-Cash Cost per Mile	**$2.11**

Source: WSP PRISM Model

4.1.5 IMPLEMENTATION CONSIDERATIONS

As discussed in the analysis, the baseline E10 gasoline scenario has relatively low lifecycle costs. However, it has high GHG emissions and local air pollutants. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline.

Furthermore, there are other aspects that should be considered in the transition, such as current policy support and funding trends. Currently, gasoline sold in Oregon has to be E10 gasoline or better. No incentives are required to support its adoption. Instead, the regulations are moving toward incentivizing the adoption of cleaner low emission or ZE technologies. For instance, the state has adopted California Advanced Clean Trucks requirements, in which manufacturers need to gradually increase the sales percentage of their zero-emission trucks. The state also established state-wide ZEV adoption goal. Both examples indicate that ZEVs might be the preferable option for future vehicle technology in the state of Oregon.

4.2 SCENARIO 1: RENEWABLE PROPANE VEHICLE FLEET

4.2.1 TECHNOLOGY OVERVIEW

Propane or liquefied petroleum gas has been used as a vehicle fuel for decades and is the world's third most common transportation fuel behind gasoline and diesel. It is a clean-burning alternative fuel. If spilled or released from a vehicle, it presents no threat to soil, surface water, or groundwater.

Currently, the majority of propane is produced as a by-product of natural gas processing and crude oil refining. RNP, which is produced from renewable feedstocks is being explored. Although the number of producers is limited, some biodiesel refineries are also producing RNP. RNP is chemically identical to conventional propane and is compatible with any propane vehicles.

Propane vehicles operate much like gasoline vehicles with spark-ignited engines. Propane is stored onboard in a tank pressurized to approximately 150 pounds per square inch, which converts the gas to a more energy dense liquid form. Propane vehicles' power, acceleration, and cruising speed are similar to conventional gasoline vehicles. Propane has slightly lower fuel economy and a higher octane rating than gasoline. Propane is also completely gaseous when it enters the engine, which will provide a more stable performance during cold weather than liquid fuels.

VEHICLE AVAILABILITY

RNP can be used in any propane vehicle. A propane conversion kit, to convert gasoline vehicle to propane vehicle, is available from several official vehicle OEMs or via third-party conversion-kit manufacturers. All third-party conversion kits need to be certified and compliant with U.S. Environmental Protection Agency (EPA) regulations. The conversion process itself needs to be done by a qualified system retrofitter or vehicle modifier who can reliably convert certain vehicle models for propane operation.

Table 4-3 lists available vehicle models with official OEM-provided conversion kits that closely match LTD's existing vehicle types. The conversion of light-duty vehicles such as minivans will require third-party conversion kits. The list of certified third-party conversion kits with the relevant vehicle options can be accessed on EPA's page.[22]

Table 4-3. Paratransit Fleet – Models with Official Propane Conversion Kit from Vehicle Manufacturers

Vehicle Type	Manufacturer	Model	Conversion
Passenger Van	Ford	Transit Connect	"Prep package" kit from Ford.
	Chevrolet	Express 2500	"Prep ready" engine conversion kit from OEM
	GMC	Savana 2500	"Prep ready" engine conversion kit from OEM

Source: Alternative Fuels Data Center

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[22] EPA. 2022. List of EPA-Compliant Alternative Fuel Conversion Systems. https://www.epa.gov/ve-certification/lists-epa-compliant-alternative-fuel-conversion-systems

FUEL AVAILABILITY

Conventional propane fueling stations are widely available in the United States. However, RNP is considered nascent with limited production. The production capacity is expected to scale up if there are increasing market demand and policy support.

4.2.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS AND CONSTRUCTION SCHEDULE

Currently, all vehicles are being fueled at an off-site fueling station. Assuming there will be no changes to the fueling method, no facility upgrade is needed.

VEHICLE PROCUREMENT SCHEDULE

Using the existing procurement plan as a baseline, any vehicles delivered in 2025 and beyond are assumed to be RNP vehicles. No fleet expansion is expected. Considering that the average vehicle lead time is approximately 12 months, LTD will need to start the procurement process in fiscal year 2024 to have vehicles delivered in 2025.

Table 4-4 details the proposed procurement schedule for the RNP scenario, showing the number of new vehicles that will be delivered each year. The schedule is developed with the assumption that vehicles will be replaced at end of useful life. Cutaways are expected to have eight years of useful life, while vans are expected to have five years of useful life. Several vehicles may need to be operated past their useful life to evenly distribute the number of vehicles procured annually.

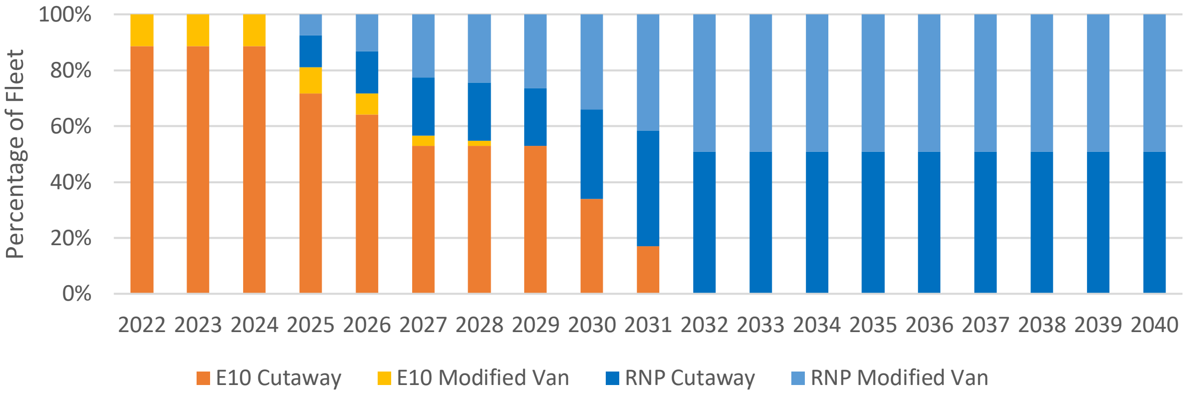
Table 4-4. Paratransit Fleet – RNP Scenario Proposed Procurement Schedule

Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
E10 Cutaway	0	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E10 Modified Van	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RNP Cutaway	0	0	0	6	2	3	0	0	6	5	5	6	2	3	0	0	6	5	5
RNP Modified Van	0	0	0	4	3	5	1	1	5	5	5	3	3	4	2	2	5	5	5
Total	1	10	10	10	5	8	1	1	11	10	10	9	5	7	2	2	11	10	10

Source: WSP, LTD

Figure 4-3 illustrates the future vehicle inventory. Based on the current assumed vehicle useful life, all E10 vehicles will be replaced in 2032.

Figure 4-3. Paratransit Fleet – RNP Scenario Future Vehicle Inventory



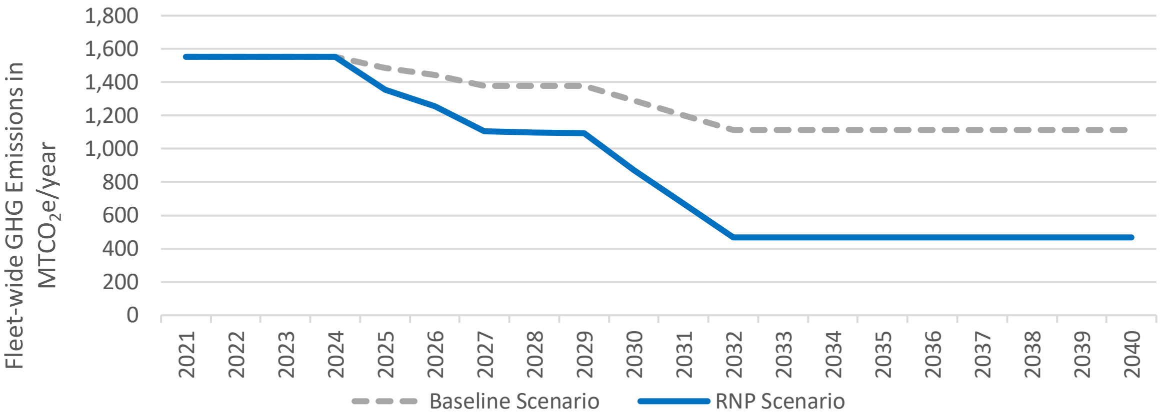
Source: WSP, LTD

4.2.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the RNP scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation. The transition to RNP fleet results in a 70 percent decrease of lifecycle GHG emissions in 2040 compared to 2021, which is an additional 42 percent reduction from the baseline E10 gasoline scenario (Figure 4-4). RNP has significantly lower upstream GHG emissions than gasoline, but the tailpipe emissions of other pollutants are relatively the same for the two fuel types. RNP has slightly lower VOC emissions compared to E10 gasoline.

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory, procurement schedule, and estimated duty cycles (mileage). The RNP and baseline scenarios have the same emissions profile until 2024. Then they start to diverge after the transition to RNP fleet begins in 2025. The number does not include emissions from vehicle components production.

Figure 4-4. Paratransit Fleet – RNP Scenario Annual GHG Emissions



Source: WSP

4.2.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet/technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[23]

Based on the analysis, transitioning to a full RNP fleet has a higher total lifecycle cost compared to the baseline scenario, mainly due to the higher capital and O&M costs. The total lifecycle cost of the RNP fuel/technology scenario is approximately $129 million or $2.60 per mile, 23 percent ($24 million) higher than the baseline E10 gasoline scenario (Table 4-5).

In terms of capital costs, RNP has higher total costs compared to the baseline scenario due to the higher vehicle costs. Both RNP and baseline scenarios will not need any facility upgrades. RNP fuel/technology scenario total capital cost is $47 million, 45 percent ($14.5 million) higher than the baseline scenario.

RNP O&M costs are 18 percent ($11.1 million) higher than the baseline scenario due to a slightly higher vehicle maintenance cost and new technology training. RNP total O&M cost is $74 million. The total cash cost (capital, O&M, and disposal costs) of the RNP fuel/technology scenario is 30 percent ($28 million) higher than the baseline scenario, with a total of $120 million or $2.42 per mile.

When combining both GHG and local air pollutants, the total environmental costs of the RNP fuel/technology scenario are slightly better than the baseline E10 gasoline vehicles due to the lower tailpipe and upstream emissions. The environmental cost of the scenario is 27 percent ($3.3 million) lower than the baseline E10 gasoline scenario. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components and the supporting fueling infrastructure.

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[23] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

Table 4-5. Paratransit Fleet – RNP Scenario 2022-2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline	RNP
Cash Costs			
Capital Costs	Vehicle Purchase Price	$31.9	$46.3
	Modifications and Contingency	$0.3	$0.5
	Charging/Fueling Infrastructure	$0.0	$0.0
	Total Capital Costs	**$32.3**	**$46.8**
O&M Costs	Vehicle Maintenance	$52.4	$53.0
	Vehicle Tires	$0.0	$0.0
	Vehicle Fuel Costs	$10.8	$8.0
	Charging/Fueling Infrastructure	$0.0	$0.0
	Training	$0.0	$13.2
	Total O&M Costs	**$63.2**	**$74.3**
Disposal Costs	Battery Disposal	$0.0	$0.0
	Bus Disposal	-$2.9	-$0.8
	Total Disposal Costs	*-$2.9*	*-$0.8*
Total Cash Costs		**$92.5**	**$120.2**
Total Cash Cost per Mile		$1.86	$2.42
Non-Cash Costs			
Environmental Costs	Emissions – Tailpipe	$0.9	$0.5
	Emissions – Refining/Utility	$6.2	$3.3
	Noise	$5.3	$5.3
	Total Environmental Costs	$12.3	$9.0
Total Cash and Non-Cash Cost		$104.8	$129.2
Total Cash and Non-Cash Cost per Mile		$2.11	$2.60

Source: WSP PRISM Model

4.2.5 IMPLEMENTATION CONSIDERATIONS

As discussed in the analysis, the RNP scenario reduces GHG emissions and local air pollutants. However, it has higher lifecycle costs than the baseline scenario. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects that should be considered, as described below.

POLICY SUPPORT AND FUNDING

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. Propane is generally considered as low emission alternative fuel and is eligible for alternative fuel funding. There are currently no specific incentives available on the state level for low emissions vehicles.

There are several incentives and funding sources at the federal level that can potentially fund RNP vehicles, including:

- FTA Low or No Emission Vehicle Program (part of the BIL): May be used for the purchase or lease of low emission or ZEVs

- CMAQ Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure.
- CRP: Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- USDOT RAISE competitive grant program
- Alternative Fuel Excise Tax Credit: $0.50 per DGE tax credit for fuel that is used to operate vehicles

FHWA's AFC grant aims to establish interconnected networks of public alternative fueling corridors, including propane fueling stations. This program is essential for LTD's paratransit service because the vehicles will be fueled at off-site public fueling stations. However, there is no guarantee that the fueling stations will provide RNP in addition to conventional propane.

FUEL AVAILABILITY

As discussed in section 4.2.1, current RNP producers are very limited. Conventional propane fueling stations most likely will not have RNP. The production scale is expected to increase as the market demand increases. However, in the short term if choosing RNP, LTD will need to find other fueling solutions for the paratransit fleet. Conventional propane, on the other hand is widely available, with several fueling stations located near the paratransit facility. However, it will have greater GHG than to RNP.

4.3 SCENARIO 2: BATTERY-ELECTRIC VEHICLE FLEET

4.3.1 TECHNOLOGY OVERVIEW

As discussed in section 3.3.1, BEVs use on-board batteries to store and distribute energy to power an electric motor and other on-board systems. Batteries are heavy and less energy dense than other forms of fuel. With existing technologies, adding battery capacity often comes at a cost of reducing passenger capacity to meet GVWR restrictions. Vehicle energy consumption rates are typically measured as kWh per mile, and route and operating characteristics such as hills, driver behavior, and HVAC load can all affect energy consumption rates and thus reduce vehicle range.

CHARGING INFRASTRUCTURE

The successful deployment of a battery-electric fleet requires a comprehensive understanding of the various charging systems available. Section 3.3.1 provides comparison of the three most common charging systems—plug-in, pantograph, and inductive. However, not all charging types are compatible with the vehicle types in LTD's paratransit fleet. Only plug-in dispensers are flexible enough to be used for both electric minivans and cutaways.

Moreover, smaller vehicles will have smaller charge acceptance rates than heavy-duty vehicles. For example, the GreenPower EV Star van can only accept a maximum charge rate of 61 kW. Even if it is charged by using a charger with a higher maximum charge rate, the vehicle can only charge at its maximum acceptance rate. The total charge time will depend on different factors such as the power rate, charger configuration, and BEB battery capacity.

VEHICLE AVAILABILITY

Technological advances over the past 20 years have made battery-electric technology a viable option for paratransit service. Table 4-6 summarizes the available battery-electric vehicles on the market that best align (based on length and vehicle type) with LTD's existing fleet.

Currently, no electric minivans are mass-produced and available in the market, but several models are in development to be released in the next several years. The range for an electric minivan is currently advertised to be approximately 200 to 250 miles.

Table 4-6. Paratransit Fleet – Available BEBs in the U.S. Market

Manufacturer	Length	Capacity (kWh)
GreenPower	Cutaway	118
Forest River Bus LLC	Cutaway	100

Source: WSP

FUEL AVAILABILITY

Electricity is generally available as long as the power grid and the transit fleet facility have enough electrical capacity and are equipped with infrastructure to support the required load. If any upgrades are needed, the timeline will vary depending on the scale of the upgrades. Ideally, the BEV delivery will happen after the electricity and charging stations are available on site. Depending on the utility provider, it might be possible to gradually bring power to the site. Considering that the solution will be site-specific, continuous coordination with the utility provider is strongly encouraged to ensure a seamless transition to a full BEB fleet.

4.3.2 TRANSITION SCHEDULE

FACILITY REQUIREMENTS

Overnight depot charging ensures that vehicles have a full state of charge for morning pullout. However, depot charging requires significant amounts of power to be brought on site and would likely require upgrades to LTD's existing utility service, including transformers and switchgears. Redesigning or constructing the paratransit facility to support charging involves additional effort and efficient utilization of space. A phased approach is recommended, in which sites are prepared for electrification in alignment with regular procurement cycles that convert the fleet to BEVs.

Figure 3-9 illustrates the various components of a BEV charging system. The needed infrastructure and equipment include charging cabinet(s), which dispense and, in most cases, convert power from alternating to direct current; transformer(s), which step down electricity to a safe and suitable limit; and switchgear(s), which allow for the isolation of power. Other components can also be considered, such as battery storage, photovoltaics (solar panels), and backup generators.

CONSTRUCTION SCHEDULE

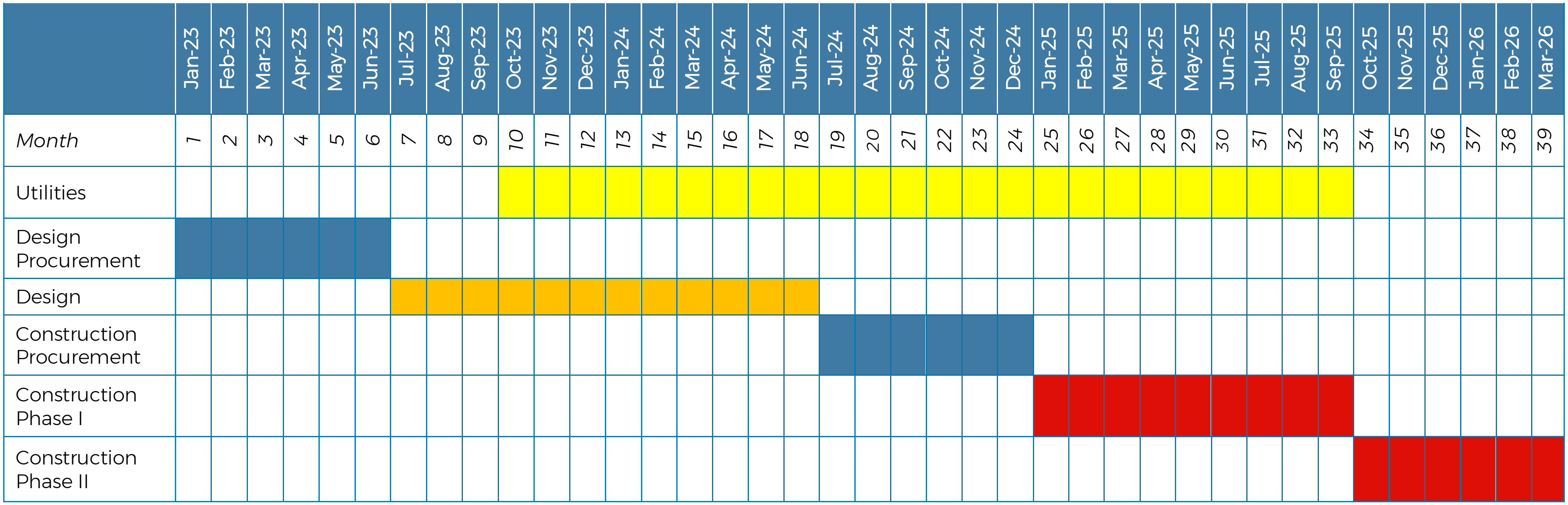
The vehicles for the battery-electric scenario should only be delivered once the facility is upgraded to accommodate charging for BEVs. The design procurement phase of the battery-electric infrastructure is assumed to occur between January and June 2023, followed by 12 months of design. Utility coordination and construction procurement phases will occur simultaneously with the design phase. Construction for a BEV fleet is assumed to be completed in two phases, with the first phase being completed in September 2025 and the second concluded in March 2026. The construction timeline for the battery-electric scenario reflects a conservative schedule. BEV delivery can begin once the phase 1 construction is completed in September 2025. Figure 4-5 illustrates the construction timeline for the BEV fleet.

VEHICLE PROCUREMENT SCHEDULE

Based on the assumed schedule, the facility will be ready to support BEV delivery in 2025. Therefore, any vehicles delivered during the construction process, between 2023 and 2025, are assumed to be E10 vehicles, while vehicles delivered in 2025 and beyond are assumed to be battery-electric. Considering that the average vehicle lead time is approximately 12 months, LTD will need to start the procurement process in 2024 to have vehicles delivered in 2025.

Table 4-7 details the proposed procurement schedule for the battery-electric scenario, showing the number of new vehicles that will be delivered each year. The schedule is developed with the assumption that vehicles will be replaced at end of useful life. Cutaways are expected to have eight years of useful life, while vans are expected to have five years of useful life. Several vehicles may need to be operated past their useful life to evenly distribute the number of vehicles procured annually

Figure 4-5. Paratransit Fleet – Battery-Electric Scenario Proposed Construction Schedule



	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24	Apr-24	May-24	Jun-24	Jul-24	Aug-24	Sep-24	Oct-24	Nov-24	Dec-24	Jan-25	Feb-25	Mar-25	Apr-25	May-25	Jun-25	Jul-25	Aug-25	Sep-25	Oct-25	Nov-25	Dec-25	Jan-26	Feb-26	Mar-26
Month	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*31*	*32*	*33*	*34*	*35*	*36*	*37*	*38*	*39*
Utilities										🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨	🟨						
Design Procurement	🟦	🟦	🟦	🟦	🟦	🟦																																	
Design							🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧	🟧																					
Construction Procurement																			🟦	🟦	🟦	🟦	🟦	🟦															
Construction Phase I																									🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥						
Construction Phase II																																		🟥	🟥	🟥	🟥	🟥	🟥

Source: WSP

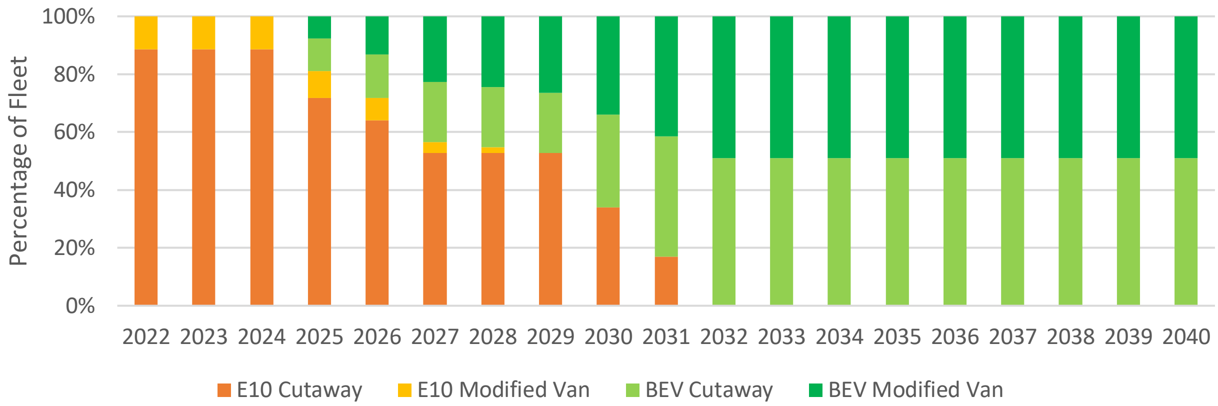
Table 4-7. Paratransit Fleet – Battery-Electric Scenario Proposed Procurement Schedule

Vehicle Type	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
E10 Cutaway	0	9	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E10 Modified Van	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BEV Cutaway	0	0	0	6	2	3	0	0	6	5	5	6	2	3	0	0	6	5	5
BEV Modified Van	0	0	0	4	3	5	1	1	5	5	5	3	3	4	2	2	5	5	5
Total	1	10	10	10	5	8	1	1	11	10	10	9	5	7	2	2	11	10	10

Source: WSP, LTD

Figure 4-6 illustrates the future vehicle inventory. Based on the current assumed vehicle useful life, all E10 vehicles will be replaced in 2032.

Figure 4-6. Paratransit Fleet – Battery-Electric Scenario Future Vehicle Inventory



Source: WSP, LTD

4.3.3 EMISSIONS

The lifecycle GHG emissions for all fuel/technology scenarios, including the battery-electric scenario, generally will decline over time due to an expected increase of more sustainable means of fuel/energy generation.

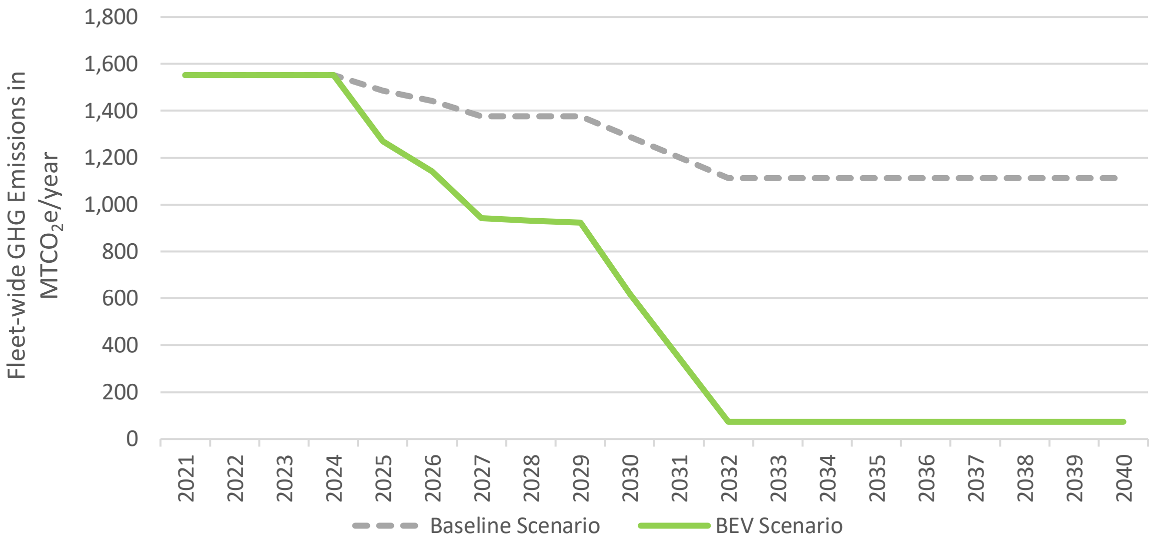
The battery-electric scenario provides the greatest reduction in lifecycle GHG emissions. The estimated reduction from this scenario in 2040 is 95 percent as compared to 2021 emissions, which is an additional 67 percent reduction as compared to the baseline scenario (Figure 4-7). The lifecycle GHG emissions from the battery-electric scenario are exclusively from the upstream emissions due to electricity generation. BEVs do not produce tailpipe emissions, but particulate emissions from brake and tire wear would occur. No other tailpipe pollutants would be present in 2040 in the battery-electric scenario.

The annual lifecycle GHG emissions (CO_2e) from 2021 to 2040 were calculated using the presumed fleet inventory, procurement schedule, and estimated duty cycles (mileage). The RNP and baseline scenarios have the same emissions profile until 2024. Then they start to diverge after the transition to the RNP fleet begins in 2025. The number does not include emissions from vehicle components production.

Upstream GHG emissions from vehicles, engines, batteries, and fuel cells production were not evaluated as part of this analysis. The emissions will greatly vary depending on the source of raw materials and the production process used by the vehicle components' OEMs. There is currently no standardized method to estimate these emissions.

The quantification of project-level GHG emissions from the battery lifecycle is an ongoing area of research. It is estimated that the full lifecycle emissions of a battery electric passenger vehicle are lower than those of a passenger ICEV.[24] The battery manufacturing process will add a new emissions component compared to traditional ICEVs. However, the overall lifecycle emissions of BEVs will be lower due to the lower emissions from electricity production and the zero tailpipe emissions. More studies are needed to determine if the same conclusion is true for different battery chemistries and vehicle types, especially when considering the larger battery requirements for medium-duty vehicles such as cutaways.

Figure 4-7. Paratransit Fleet – Battery-Electric Scenario Annual GHG Emissions



Source: WSP

4.3.4 LIFECYCLE COSTS

Lifecycle cost analysis capture the total costs of transitioning the transit fleet to future fleet/technology. It assesses direct cash costs of vehicle and infrastructure capital costs, O&M costs, and disposal/salvage costs, as well as non-cash costs, such as environmental impacts, which the lifecycle model monetizes to account for a holistic comparative cost and benefit.[25]

Based on the analysis, transitioning to a full BEV fleet has a higher total lifecycle than the baseline scenario, mainly due to the higher capital and O&M costs. The total lifecycle cost of the BEV fuel/technology scenario is approximately $206 million or $4.15 per mile, 97 percent ($101.5 million) higher than the baseline E10 gasoline scenario (Table 4-8).

In terms of capital costs, BEVs have higher total costs compared to the baseline scenario due to the higher vehicle and infrastructure capital costs for installing chargers and upgrading the maintenance facility. The baseline scenarios will not need any facility upgrades. Battery-electric fuel/technology scenario total capital cost is $88 million, 172 percent ($55.4 million) higher than the baseline scenario.

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[24] IEA. 2021. *Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle.* IEA. Paris. https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle

[25] Refer to Appendix B – Deeper Impact Analysis Report for detailed unit costs and lifecycle cost analysis assumptions

BEV O&M costs are 79 percent ($49.9 million) higher than the baseline scenario due to higher fuel cost, additional costs to maintain the charging infrastructure, and new technology training. The vehicle maintenance cost itself is slightly lower than the baseline E10 gasoline scenario. Thus, the overall O&M cost for the battery-electric scenario is $113 million. The total cash cost (capital, O&M, and disposal costs) of the BEV fuel/technology scenario is 116 percent ($107 million) higher than the baseline scenario, with a total of $200 million or $4.01 per mile.

When combining both GHG and local air pollutants, the total environmental costs of the BEV fuel/technology scenario is better than the baseline E10 gasoline vehicles due to the significantly lower tailpipe and upstream emissions. The environmental cost of the scenario is 45 percent ($5.5 million) lower than the baseline E10 gasoline scenario. Note that the analysis does not include the costs of emissions produced during the production and disposal of vehicle components and the supporting fueling infrastructure.

Table 4-8. Paratransit Fleet – Battery-Electric Scenario 2022-2040 Lifecycle Costs (YOE $ Millions)

Cost Categories		Baseline	Battery-Electric
Cash Costs			
Capital Costs	Vehicle Purchase Price	$31.9	$86.3
	Modifications and Contingency	$0.3	$1.0
	Charging/Fueling Infrastructure	$0.0	$0.4
	Total Capital Costs	**$32.3**	**$87.7**
O&M Costs	Vehicle Maintenance	$52.4	$51.7
	Vehicle Tires	$0.0	$0.0
	Vehicle Fuel Costs	$10.8	$39.8
	Charging/Fueling Infrastructure	$0.0	$8.4
	Training	$0.0	$13.2
	Total O&M Costs	**$63.2**	**$113.1**
Disposal Costs	Battery Disposal	$0.0	$0.0
	Bus Disposal	-$2.9	-$1.3
	Total Disposal Costs	*-$2.9*	*-$1.3*
Total Cash Costs		**$92.5**	**$199.5**
Total Cash Cost per Mile		**$1.86**	**$4.01**
Non-Cash Costs			
Environmental Costs	Emissions - Tailpipe	$0.9	$0.7
	Emissions - Refining/Utility	$6.2	$0.8
	Noise	$5.3	$5.3
	Total Environmental Costs	$12.3	$6.8
Total Cash and Non-Cash Cost		$104.8	$206.3
Total Cash and Non-Cash Cost per Mile		$2.11	$4.15

Source: WSP PRISM Model

O&M = operations and maintenance; YOE = year of expenditure

4.3.5 IMPLEMENTATION CONSIDERATIONS

As discussed in the analysis, the battery-electric scenario has the lowest GHG emissions and virtually zero tailpipe emissions. However, it has higher lifecycle costs due to the higher capital costs and O&M costs. LTD will need to weigh the trade-off of these aspects before making decisions regarding the future fuel type and transition timeline. Furthermore, there are other aspects relevant to the paratransit service that should be considered, as described below.

VEHICLE RANGE

Unlike the transit fleet with fixed service route, paratransit will have more flexible service that can be tailored to EV range. The dispatcher will need to ensure that the chained trips will not exceed the EV range. Currently, the advertised range for EV cutaways is 80 to 170 miles. Currently, no EV minivans are in the market, but the advertised range is supposed to be 250 miles.

CHARGING TIME AND CHARGE MANAGEMENT SYSTEM

The total charging time will vary depending on the charger speed, charging configuration, and BEV state of charge. LTD will need to make sure that the BEVs have enough time to charge. LTD may want to use Charge Management Software (CMS), which is a software that can intelligently schedule charging time to minimize peak demand and utility costs while still giving enough charge for the BEVs to complete service.

POLICY SUPPORT AND FUNDING

There is increasing support, especially at the federal level, to encourage the adoption of low- and no-emission technology. There are currently no specific incentives available on the state level for zero-emission vehicles; however, the state has established a state-wide ZEV adoption goal.[26]

There are several incentives and funding sources at the Federal level that can potentially fund BEVs, including:

- FTA Low or No Emission Vehicle Program (part of the BIL): May be used for the purchase or lease of low emission or ZEVs and related equipment, as well as the construction of supporting facilities
- CMAQ Improvement Program: Formula funding that must be used for projects that will help meet the requirements of the Clean Air Act, such as alternative fuel vehicles and infrastructure
- CRP: Formula funding that must be used for projects that will reduce transportation emissions, such as alternative fuel vehicles and infrastructure
- USDOT RAISE competitive grant program

There are also several programs that do not apply to depot fueling infrastructure but indicate a strong push toward the adoption of alternative fuels, such as the FHWA’s designated AFC grant and NEVI formula funding programs. Both programs aim to establish interconnected networks of public EV charging corridors.

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[26] AFDC. *Zero Emission Vehicle Deployment.* https://afdc.energy.gov/laws/12300

4.4 SUMMARY

Based on the analysis, only the battery-electric fuel/technology scenario will require upgrades to the maintenance facility. The future fuel/technology vehicles delivery can commence in 2025 once the facility is upgraded to accommodate the required charging infrastructure. To achieve this timeline, the design procurement process for the facility needs to start in 2023. Early and continuous coordination with utility providers is strongly encouraged to ensure seamless transition. Meanwhile, the average vehicle lead time is approximately 12 months. Therefore, LTD will need to start the procurement process in fiscal year 2024 to have vehicles delivered in 2025. All E10 gasoline vehicles will be replaced by 2032.

For the paratransit fleet, both battery-electric and RNP scenarios will provide significant improvements toward local air quality and overall GHG emissions reductions compared to the baseline E10 gasoline scenario. The battery-electric scenario results in a higher emissions reduction compared to the RNP scenario. In 2040, a full BEV fleet will provide an additional 67 percent GHG reduction as compared to the baseline scenario. Meanwhile, the RNP scenario will provide an additional 42 percent emission reduction compared to the baseline scenario.

In contrast, from the cost perspective, both battery-electric and RNP scenarios will result in higher lifecycle costs for the paratransit fleet compared to the baseline scenario. This is mainly due to the higher capital and O&M costs for both fuels/technologies. The battery-electric scenario has the highest lifecycle costs, with the total costs being 97 percent higher than the baseline scenario. The RNP scenario lifecycle cost is 23 percent higher than the baseline scenario. Table 4-9 summarizes the emissions and cost findings for the paratransit fleet.

Other aspects besides lifecycle costs and emissions, such as impact to operation, technology development, market outlook, policy trend, and funding will also need to be considered by LTD before making the decision on the preferred fuel/technology. Currently, there is an increase in policy support and incentives toward low- and zero-emission vehicles. The higher costs of these technologies can be partially offset by the available funding.

Table 4-9. Paratransit Fleet – Summary of Results

Indicators	Fuel/ Technology Scenario		
	Baseline (E10 Gasoline)	Renewable Propane	Battery-Electric
Annual GHG emissions in 2040 compared to 2021	28% reduction	-42% from baseline	-67% from baseline
Tailpipe Air Pollutants Emissions*	Highest emissions	Less compared to baseline	Zero emissions
Environmental Costs**	$12.3	$9.0	$6.8
Capital Costs**	$32.3	$46.8	$87.7
Operating Costs**	$63.2	$74.3	$113.1
Disposal Costs**	-$2.9	-$0.8	-$1.3
Total Costs**	**$104.8**	**$129.2** (+23% from baseline)	**$206.3** (+97% from baseline)
Total Costs/mile	**$2.1**	**$2.6**	**$4.2**

Source: WSP

* Detailed amounts of air pollutants emissions can be found in the Excel-based Sustainability Tool

** All costs are in YOE $ Millions

5 SUMMARY AND NEXT STEPS

5.1 SUMMARY

The most suitable future fuel/technology scenario will depend on LTD's approach to weigh and prioritize the aspects that make up the Triple-Bottom-Line Approach to Sustainability: impact on operations, social equity and environment, and costs. Based on the analysis, it is clear that no single future fuel/technology has absolute advantages over the other options. The newer ZE technologies offer substantial reduction in GHG emissions and local air pollutants, but currently have significantly higher lifecycle costs and potential impact to service operation. Meanwhile, the existing fuels generally have the least lifecycle costs and impact to operation but have the biggest environmental costs. Table 5-1 presents the best fuel/technology for each Triple-Bottom-Line aspect, considering overall performance (including the existing fuel) and future fuel and technology only options.

Table 5-1. Scenario Findings Summary

Triple-Bottom-Line Approach		Transit Fleet	Paratransit Fleet
Least Impact to Operations*	Overall	R99 Renewable Diesel	E10 Gasoline
	Future Fuel/Technology-only	Renewable Natural Gas	Renewable Propane
Highest Emission Reduction	Overall	Battery-Electric	Battery-Electric
	Future Fuel/Technology-only	Battery-Electric	Battery-Electric
Least Costs	Overall	Renewable Natural Gas	E10 Gasoline
	Future Fuel/Technology-only	Renewable Natural Gas	Renewable Propane

Source: WSP

* Based on current vehicle range

Moreover, there are several other aspects that need to be considered:

- Policy Support and Funding: Currently, there is increasing policy support and incentives toward low- and zero-emission vehicles. LTD can utilize these fundings to offset the higher costs of the future fuel/technology options. Moreover, Oregon has decided to phase out ICE trucks and established state-wide ZEV adoption goal. Both examples indicate that ZEVs might be the preferable option for future vehicle technology in the state of Oregon.

- Fuel Availability: Currently, the supply of RNP is very limited. There are uncertainties regarding whether the fuel will be widely adopted. If choosing RNP, in the near-term, LTD will need to rely on limited suppliers, which comes with risks in the event of disruptions. R99 renewable diesel faces the same challenge, but it is more widely adopted and produced compared to RNP.

- Procurement Schedule: The minimum useful life required by FTA for heavy-duty buses is 12 years or 500,000 miles. Therefore, if LTD wants to achieve the goal of eliminating fossil fuel by 2035, any R99 renewable diesel transit buses procured in 2023 need to be retired in exactly 12 years, while vehicles procured in 2024 and beyond will need to achieve 500,000 miles in 2035.

Table 5-2 lists the pros and cons of the different fuel/technology scenarios discussed in this Procurement Plan.

Table 5-2. Fuel/Technology Scenario Pros and Cons Summary

Fleet	Fuel/Technology Type	Pros	Cons
Transit	R99 Renewable Diesel	– Significant GHG emissions reduction compared to conventional diesel. 60% GHG remissions reduction in 2040 compared to 2021 level. – Relatively low lifecycle costs (only slightly higher than RNG). – No impact to current operations. – Requires the fewest changes: no facility upgrades and no changes in vehicle technology. – Production capacity is forecasted to grow significantly in upcoming years.	– Chemically identical to conventional diesel and has similar level of tailpipe air pollutants. – Policy trend shows increasing support toward low- and zero-emission vehicles along with stricter standard for diesel vehicles. – Limited supply. LTD will need to rely on limited suppliers, which increases risks for supply, quality, and price.
	RNG	– Significant particulate matter and NO_X reduction compared to diesel buses. – Lowest overall lifecycle costs due to lower O&M costs. – Range is shorter than diesel buses but will be adequate for most service. – Considered as alternative fuel and low emission fuel, which makes it eligible for alternative fuel funding.	– Lifecycle GHG emissions are higher than R99 diesel – Required retrofit of maintenance facility to support lighter-than-air fuel. – Additional space requirement for new fueling stations.
	Battery-Electric	– Greatest GHG emissions reduction. – Zero tailpipe emissions. – Eligible for alternative and zero-emission fuel funding. – Increasing policy support and mandate to transition to ZEVs. – Relatively lower fuel costs. – Range and reliability are expected to improve in the upcoming years as technology matures.	– High lifecycle costs due to high capital and O&M costs. – High potential impact on existing service due to lower vehicle range and reliability. – Depending on the transition timeline, might require more than a 1:1 replacement ratio due to the range limitation. – Additional space requirement for charging stations.
	Hydrogen	– Zero tailpipe emissions. – Greater range than BEBs. – Eligible for alternative and zero-emission fuel funding. – Increasing policy support and mandate to transition to ZEVs.	– Most hydrogen is currently produced from natural gas with a very high carbon footprint. Highest GHG emissions compared to other scenarios with this production method. – Green hydrogen suppliers are still very limited. – Large space needed for new fueling stations and the safety setback requirements. – Lower reliability than diesel buses but higher than BEBs.
Paratransit	E10	– Lowest lifecycle costs. – No impact on current operations.	– Greatest GHG emissions and local air pollutants.

Fleet	Fuel/Technology Type	Pros	Cons
			– Policy trend shows increasing support toward low- and zero-emission vehicles along with stricter standard for gasoline vehicles.
	RNP	– Lower GHG emissions than E10 gasoline. – Fewer air pollutants than E10 gasoline. – Considered as alternative fuel and low emission fuel, which makes it eligible for alternative fuel funding.	– Very limited supply of RNP fuel; conventional propane is more widely used. LTD will need to rely on limited suppliers, which poses a higher risk.
	Battery-Electric	– Greatest GHG emissions reduction. – Zero tailpipe emissions. – Eligible for alternative and zero-emission fuel funding. – Increasing policy support and mandate to transition to ZEVs. – EV minivans are expected to be mass-produced in the next several years.	– Currently, no electric minivans are available. – Requires facility upgrade to support charging infrastructure. – Highest lifecycle costs due to the significant capital and O&M costs.

Source: WSP

5.2 NEXT STEPS

This section discusses the next steps that need to be taken by LTD to start the transition to future fuel/technology. The strategies are divided into three five-year phases: short-term, mid-term, and long-term.

5.2.1 SHORT-TERM (ONE TO FIVE YEARS)

In the next one to five years, LTD should focus on selecting the preferred future fuel/technology and initiating the transition. The following key next steps need to be taken:

1. Early Communication with Fuel Suppliers

LTD should start the discussion with potential fuel suppliers to get an early estimate on fuel availability, fuel price, required fueling infrastructure, the power needed to support the fueling infrastructure, and preliminary total cost estimates. For the RNG scenario, the fuel provider (NW Natural) may be different from the fueling infrastructure provider. Generally, depending on LTD's current electrical capacity, no electrical system upgrades are needed to operate RNG and hydrogen fueling stations.

2. Choose Preferred Fuel/Technology

This report provides various metrics for comparing each of the alternative fuels assessed in this Plan. These metrics, along with the findings from detailed conversations with fuel suppliers may be evaluated and ranked based on LTD's priorities and values. For example, LTD could use a Multi-Objective Decision Analysis (MODA), to score each fuel by assigning weighted values to the metrics that LTD finds most important.

3. Assessing the Transition Timeline

The plan outlined in this document assumes that the design procurement for any maintenance facility upgrade will start in January 2023. Depending on when LTD makes the decision on the preferred fuel/technology, the assumed timeline may need to be adjusted. The adjusted timeline has to consider the Climate Action Policy Statement and Fleet Procurement Goals.

4. Integrating Vehicle Procurement and Deployment Strategy

Assuming the current Climate Action Policy goal of eliminating fossil fuels by 2035, the future fuel/technology vehicle procurement will need to start soon after this Plan is finalized. This is considering that the buses in the transit fleet have 12 years or 500,000 miles minimum useful life requirement. Any delays in the vehicle procurement will result in two strategies: pushing back the transition goal or strategically utilizing the newer ICEBs to reach 500,000 miles before the transition goal. Dispatchers will need to be involved and informed if the latter strategy is chosen.

Due to the current limited range, any BEBs procured in the near term should be deployed on shorter service blocks. BEBs can be deployed on longer blocks as the technology grows and the range increases. Therefore, for the battery-electric scenario, specifically, vehicle procurement can also be aligned with expected range increase and LTD's service. However, other strategies (i.e., service adjustment, additional vehicles, opportunity charging) may be needed if BEB technology improvement does not match LTD's service needs.

5. Initiate the Process for Facility Upgrade (if needed) and Vehicle Procurement

Once LTD decides on the preferred fuel and transition timeline, the design procurement for facility upgrade and vehicle procurement can commence. The facility upgrade will need to align with the vehicle procurement schedule to ensure equipment is in place to support the first installment of new vehicles.

6. Monitor Available Funding

Considering the higher capital costs of the new fuel/technology, funding and incentives will be essential to ensure seamless transition. LTD should continue to monitor any potential funding at the federal, state, and local levels.

5.2.2 MID-TERM (5 TO 10 YEARS)

The next five to ten years of the transition should focus on assessing the real-world performance of the new fuel/technology and its impact on the Triple-Bottom-Line Approach to Sustainability and the Climate Action Policy Statement and Fleet Procurement Goals. The following steps need to be taken:

1. Fuel/Technology Performance Assessment

LTD should continuously gather performance data to assess the fuel/technology impact to LTD’s operation, equity and environmental sustainability, and costs implication. The findings will provide insight on whether the fuel/technology performs as initially expected and offer insight into opportunities for improvement.

2. Climate Action Policy Statement and Fleet Procurement Goals Assessment

The performance data gathered can also be used to assess whether LTD is on track to achieve the Climate Action Policy Statement and Fleet Procurement Goals.

3. Monitor Technology and Market Development

If more nascent technology was chosen, it is essential for LTD to monitor the technology growth from the performance, sustainability, and costs perspective. Desired improvements include longer range, improved reliability, more sustainable production method, and lower costs. This information may be used to adjust the fleet transition strategy and refine budgets.

4. Procurement Strategy Refinement

Based on the real-world performance, goals assessment, and technology development, LTD can review the procurement strategy and make adjustments as needed.

As mentioned, especially for the battery-electric scenario, if BEB technology improvement does not match LTD’s service needs, other strategies (i.e., service adjustment, additional vehicles, opportunity charging) may be necessary.

5. Monitor Available Funding

Considering the higher capital costs of the new fuel/technology, funding and incentives will be essential to ensure seamless transition. LTD should continue to monitor any potential funding at the federal, state, and local levels.

5.2.3 LONG-TERM (10 TO 15 YEARS)

Between years 10 and 15 of the transition, the assumption is that LTD has had enough experience with the technology and has implemented the necessary adjustments to address the fuel/technology shortfalls. It is also expected that the technology will improve and will cause less strain on LTD’s operations, sustainability, and funding. The steps that need to be taken in this phase are similar to those in years 5 to 10. In this phase, LTD will need to provide final assessment on the Climate Action Policy Statement and Fleet Procurement Goals.