ACTION PLAN
FOR ELECTRIFICATION AND SERVICE GROWTH

FINAL PLAN

RHODE ISLAND PUBLIC TRANSIT AUTHORITY

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Acronyms

APEG	Action Plan for Electrification and Service Growth
BEB	Battery Electric Bus
DMV	Department of Motor Vehicles
DPUC	Division of Public Utilities and Carriers
DSP	Division of Statewide Planning
FTA	Federal Transit Administration
FY	Fiscal Year
GHG	Greenhouse Gas
HFCB	Hydrogen Fuel Cell Bus
HVAC	Heating, Ventilation, and Air Conditioning
ICE	Internal Combustion Engine
kg	kilogram
kWh	kilowatt hour
O&M	Operations and Maintenance
OEM	Original Equipment Manufacturer
PMO	Program Management Office
RFP	Request for Proposal
RIDOT	Rhode Island Department of Transportation
RIPTA	Rhode Island Public Transit Authority
SARTA	Stark Area Regional Transit Authority
SOGR	State of Good Repair
TCRP	Transit Cooperative Research Program
TERM	Transit Economic Requirements Model
TMP	Transit Master Plan (*Transit Forward RI 2040*)
ULB	Useful Life Benchmark
YOE	Year of Expenditure
ZEB	Zero Emission Bus

1. Introduction

In December 2020, the Rhode Island Public Transit Authority (RIPTA), in partnership with the Rhode Island Department of Transportation (RIDOT) and the Division of Statewide Planning, completed development of a 20-year transit master plan entitled *Transit Forward RI 2040*. The core of the plan focuses on the improvement of existing services and offering service to new areas. Providing frequent, reliable transit service is paramount toward helping Rhode Island achieve multiple goals including reducing greenhouse gas (GHG) emissions, supporting economic and workforce development, and enhancing equitable mobility for all.

During this same time timeframe, RIPTA was also taking steps toward decarbonizing its fleet, including full electrification of the R-Line - its busiest and most frequent route - and all transit services based out of its Aquidneck Island operations center. To aid in determining the next phase of these decarbonization efforts, RIPTA commissioned the Action Plan for Electrification and Service Growth (APEG). This study envisions how RIPTA can achieve a fully zero emission transit fleet across several scenarios through the lens of full implementation of the service improvements and expansions outlined in *Transit Forward RI 2040*. The scenarios include a mix of fleet conversion methods, including hybrid vehicles, a mix of hydrogen fuel cell buses (HFCBs), battery electric buses (BEBs), depot charging, and on-route charging. Scenarios are outlined in Table 1.

Table 1 RIPTA Growth Scenarios

Name	Description
Scenario 1	TMP implementation with existing fleet mix; no additional decarbonization
Scenario 1A	TMP implementation with diesel-electric hybrid purchase after vehicles age out
Scenario 2	TMP implementation with 100% conversion to electric fleet, using only depot charging
Scenario 3	TMP implementation with 100% conversion to electric fleet, using depot charging and on-route charging
Scenario 4	TMP implementation with 100% conversion to HFCBs
Scenario 5	TMP implementation with BEB, depot and on-route charging; BEB for non-1:1 BEB or HFCB replacements (94% BEB, 6% HFCB)
Scenario 6	TMP implementation with BEB, depot and on-route charging; HFCB for non-1:1 BEB replacements (71% BEB, 29% HFCB)

This report outlines existing conditions in RIPTA’s bus network, including an overview of service levels, the condition of fleet and facilities, staffing levels, and TMP service changes. Additionally, the report describes the cost of fleet, facility, and staffing needs under the suite of growth and decarbonization scenarios, including a high-level overview of foreseeable risks, to identify next steps for TMP implementation and decarbonization.

2. Existing Conditions

An initial conditions assessment is vital for evaluating RIPTA’s needs as service expands under TMP growth over the next 20 years. Establishing the initial inventory of services, vehicles, facilities, and staffing is the first step in assessing the needs and costs of growth associated with transit service expansion. This plan gathered information on existing conditions from the 2022 Transit Asset Management Plan update (required per 49 CFR 625), facility data from Michael Baker International developed for RIPTA, interviews with key staff, a review of public records provided to the National Transit Database, and individual data sources from various RIPTA departments.

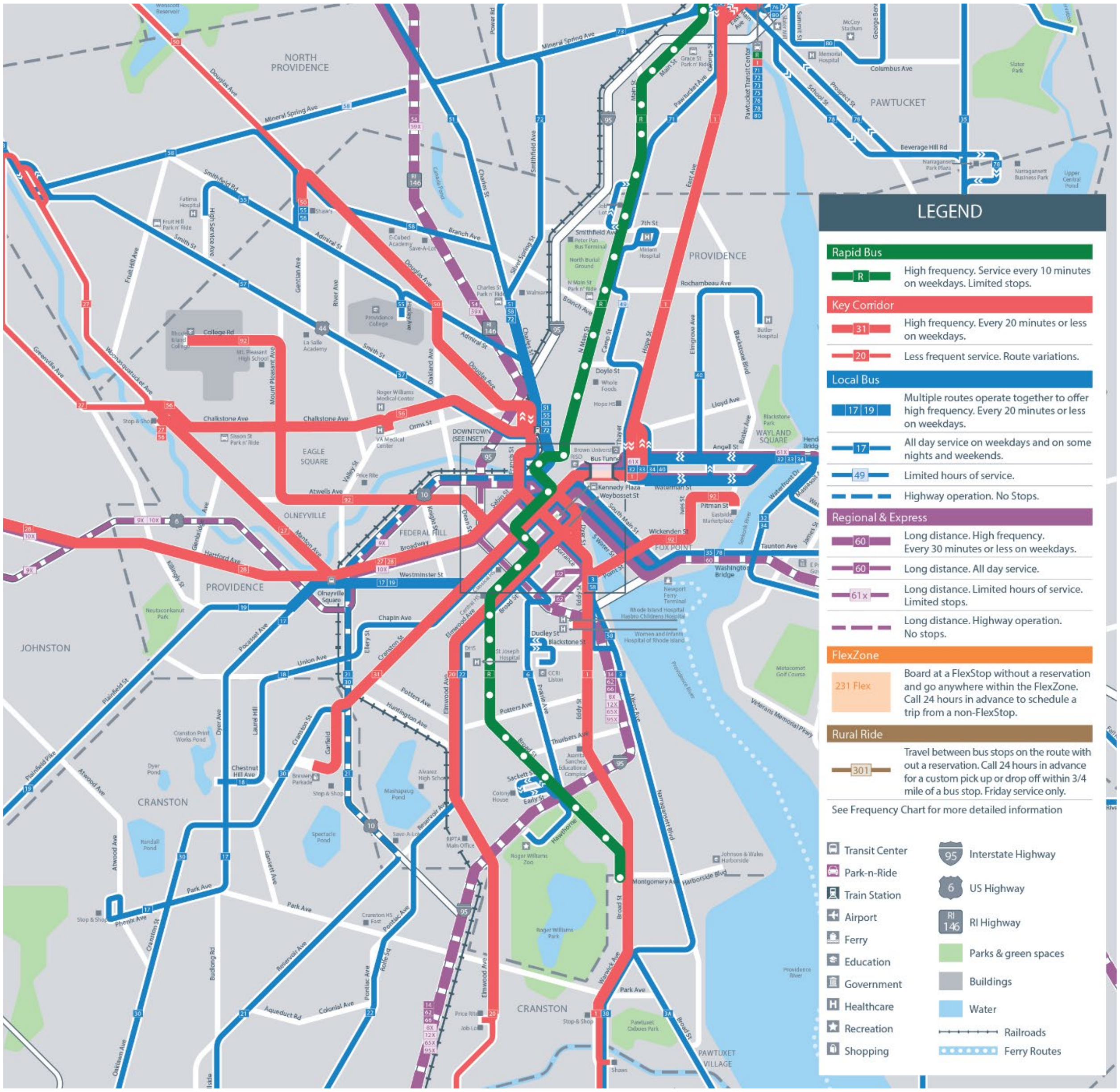
2.1 Service Overview

As of 2022, RIPTA provides 36 Rhode Island communities with fixed route bus service, utilizing 206 buses. Service includes 60 routes, characterized by varying frequency and hours of operation (Table 2). Operations for select routes begin as early as 4:30 am on weekdays, with an average system start time of approximately 6 am and an average end time of 9:45 pm. Service on weekends is generally reduced from weekday operations, running fewer routes less frequently for narrower average time windows. RIPTA also offers FlexZone and paratransit service. Figure 1 provides a detailed system map.

Table 2 RIPTA Fixed Route Service Characteristics

Type	Count	Average Weekday Operations	Average Saturday Operations	Average Sunday Operations
Bus Rapid Route	1	10-minute headways 5:15 am – 1:15 am	15 to 20-minute headways 5:15 am – 1:00 am	15 to 20-minute headways 6:30 am – 12:15 am
High-Frequency Route	7	15 to 25-minute headways 5:30 am – 11:15 pm	15 to 40-minute headways 6:15 am – 10:30 pm	20 to 45-minute headways 6:45 am – 8:45 pm
Local Route	39	30-minute+ headways 5:45 am – 9:30 pm	45-minute+ headways 7 am – 9 pm	50-minute+ headways 7:45 am – 8 pm
Express Route	8	30-minute+ headways	N/A	N/A
Special Service Route	5	Varies	Varies	Varies

Figure 1 RIPTA Current (2023) Service Map



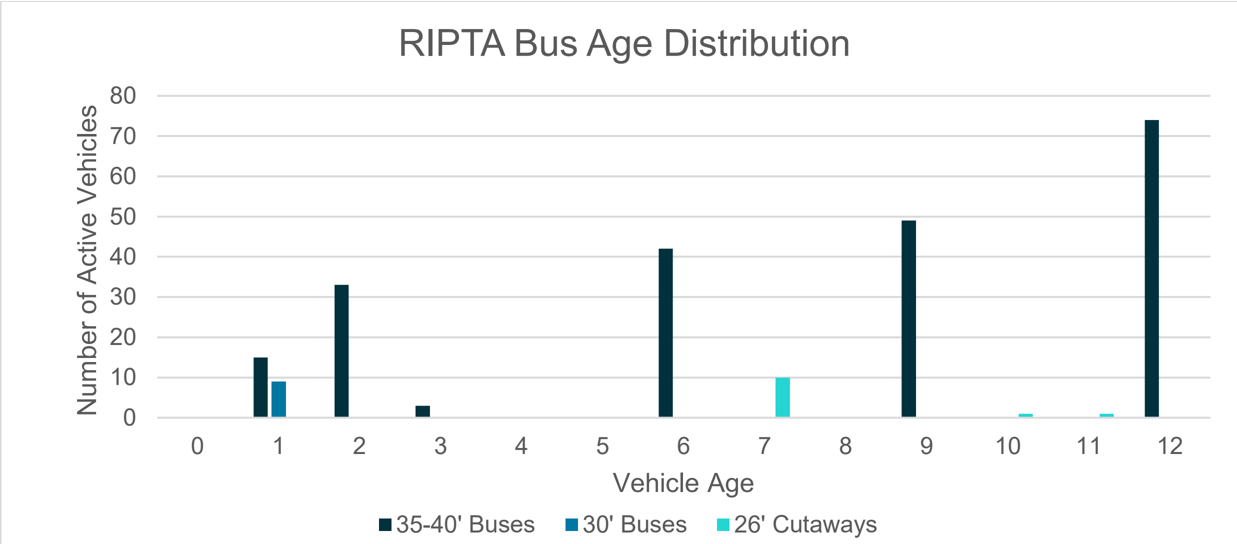
Source: RIPTA System Map[1]

2.2 Fleet

RIPTA operates a diverse fleet of buses on fixed route service, ranging from recently acquired BEBs to diesel and diesel-electric hybrid buses over 10 years old (Figure 2). Following Federal Transit Administration (FTA) guidance, RIPTA assigns a useful life benchmark (ULB) of 12 years for heavy duty diesel buses, and 13 years for diesel-electric hybrid buses.[2] RIPTA's maintenance practices follow original equipment manufacturer (OEM) recommendations at a minimum, replacing engines and transmissions after buses reach the 300,000-mile mark, or approximately half-way through the bus's ULB. By these standards, approximately **37 percent of the bus fleet will reach retirement age within the next 3 years**.

[1] RIPTA, System Map, 2017, https://www.ripta.com/wp-content/uploads/2020/04/ripta_sys_map_2017_web8.pdf.
[2] Federal Transit Administration, Asset Inventory Module Reporting Manual, 2017, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/FTA%20TAM%20ULB%20Cheat%20Sheet%202016-10-26.pdf.

Figure 2 RIPTA Revenue Bus Fleet Age Distribution



2.3 Facilities

RIPTA has seven facilities, including two bus maintenance facilities, four facilities that combine administrative functions and operations, and one passenger facility (Table 3). The facilities' construction dates range from 13 to 95 years ago and the last major renovation took place in the 1990s. Accounting for renovations, RIPTA's facilities have an average age of approximately 25 years. In 2022, each of the facilities was assigned a rating based on the FTA's 5-point Transit Economic Requirements Model (TERM), which assesses the condition of the facility, including heating, ventilation and air conditioning (HVAC), electrical, and fire protection components. RIPTA's 265 Melrose Street facility fell below the marginal rating (2 points or less), meaning it is defective or deteriorated and in need of replacement, as it has exceeded its useful life. Another of RIPTA's facilities, 335 Melrose Street, is rated below adequate (3 points or less), meaning it is moderately deteriorated or defective and is approaching its useful life. The remaining five facilities are rated above adequate (3 points or more), meaning that they have not yet exceeded useful life and are in a state of good repair (SOGR).

Table 3 RIPTA Facilities Inventory and Condition

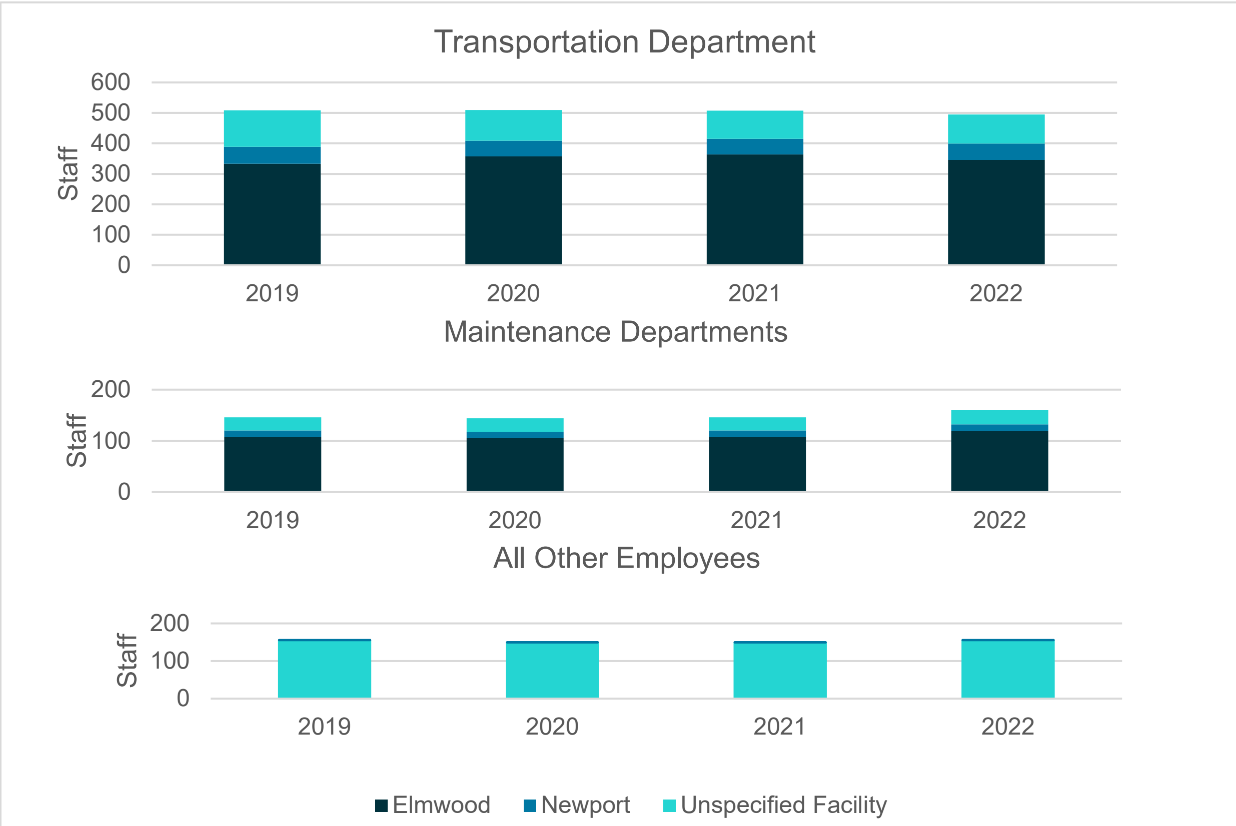
Name	Location	Facility Type	Year Built	Last Rehab	Vehicle Capacity	Condition Rating
265 Melrose Street	Providence	General Purpose Maintenance	1927	1997	15	1.8
269 Melrose Street	Providence	General Purpose Maintenance	1990	1997	80	3.4
750 Elmwood Avenue	Providence	Heavy Maintenance	2000	NA	0	3.5
325 Melrose Street	Providence	General Purpose Maintenance	1960s	1990s	0	2.6
1 Kennedy Plaza	Providence	Passenger Facility	2001	NA	0	3.0
350 Coddington Highway	Middletown	General Purpose Maintenance	1993	NA	5 - 20	3.1
705 Elmwood Avenue	Providence	Paratransit Maintenance and Storage Facility	2009	NA	80 - 100	3.7

See the *Action Plan for Electrification and Service Growth: Existing Fleet and Facilities Conditions Technical Memorandum* for more information.

2.4 Staffing

As of 2022, RIPTA employed 814 people across 22 departments. As described in the *Annual Financial Plan FY 2023-2028*[3] and in interviews with agency personnel, RIPTA is currently understaffed, especially for operators in its Transportation and Paratransit Departments. For the purposes of this analysis, staff across these departments have been classified into three groups: maintenance, operators, and other, which includes administration, safety, and training (Figure 3).

Figure 3 RIPTA Staffing Levels by Group



2.5 TMP Service Changes

TMP service improvements focus on providing expanded service where demand is highest, in Providence, Pawtucket, Central Falls, North Providence, East Providence, Warwick, and Cranston. RIPTA plans on increasing service frequency, operating for longer hours, making service faster on existing routes, consolidating underutilized routes or routes with redundancy, and introducing 12 new routes to address demand for increased coverage (Table 4). Figure 4 is a map of proposed service.

Table 4 TMP Service Changes by Route Type

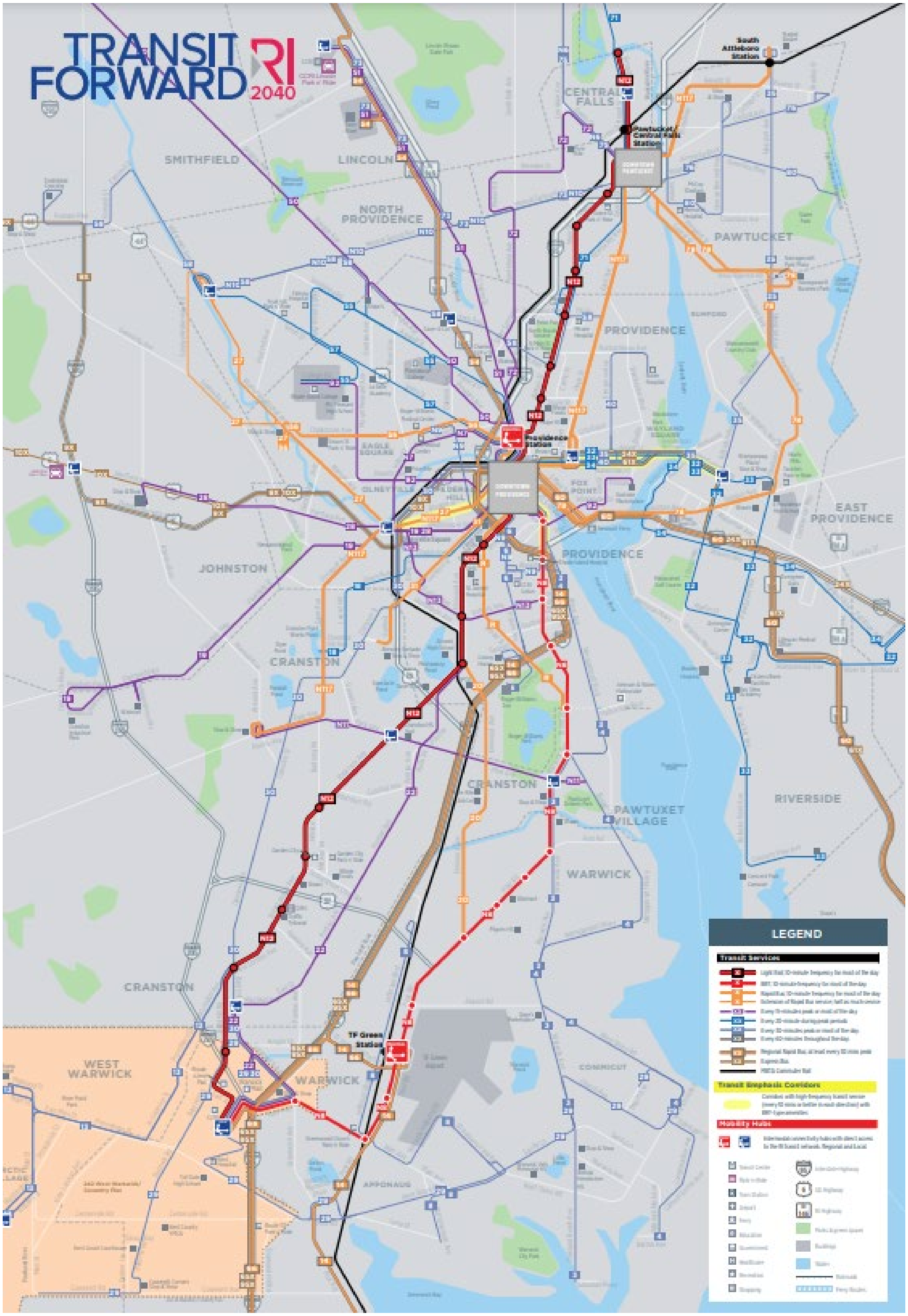
Route Type	Headway	Routes
10 All Day	10 minutes all day, 20 late night	R, 20, 27, 31, 56, 78, N8, N12, N17
15 All Day	15 minutes all day, 30 night	19, 22, 28, 50, 51, 72, 92, N7, N11
15 Peak/30 Off-Peak	15 minutes in peak, 30 off-peak	54, 6
20 Peak/30 Off-Peak	20 minutes in peak, 30 off-peak	18, 32, 33, 34, 55, 57, 63, 67, 71

[3] RIPTA, Annual Financial Plan FY 2023-2028, 2022, https://www.ripta.com/wp-content/uploads/2022/09/RIPTA-FY-2023-Financial-Plan.pdf.

Route Type	Headway	Routes
30 All Day	30-minutes all day, 60 late night	3, 4, 13, 14, 30, 58, 64, 66, 69, 73, 75, 76, 87, N9, N10, N16, N18, N20
30 Peak/60 Off-Peak	30-minutes in peak, 60 off-peak	6, 16, 23, 29, 80, N16, N19
Express	At least three trips per peak	9x, 10x, 24L, 61x, 65x, 95x, QX
Discontinued [a]	Route will not operate	1, 8x, 12x, 21, 49, 59x, 62, N13, N14, N15

[a] *Includes routes that were proposed in the TMP but will not be implemented.*

Figure 4 TMP Service Map



Source: RIPTA Transit Master Plan Service Map

3. Methodology

To project the fleet, facilities, and staffing increases needed to support RIPTA's rollout of the TMP's proposed service increases, a series of assumptions were made based on historical trends, industry best practices, and accepted literature. This chapter provides a brief overview of the methods used to calculate projections for six growth scenarios (Scenarios 1 through 6). A seventh scenario, Scenario 1A; was incorporated later and modeled off of Scenario 1, varying only in that baseline growth was achieved using diesel-electric hybrid buses rather than internal combustion engine (ICE) vehicles. Discussion of the fleet, facilities, staff, total cost, and emissions associated with each of the seven scenarios can be found in section 0.

3.1 Fleet

This section describes the modeling completed to estimate the vehicle and energy requirements needed to deploy zero emission buses (ZEBs) on the proposed service in the TMP, including the preliminary schedules and route blocking that were necessary inputs for the modeling process. Additionally, this section includes an overview of the methodology used to model block performance with two different ZEBs: BEBs and HFCBs.

For a complete methodology, see the *Action Plan for Electrification and Service Growth: Route and Block Analysis and Energy Modeling Technical Memorandum*.

3.1.1 Schedule Development

Schedule development involves creating route and service-level assumptions that are used in blocking to estimate revenue hours, service miles, and vehicles operated in maximum service.

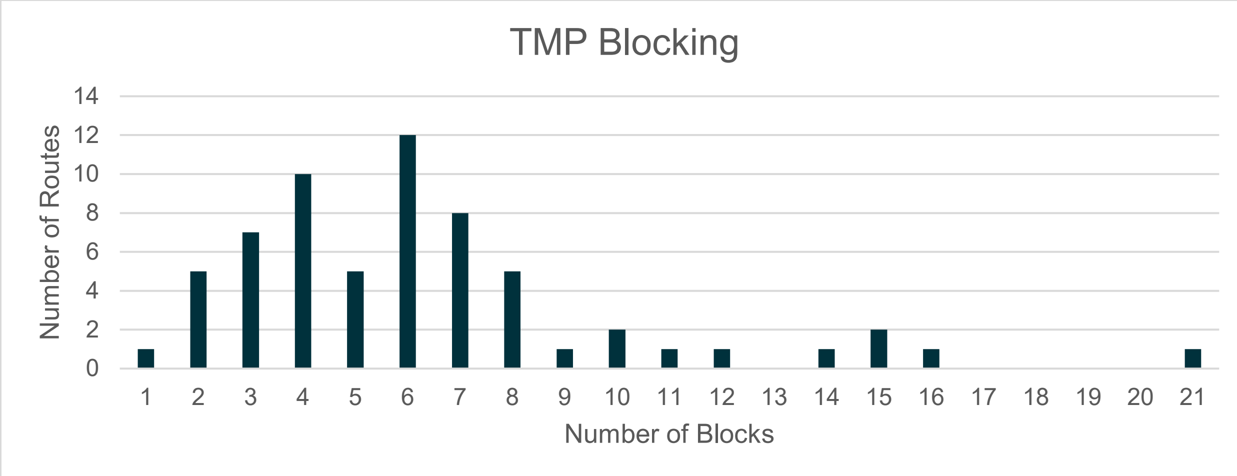
High-level schedules were built for the entire TMP system – 64 routes – and include routing, headway, and span changes aligned with service expansion. Routes were classified by target headways and assigned headways by time period.[4] Service was assumed to begin at approximately the current scheduled times, except for new routes, which begin at 5:00 am. All routes were assumed to end by midnight, except for those that currently end later. Finally, maximum vehicle requirements were expected to fall on weekdays, and as such, schedules were only developed for weekday service. Saturday service was assumed to require 67 percent of weekday vehicles, and Sunday and holiday service were assumed to require 40 percent. A complete list of TMP routing assumptions can be found in the *Action Plan for Electrification and Service Growth: Route and Block Analysis and Energy Modeling Technical Memorandum*.

3.1.2 Blocking

To understand vehicle needs and mileage requirements, blocking was developed for each route. Blocking is the process of linking trips on a schedule to create vehicle assignments. A route's headway target and average vehicle speed information was used to determine the cycle time and number of blocks needed to serve each route (Figure 5). Within this modeling effort, each route was required to have a 25 percent layover time and a minimum 15-minute layover available. If routes are currently interlined and the proposed changes retained the same alignment and headways, interlines remained in the TMP blocking. Each block was assigned to a garage based on current assignment or the garage closest to the block's last timepoint. Finally, if a vehicle serving a route traveled back to the garage mid-day due to shorter headways during the peak, the route was assigned a different AM and PM block number.

[4] The TMP and RIPTA's period designations were used in the analysis. The AM peak is 6:00 am to 9:00 am, midday 9:00 am to 3:00 pm, PM peak 3:00 pm to 6:00 pm, night 6:00 pm to 9:00 pm, and late night after 9:00 pm.

Figure 5 TMP Blocking



3.1.3 Modeling

The feasibility of using 40-foot BEBs or HFCBs to operate the proposed service was modeled using a software called Autonomie. Autonomie[5] is a vehicle simulation software produced by Argonne National Laboratory used for predictive modeling for energy consumption of an electric bus on a route based on vehicle characteristics, acceleration and deceleration patterns, grade changes, and weather conditions. The modeling process included two scenarios developed to understand battery requirements under "nominal" conditions and "strenuous" conditions, varying in passenger loads and ambient air temperatures, which greatly impact efficiency (Table 5).

Table 5 BEB and HFCB Energy Use Conditions

	BEB and HFCB Passenger Load	BEB Air Temperature	HFCB Air Temperature
Nominal	50% seated capacity	51°F	51°F
Strenuous	100% seated capacity	98°F	22°F

3.1.3.1 Battery Electric Bus

The vehicle used in the BEB simulation was modeled after a New Flyer Xcelsior Charge Next Generation 40-foot bus with a 525-kilowatt hour (kWh) battery capacity using diesel heaters. While the nameplate capacity is 525 kWh, the usable kWh is only 315 kWh due to battery degradation, unusable regions of the battery, and operational best practices.

For BEBs, the nominal scenario assumes 50 percent of passenger seating is occupied and a moderate temperature of 51°F, with no need for HVAC. The strenuous scenario assumes 100 percent full passenger seating and 98°F temperatures, incurring maximum use of the HVAC system. Cold temperatures do not require maximum use of the HVAC system because the vehicle relies on a diesel heater. Autonomie relied on GPS (Global Positioning System) data collected for existing routes to understand the average energy consumption (kWh/mile) in nominal and strenuous conditions.

3.1.3.2 Hydrogen Fuel Cell Buses

The vehicle used in the HFCB simulation was modeled after a New Flyer Xcelsior Charge Fuel Cell 40-foot bus with a storage capacity of 37.5 kilograms (kg) of gaseous hydrogen, of which 35.625 kg is usable for service. The modeling process used the same nominal conditions as the BEB model, but strenuous conditions included 100 percent full passenger load and a temperature of 22°F, as HFCBs cannot rely on diesel heaters like BEBs; therefore, maximum energy use is in the winter.

[5] Argonne National Laboratory, Vehicle & Mobility Systems Department, Autonomie, https://vms.taps.anl.gov/tools/autonomie/.

3.2 Facilities

Building out RIPTA's fleet in accordance with TMP service changes will require an increase in the quantity of buses, regardless of how or if decarbonization is achieved. With an increased number of buses comes an additional need for storage space, operations and maintenance (O&M) space, and space for BEB chargers or hydrogen fuel storage.

3.2.1 Facilities Expansion

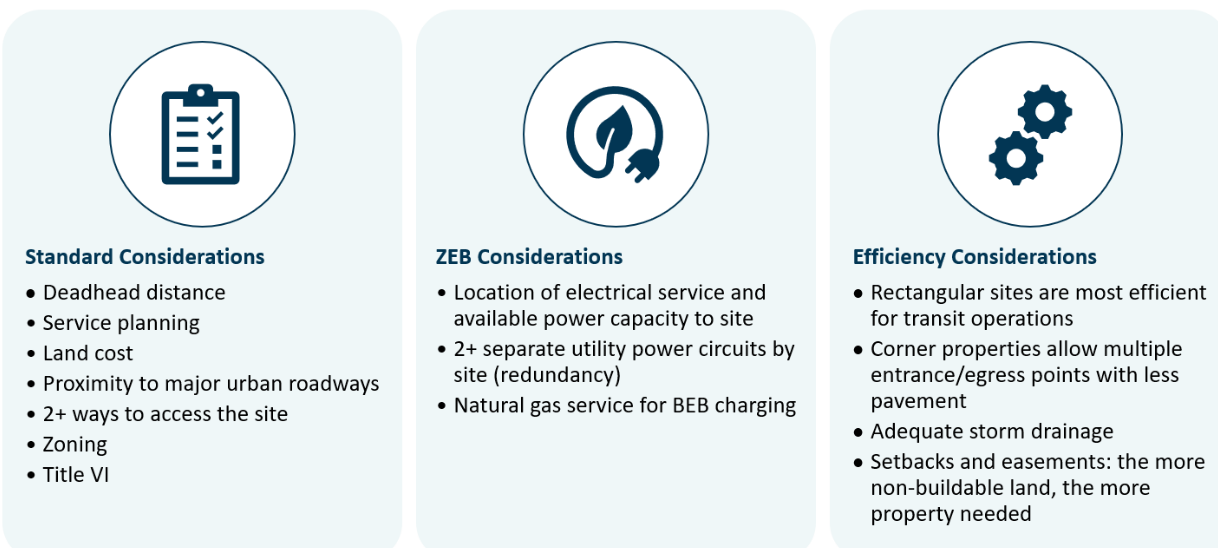
The facilities expansion strategy used for RIPTA's fleet growth across Scenarios 1 through 6 prioritizes parcels that are already in the state's portfolio to accommodate demand. As such, RIPTA' s Providence campus – including 705 Elmwood Avenue, 750 Elmwood Avenue, 265 Melrose Street, 269 Melrose Street, and 325 Melrose Street – and Newport Facility – at 350 Coddington Highway in Middletown – were analyzed to determine new configurations to store and service RIPTA's growing fleet.

One main goal of efficiently transitioning a facility from conventional diesel fueling to electrification is to keep the onsite vehicle flow the same with electrification as before electrification. This is an efficiency goal because:

- The same vehicle patterns used for years onsite remain in place and eliminate the need to train staff to circulate BEBs differently than ICE buses.
- Allows for progressive implementation of BEBs into the fleet gradually over time.
- Allows for staged / phase construction on the BEB improvements with minimal disruption to ongoing onsite transit operations.
- Allows for same onsite flow for all buses regardless of propulsion type.

If additional operations, maintenance, and storage space beyond the optimization and maximization of existing RIPTA-owned property is necessary, then RIPTA will need to site new facilities. Considerations for new facilities are highlighted in Figure 6.

Figure 6 Siting Considerations



For further information on facilities expansion, see the *Action Plan for Electrification and Service Growth: Long Range Facilities Planning and Financial Projections Technical Memorandum*.

3.2.2 On-Route Charging

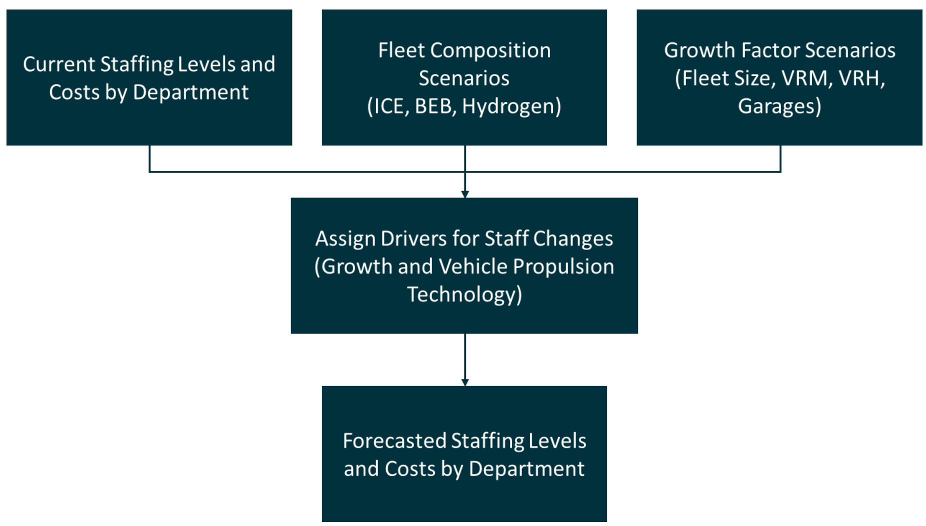
On-route charging facilities were identified through collaboration with RIPTA Service Planning and facility site visits. Each site was analyzed to determine which routes would charge at the location and the number of vehicles that could potentially charge at the location in the peak hour. For further information on charging infrastructure, see the *Action Plan for Electrification and Service Growth: Zero Emission Bus Infrastructure Technical Memorandum*.

3.3 Staffing

The primary driver of staffing needs over the 20-year forecast is the growth of service levels planned in the TMP. These increases in service will require significant expansions to the bus fleet, many additional operators, additional maintenance facilities and staff, and additional staff in most other departments across the agency. The transition to a BEB or HFCB fleet will also necessitate training and new skills across many departments.

The staffing model is informed by RIPTA's current staffing profile and draws on the experience of other transit agencies nationally who have conducted or planned for transitions to BEB or HFCB fleets. This includes national research from the Transit Cooperative Research Program (TCRP), U.S. Department of Energy, National Center for Sustainable Transportation, and Center for Transportation and the Environment; and agency examples including Alameda Contra-Costa Transit, New York Metropolitan Transportation Authority, Charlotte Area Transit System, San Diego Metropolitan Transit System, and Foothill Transit. It also relies on information gathered from press releases and safety training materials.

Figure 7 Staffing Model



Existing and future staff were divided into five departments: transportation operators, maintenance, administration, safety, and training. To arrive at staffing projections, the study team developed a spreadsheet model to forecast the impacts of vehicle technology change. The model takes, as inputs, the current staffing levels and costs by department, and a forecast of fleet composition scenarios and growth factor scenarios (Figure 7). These scenarios show how the agency grows over time as measured by fleet size, vehicle revenue hours, vehicle revenue miles, bus maintenance facilities, and the share of vehicles that are using diesel, battery-electric, or hydrogen propulsion. For each RIPTA department, drivers of change are assigned to denote how staffing within that department would need to change as the agency grows or changes its mix of vehicle propulsion technologies. These are all combined in a department-level forecast of staffing levels and costs over a 20-year period. See the *Action Plan for Electrification and Service Growth: Staffing Growth and Financial Projections Technical Memorandum* for more details.

3.4 Total Cost of Ownership

The total cost of ownership for converting RIPTA's current fleet and new bus purchases are based on the fleet requirements for Scenarios 1 through 6 using Autonomie modeling results. The TMP was used to develop a growth strategy to estimate how many buses would be needed to meet the master plan's goals over a 20-year time horizon and the associated energy requirements. Considering the TMP timeline from 2020 to 2040 would be complicated for RIPTA to follow precisely, and that 2 years have already passed, the analysis established a new timeline incorporating the guidelines from the TMP, from fiscal year (FY) 2023 through 2042:

- Baseline fleet growth under TMP implementation follows the service development schedule provided by RIPTA. Year by year, route-level bus procurement reflects an estimated increase in buses needed based on the current fleet and future blocking under TMP implementation. The existing fleet is included in the buses needed under each scenario.

- For Scenarios 2 through 6, buses needed by route were modeled in Autonomie to generate the total number of vehicles required to achieve service growth according to the TMP. The procurement schedule beyond replacement of the existing fleet was distributed over the 20-year timeline to match or exceed fleet growth in Scenario 1 “Baseline” so that adequate service can be provided during the transition.

RIPTA provided the active fleet inventory on August 17, 2022, which contained information on the vehicles including fuel type, model year, purchase date, useful life, purchase price, and replacement date. It is understood that it was a snapshot in time, as the fleet is constantly changing. Therefore, the fleet numbers are best treated as approximations to represent the fleet composition. Costs were calculated using 2022 dollars and scaled up to year of expenditure (YOE) using a 3 percent inflation rate.

This analysis considers capital costs, O&M costs, and mid-life overhaul costs. For the baseline, O&M costs are assumed to be constant over time. The capital costs include initial bus purchase, battery, chargers, charger installation, charger replacement at the end of useful life, and bus refurbishment halfway through the useful life.

It’s assumed that the cost of hybrid and BEBs decreases by 2 percent each year from 2025 to 2050. The cost of electricity is estimated to increase by two and six-tenths of a percent per year, consistent with regional trends. HFCBs and their fuel are assumed to decrease in cost by 3 percent each year over the same time horizon.

The analysis excludes major infrastructure upgrades, including trenching, substation improvements, and hydrogen facility construction. All scenarios assume the fuel needs (diesel, electricity, and hydrogen) are readily available. Scenarios 4, 5, and 6, therefore, assume that the hydrogen is delivered and excludes the cost of hydrogen storage needs, whether onsite or offsite.

The analysis assumes the fleet size will grow over time as described in the TMP for all scenarios (only fixed routes); flex and paratransit vehicles will be included in later analyses.

Scenario-specific cost assumptions are detailed in subsequent sections of the report; for additional detail on cost modeling assumptions, see the *Action Plan for Electrification and Service Growth: Financial Projections for Vehicle Replacement and Fleet Growth Technical Memorandum*.

3.5 Emissions Analysis

GHG emissions – including carbon dioxide, methane, and nitrous oxide – and criteria pollutants that affect local air quality were analyzed to determine each scenario’s impact on emissions over time.

The main resource used to obtain data for this analysis was the Greenhouse gases, Regulated Emissions, and Energy use in Technologies (GREET) model.[6] This model was developed by Argonne National Laboratory to simulate lifecycle energy use and emissions for different vehicles and fuels. The GREET Model allows users to select how certain fuels are created or extracted; the model offers a well-to-pump analysis for many fuel types, and a well-to-wheel analysis for certain fuel/vehicle combinations.

This analysis distinguishes between on-road emissions and total emissions to characterize each scenario’s environmental impact. On-road emissions represent the emissions coming directly out of the tailpipe while the vehicle is operating; vehicles using electricity or hydrogen to operate do not generate tailpipe emissions and are therefore referred to as ‘zero emission vehicles.’ Total emissions, however, include tailpipe emissions and the well-to-pump emissions that can come from extraction of a fuel, generation of a fuel, combustion of fuels to generate energy, and so on.

Scenario fleet size, mileage, and fuel requirements are based on the assumptions used in the financial analysis from Autonomie. For additional detail on emissions analysis methodology, assumptions, and total

[6] Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model, Argonne National Laboratory, 2022, https://greet.es.anl.gov/.

emissions, see the *Action Plan for Electrification and Service Growth: Financial Projections for Vehicle Replacement and Fleet Growth Technical Memorandum*.

4. Scenarios

Each scenario modeled assumes a different fleet composition, varying in propulsion type and size, to meet RIPTA's TMP goals by 2042 (Table 6).

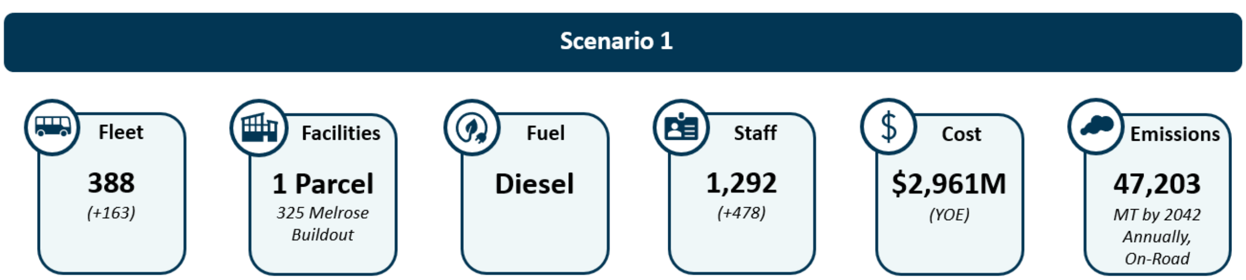
Table 6 Overview of Scenarios

Scenario	Description	Fleet	New Facilities	Staffing	YOE Cost (millions)	On-Road Annual Emissions by 2042 (MT)[7]
1	Baseline (Diesel)	388	1	1,292	$2,961	47,203
1A	Hybrid	388	1	1,292	$3,291	32,716
2	BEB Depot Charging	668	2	1,481	$4,209	0
3	BEB On-Route Charging	418	1	1,372	$3,480	0
4	100% HFCB	389	1	1,313	$3,150	0
5	94% BEB, 6% HFCB	394	1	1,395	$3,448	0
6	71% BEB, 29% HFCB	379	1	1,332	$3,264	0

4.1 Scenario 1

Scenario 1, "Baseline," assumes RIPTA's existing active fleet of 225 buses grows with the implementation of the TMP, but no decarbonization takes place. Scenario 1 is the lowest cost option for achieving *Transit Forward RI 2040* goals (Figure 8).

Figure 8 Scenario 1 Overview



4.1.1 Fleet

TMP implementation using diesel vehicles would require 337 vehicles to be operated in maximum service; with spares the fleet size would be 388. This is an increase of 163 vehicles to meet TMP service levels. Eighty-five percent of blocks would be operated from the Providence Campus and 15 percent from the Newport Campus. These figures do not include flex routes or demand response zones.

[7] On-road emissions are less than total emissions, which include well-to-pump emissions. Though the transition to a 100% ZEB fleet results in no on-road emissions, these fleets still contribute to upstream emissions. Although RIPTA is not responsible for these emissions, implementing various policies could ensure the minimization of total emissions, such as ensuring electricity and hydrogen are produced by renewable sources and selecting fuel providers that are local to the region rather than importing fuels in.

4.1.2 Facilities

In this scenario, 163 new vehicles are phased into RIPTA's fleet over time. Fleet growth necessitates increased maintenance operations and additional storage infrastructure for vehicles. The most expedient locations for expansion are on parcels of land already owned by RIPTA or other state agencies. Specifically, the parcel at 325 Melrose Street in Providence, formerly used by the Department of Motor Vehicles (DMV) as a Road Test Site (Figure 9), and unused for the last few years, offers potential to support RIPTA's fleet growth.

325 Melrose Street is in an advantageous location, as RIPTA owns property surrounding the parcel and currently stores buses in the vicinity. Since the DMV no longer utilizes the site, RIPTA could remove the existing building and use the entirety of the parcel for vehicle storage. The approximately 4.3-acre site could accommodate 285 additional buses parked nose to tail at grade level, far exceeding the fleet growth in Scenario 1.

Figure 9 325 Melrose Street Parcel

4.1.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,292 employees by 2042. The increased service in the TMP results in the fleet size growing from 225 to 388 vehicles, driving growth in staffing needs across several departments. Transportation is the area of largest growth, with an increase of about 333 operators between 2022 and 2042. Maintenance staff needs grow by 69 additional staff during this time. Other areas of significant growth are paratransit (+21 staff), street supervision (+16), and customer service (+10). In total, staffing in Scenario 1 grows from 814 in 2022 to 1,292 in 2042.

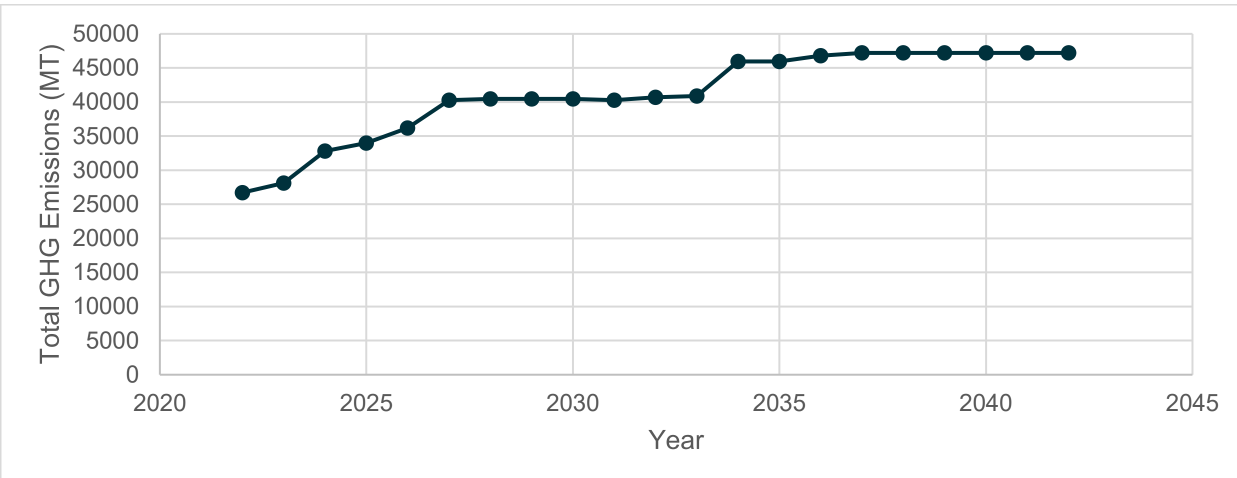
4.1.4 Cost

Under Scenario 1, ICE buses are purchased to replace the existing fleet and expand the service to meet the needs of the TMP, totaling $2,961 million (YOE) 2023-2042.

- Fleet costs total $1,387 million (YOE) for 2023-2042. Of this total, $802 million is associated with capital costs due to fleet growth, $246 million is associated with fuel costs, and $339 million is associated with maintenance.
- Building out 325 Melrose Street to include enough capacity for the additional fleet growth and parking for employees would cost $26 million (YOE).
- Workforce growth adds $1,549 million (YOE) from 2023 to 2042 in addition to current staffing.

Scenario 1 is the least costly method for achieving TMP service expansion but does not address RIPTA's long-term sustainability goals (Figure 10). Because no decarbonization takes place, it achieves the least reduction in GHGs across all scenarios. On-road emissions grow corresponding to ICE vehicle fleet expansion, reaching an apex of approximately 47,000 metric tons per year in 2042.

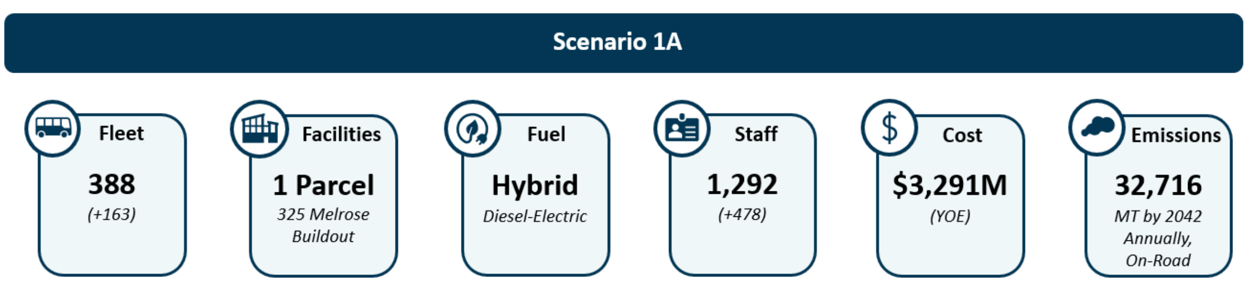
Figure 10 Scenario 1 On-Road GHG Emissions per Year (2023–2042)



4.2 Scenario 1A

Scenario 1A assumes RIPTA's existing active fleet of 225 buses grows with the implementation of the TMP, gradually phasing in diesel-electric hybrid buses as the existing fleet's vehicles reach the end of their useful life (Figure 11).

Figure 11 Scenario 1A Overview



4.2.1 Fleet

TMP implementation using diesel vehicles would require 337 vehicles to be operated in maximum service;[8] with spares, the fleet size would be 388. This is an increase of 163 vehicles to meet TMP service levels, the same increase as the baseline scenario.

[8] This does not include flex routes or demand response zones.

4.2.2 Facilities

In this scenario, 163 new vehicles are phased into RIPTA's fleet over time. As with the baseline scenario, the former DMV Road Test Site, 325 Melrose Street, is an ideal candidate for buildout, as it is owned by RIPTA, abuts parcels hosting current operations, and has adequate space to store and maintain the additional vehicles.

4.2.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,292 employees by 2042, the same quantity as the baseline scenario. Roles experiencing substantial growth as a result of service expansion include vehicle operators and maintenance staff. In total, staffing in Scenario 1A grows from 814 in 2022 to 1,292 in 2042.

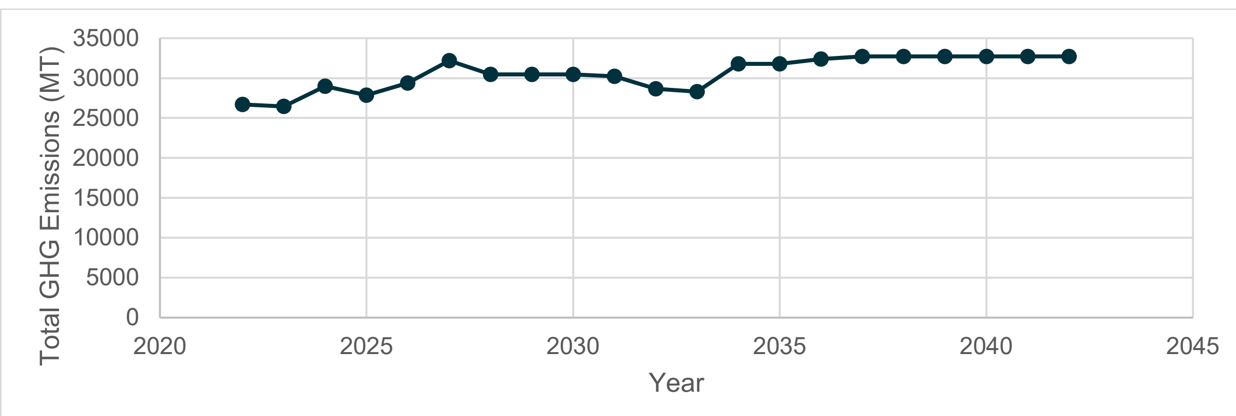
4.2.4 Cost

In Scenario 1A hybrid buses are purchased to replace the existing fleet and expand the service to meet the needs of the TMP, totaling $3,291 million (YOE) 2023-2042.

- Fleet costs total $1,717 million (YOE) for 2023-2042. Of this total, $878 million is associated with capital costs due to fleet growth, $202 million is associated with fuel costs, and $637 million is associated with maintenance.
- Building out 325 Melrose Street to include enough capacity for the additional fleet growth and parking for employees would cost $26 million (YOE).
- Workforce growth accounts for $1,549 million (YOE) in additional spending from 2023 to 2042, on top of current staffing levels.

Scenario 1A is a low-cost option for achieving TMP service expansion goals while achieving some level of emission reduction. Because Scenario 1A assumes the adoption of hybrid vehicles rather than BEBs or HFCBs, it achieves the second least reduction in GHGs across all scenarios, behind Scenario 1. By 2042, annual on-road emissions reach almost 33,000 metric tons, about 30 percent less than Scenario 1 (Figure 12).

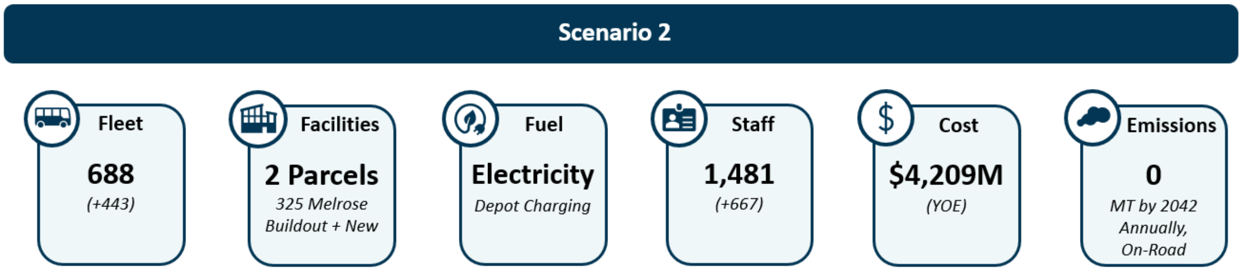
Figure 12 Scenario 1A On-Road GHG Emissions per Year (2023–2042)



4.3 Scenario 2

Scenario 2, "BEB Depot Only," assumes BEBs are purchased to replace the existing fleet at the end of the bus's useful life, to improve existing services and expand services to new areas according to the strategy laid out in the TMP (Figure 13). Scenario 2 does not include on-route charging. Finally, there is an interim goal to end all diesel purchases starting with FY 2027 for the existing fleet; for new routes or to expand existing services. BEBs will be purchased starting in FY 2023.

Figure 13 Scenario 2 Overview



4.3.1 Fleet

For Scenario 2 in which BEBs are utilized without on-route charging, 668 vehicles would be needed (Table 7). This is an increase of 443 vehicles to meet TMP service levels with depot-only charging for a complete BEB fleet.

It is assumed that vehicles assigned to AM peak only blocks would be able to fully charge mid-day and be placed in service on PM peak only blocks.[9] While the AM peak has more blocks than the PM, more vehicles are needed to operate the PM peak because the blocks are longer, and some require a 2:1 replacement. Eighty-two percent of blocks would be operated from the Providence Campus and 18 percent from the Newport Campus.

Table 7 Scenario 2 Blocks

Replacement	All Day Blocks	AM Peak Only Blocks	PM Peak Only Blocks	Total
1:1	19	67	44	130
2:2	202	0	18	220
3:1	37	0	0	37
4:1	12	0	0	21
Total Blocks	270	67	62	399
Total Vehicles Needed	582	67	80	668

4.3.2 Facilities

In this scenario, 443 new vehicles will be phased into RIPTA's active fleet over time, totaling 668 vehicles in full. The DMV's former Road Test Site at 325 Melrose Street can be reconfigured to accommodate 285 new vehicles, regardless of fueling type, at grade level. If the totality of the ground floor is used to store and charge buses, an overhead parking structure would need to be built to accommodate employee parking. By designing the parking deck to support bus charging, additional BEBs could be stored on the site. Adding a parking deck for staff parking and bus storage/charging could bring the total storage capacity of the Providence Campus up to 450 to 500 buses.

Because there is a 168 to 218 bus discrepancy between fleet size and storage capacity in Scenario 2, RIPTA would need to look at other sites to meet its needs.

4.3.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,481 employees by 2042. The conversion to a BEB fleet with no on-route charging requires a significantly larger fleet size than the other scenarios, driving growth in staffing needs across several departments. The most significant area of growth is in the

[9] This does not account for additional deadhead time/miles to replace vehicles or the possibility of additional capacity existing for mid-day depot charging. It is feasible that early morning vehicles assigned to all day routes could return to the garage to charge and be placed back in service on the route in the evening, thus reducing the number of unique vehicles needed to operate the block.

Transportation department, with 333 additional operators needed, and the Maintenance department, with an increase of about 229 staff between 2022 and 2042, compared to current levels. Other areas of significant growth are paratransit (+21 staff), street supervision (+16), training (+18), and customer service (+10). In total, staffing in Scenario 2 grows from 814 in 2022 to 1,481 in 2042.

4.3.4 Cost

In Scenario 2, BEBs are purchased to replace the existing fleet and meet TMP service growth goals. The cost of Scenario 2 is $4,209 million (YOE) 2023-2042.

Fleet costs total $2,038 million (YOE) for 2023-2042. Of this total, $1,698 million is associated with capital costs due to fleet growth, $155 million is associated with fuel costs, and $186 million is associated with maintenance.

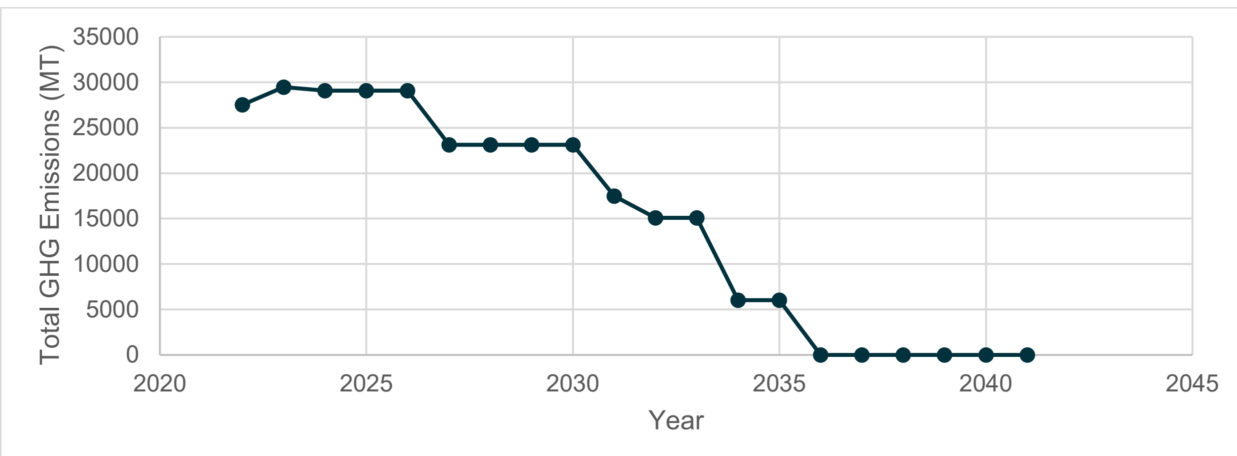
Additional, facilities-related costs in this scenario total $312 million (YOE) over the 20-year time horizon. Among these facilities upgrades are:

- Building out 325 Melrose Street to include BEB charging infrastructure and a parking deck for employees
- Acquiring a new parcel to store and charge additional buses
- Retrofitting 269 Melrose Street, 265 Melrose Street, 750 Elmwood Avenue, and 350 Coddington Highway for BEB infrastructure

Staffing costs account for $1,859 million (YOE), as RIPTA must hire 667 new employees between 2023 and 2042.

Though the cost of Scenario 2 is the highest, it results in zero annual on-road GHGs emissions due to TMP implementation (Figure 14).

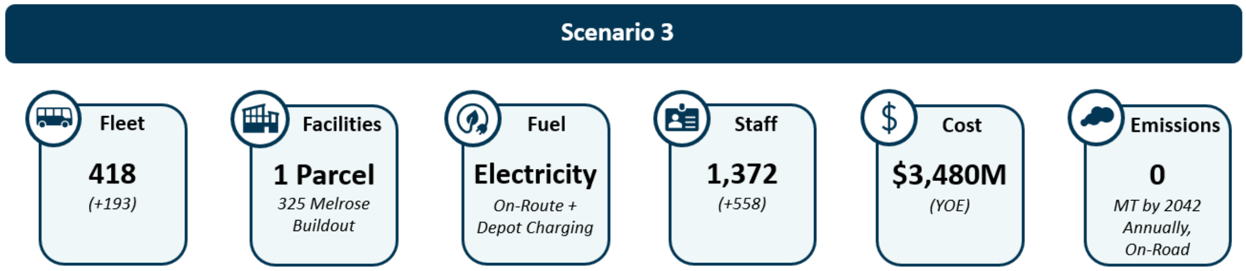
Figure 14 Scenario 2 On-Road GHG Emissions per Year (2023–2042)



4.4 Scenario 3

Scenario 3, “BEB Depot & On-Route,” assumes BEBs are purchased to replace the existing fleet at the end of the bus’s useful life, to improve existing services and expand services to new areas according to the strategy laid out in the TMP (Figure 15). This scenario considers on-route charging that allows a bus to be charged throughout the service day away from the depot. With on-route charging, fewer buses are needed to accommodate the service under Scenario 3 than Scenario 2 because the range of a vehicle is effectively extended.

Figure 15 Scenario 3 Overview

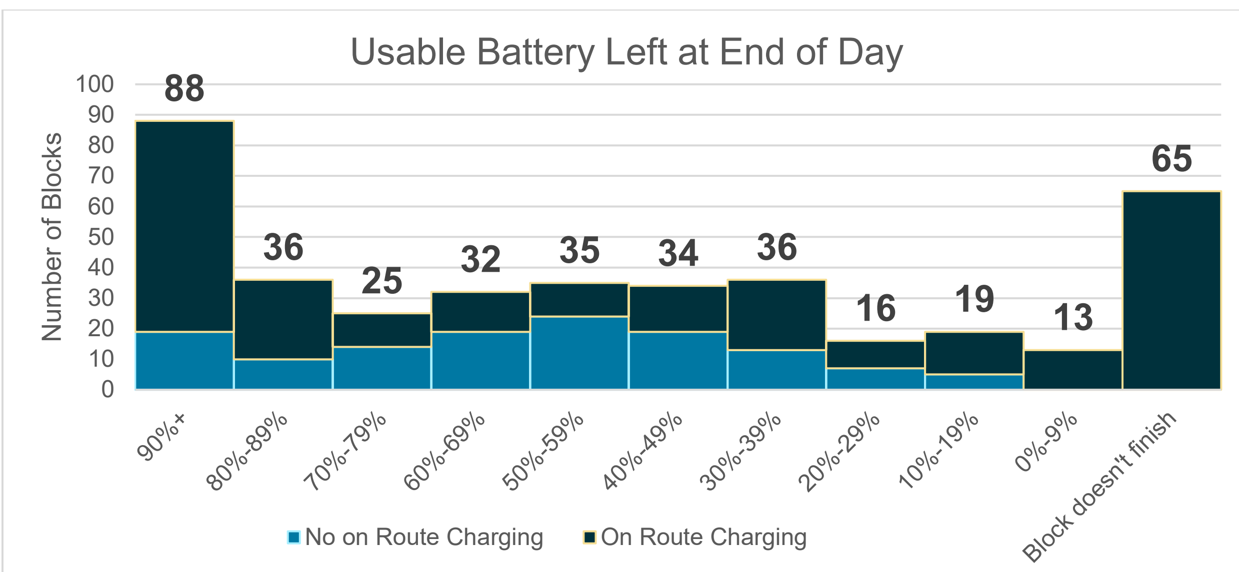


4.4.1 Fleet

At TMP service levels, a total of 418 buses would be needed; this is an increase of 193 buses. There are 130 blocks that do not require on-route charging because the range on BEBs is sufficient with depot-only charging. An additional 204 blocks could be served by a 1:1 replacement utilizing strategic on-route charging locations. However, 65 blocks would need a 2:1 or greater replacement. Seventy-eight percent of blocks would be operated from the Providence Campus and 22 percent from the Newport Campus.

Sixty-four percent of blocks with on-route charging would have 50 percent or greater usable battery capacity left at the end of the day, thus have more operational flexibility if charging opportunities are missed (Table 8). Thirteen percent would have less than 20 percent of usable battery left; missing on-route charging opportunities could result in them being unable to complete the schedule without being replaced mid-trip.

Table 8 Usable Battery Remaining with On-Route Charging

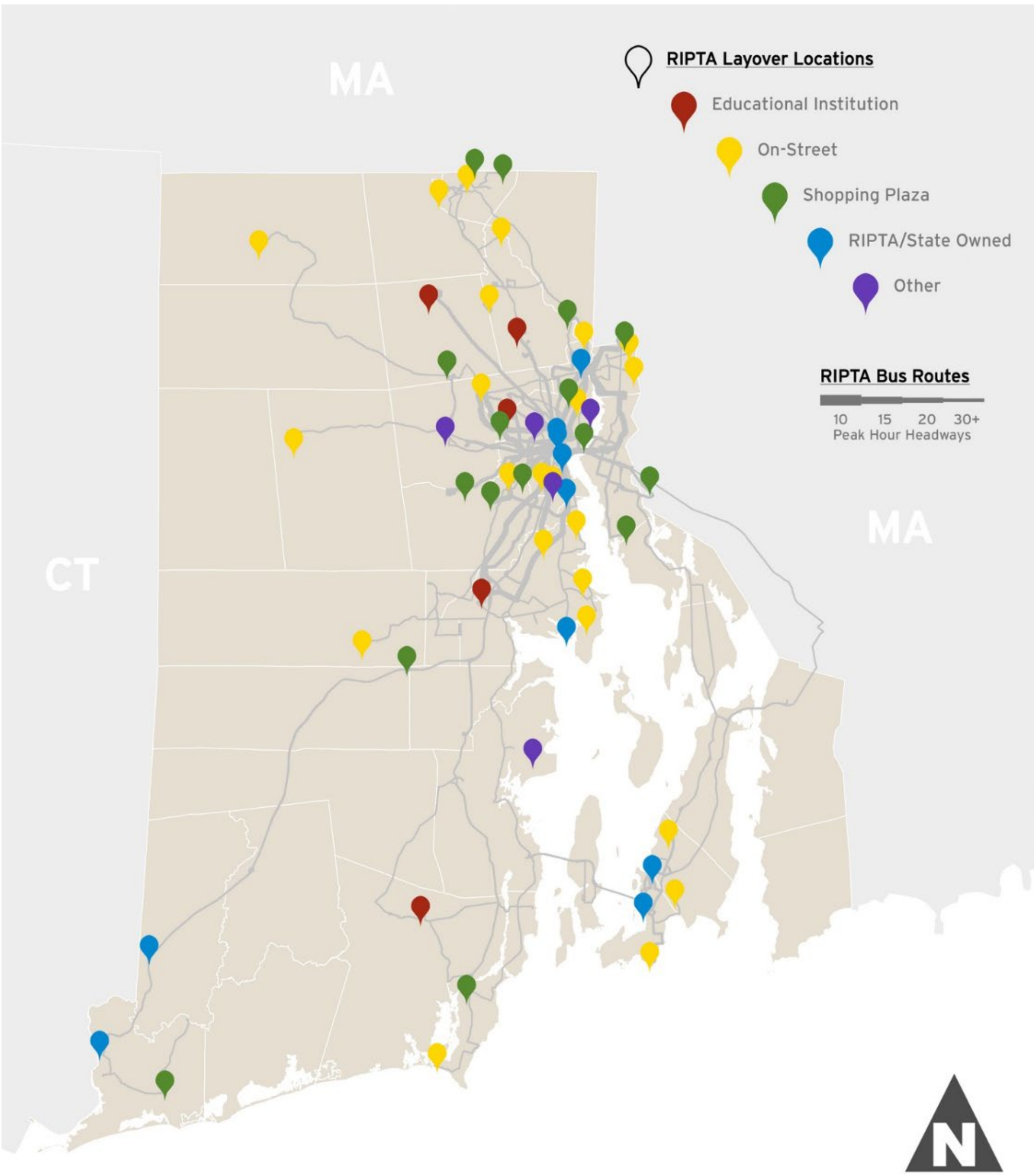


4.4.2 Facilities

In this scenario, 193 new buses will be phased into RIPTA's active fleet over time, totaling 418 vehicles to provide expanded service under the TMP. If reconfigured to maximize bus storage, fleet growth can be accommodated at RIPTA's Providence Campus, at 325 Melrose Street. Unlike Scenario 2, the addition of approximately 200 vehicles does not require RIPTA to look at external parcels to meet the storage and depot charging demand.

Fewer buses are needed to rollout TMP service because Scenario 3 incorporates charging at strategic locations (Figure 16). Charging would occur during revenue service when the bus is at a layover point or at a bus stop. Charging the bus while it is in service extends the range of the vehicle while reducing deadhead time and mileage. To effectively charge a bus in 5 to 15 minutes, a fast charger is required, which provides more power in a short time frame. While it provides more flexibility for service design, the capital costs are more significant than garage charging, particularly as when adding chargers at different geographic locations, and the operating costs can be much higher due to the higher power demands of fast charging and power draw during peak demand times. Most of these chargers would be needed in downtown Providence, while others would need to be at the terminus of the routes they serve.

Figure 16 Possible On-Route Charging Locations



4.4.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,372 employees by 2042. The conversion to a BEB fleet with both depot and on-route charging results in growth in several areas, albeit at a slower rate than in Scenario 2 due to reduced fleet size needs. Transportation staff needs increase by about 333 staff between 2022 and 2042, while about 133 additional staff are needed in the Maintenance department. Other departments with double-digit staffing growth needs over this time horizon are paratransit (+21 staff), street supervision (+16), training (+18), and customer service (+10). In total, staffing in Scenario 3 grows from 814 in 2022 to 1,372 in 2042.

4.4.4 Cost

Under Scenario 3, ICE buses will need to be purchased in FY 2023 to FY 2025. By 2037, the fleet will be fully electrified. At that point, the remaining bus purchases will be electric, increasing the fleet size up to 418 in the horizon year; this is approximately two-thirds of the BEBs needed for TMP implementation in Scenario 2. On-route charging optimizes asset utilization, which requires fewer BEBs to provide the same transit operations. A total of 43 on-route chargers will be purchased to ensure optimal operations: three chargers per year are estimated to be installed from FY 2023 to FY 2036 and one charger in FY 2037. Scenario 3 total fleet costs is $1,606 million (YOE) for 2023-2042. Of this total, $1,241 million is associated with capital costs due to fleet growth, $167 million is associated with fuel costs, and $198 million is associated with maintenance.

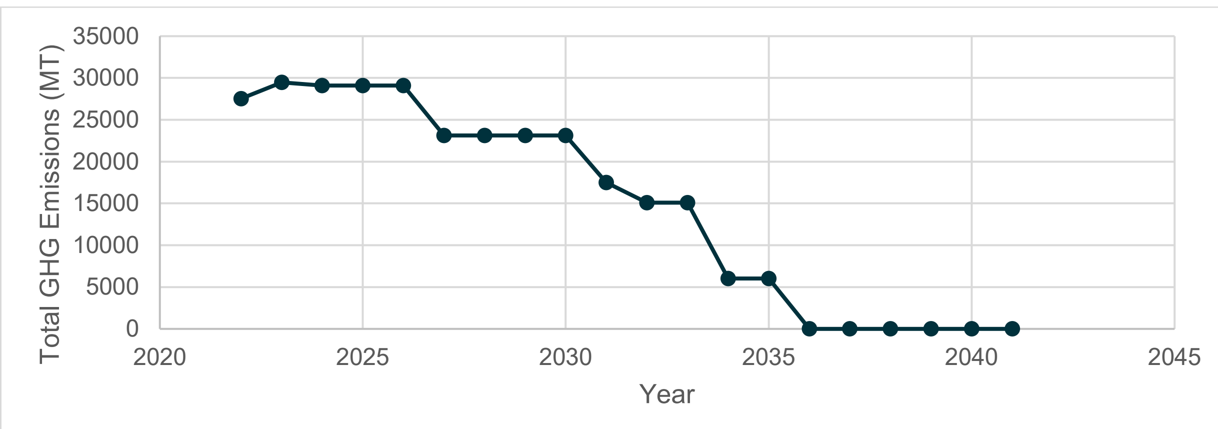
Additional, facilities-related costs in this scenario total $193 million. Among these facilities upgrades are:

- Building out 325 Melrose Street to provide capacity for fleet growth, including BEB charging infrastructure, and a parking deck for employees
- Retrofitting 269 Melrose Street, 265 Melrose Street, 750 Elmwood Avenue, and 350 Coddington Highway for BEB infrastructure

Staffing costs account for $1,681 million (YOE), as RIPTA must hire 558 new employees between 2023 and 2042.

The total cost for Scenario 3 is $3,480 million (YOE) over the 20-year period. It is less costly than Scenario 2 while achieving the same annual on-road GHG emission levels by 2042 (Figure 17).

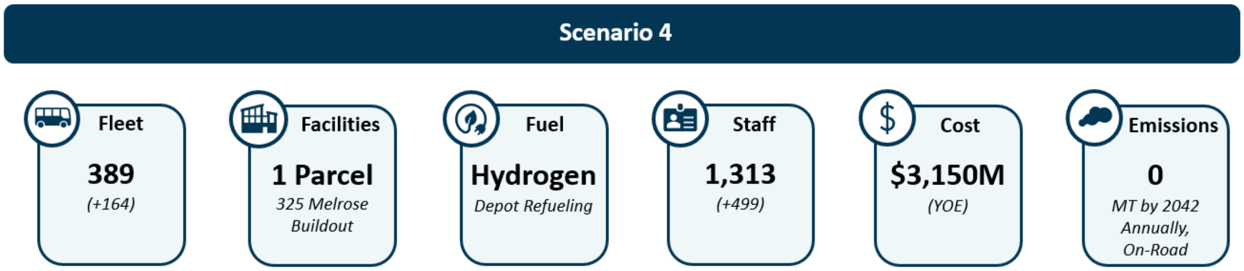
Figure 17 Scenario 3 On-Road GHG Emissions per Year (2023–2042)



4.5 Scenario 4

Scenario 4, "HFCB," assumes HFCBs are purchased to replace the existing fleet as vehicles age out beginning in FY 2023, improve existing services, and expand services to new areas according to the strategy laid out in the TMP (Figure 18). There is an interim goal to end all diesel purchases starting with FY 2027 for the existing fleet. However, this scenario excludes costs associated with hydrogen storage/fueling infrastructure.

Figure 18 Scenario 4 Overview



4.5.1 Fleet

For a scenario in which 100 percent HFCBs are utilized, 389 vehicles would be needed to grow service as outlined in RIPTA's TMP, an increase of 164 buses compared to current vehicle levels. HFCBs have a greater range than BEBs, thus Scenario 4 requires fewer vehicles than Scenarios 2 or 3, approximately totaling the number needed in an ICE-only scenario. Of these vehicles, 82 percent would be operated out of the Providence Campus and 18 percent out of RIPTA's Newport facility.

4.5.2 Facilities

In a 100 percent HFCB scenario, RIPTA's fleet grows by 164 buses to implement TMP service levels. Because 325 Melrose Street – the former DMV Road Test Site – can be maximized to accommodate up to 285 vehicles on the ground level, RIPTA does not need to acquire parcels outside of their existing Providence Campus.

4.5.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,313 employees by 2042. With a transition to 100 percent HFCBs, Scenario 4 has the somewhat lower fleet size requirements than Scenario 3. This scenario also requires fewer electricians than the BEB-dominant scenarios. Transportation department staff needs increase by about 333 staff between 2022 and 2042, while Maintenance department staff needs increase by 74 staff compared to existing conditions. Total staffing in Scenario 4 increases from 814 staff in 2022 to 1,313 in 2042.

4.5.4 Cost

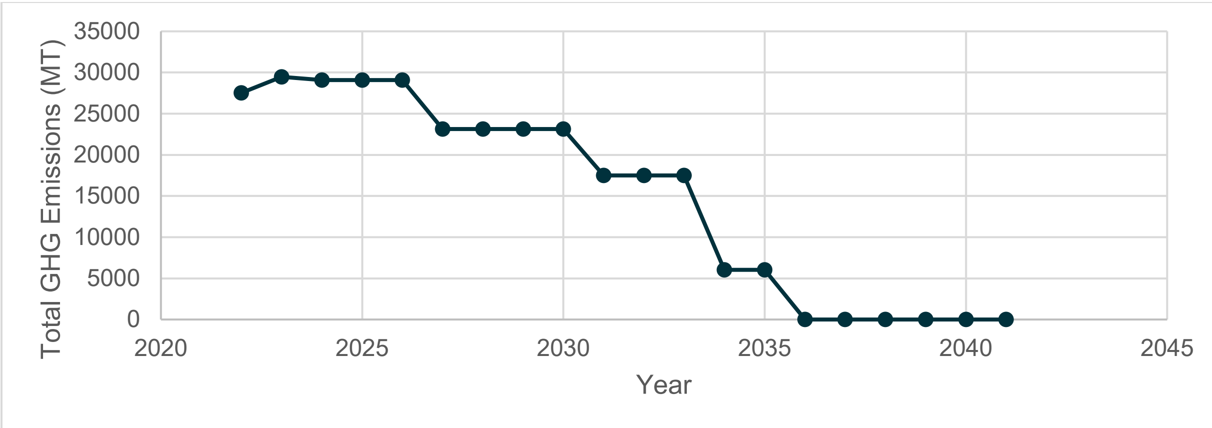
Under Scenario 4, ICE buses will need to be purchased in FY 2023 to FY 2025. By FY 2037, the fleet will have fully transitioned to HFCBs. By FY 2042, the fleet will reach its maximum size of 389 buses. Scenario 4's fleet-related total costs are $1,499 million (YOE) for FY 2023-FY 2042—less than Scenarios 2 and 3. Of this total, $1,005 million is associated with capital costs due to fleet growth, $240 million is associated with fuel costs, and $255 million is associated with maintenance.

Facilities improvements needed to store and maintain the additional fleet growth total $79 million (YOE), including building out 325 Melrose Street to include ground level storage of HFCBs and a parking deck for employees, as well as retrofitting 269 Melrose Street for hydrogen infrastructure.

Growing RIPTA's staff by nearly 500 employees will cost $1,571 million (YOE) between 2023 and 2042.

Scenario 4 totals $3,150 million (YOE) for TMP implementation and decarbonization. It is the least costly ZEB scenario, due in part to the financial modeling's exclusion of the costs associated with storing and delivering hydrogen. Scenario 4 results in zero annual on-road GHG emissions by 2042 (Figure 19).

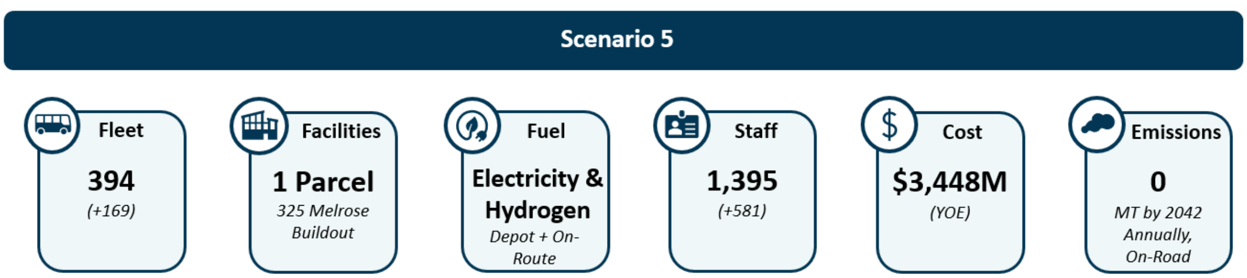
Figure 19 Scenario 4 On-Road GHG Emissions per Year (2023–2042)



4.6 Scenario 5

Scenario 5, "BEB/Lower HFCB Combination," assumes a combination of BEB and HFCBs are purchased to replace the existing fleet at the end of the useful life, improve existing services, and expand services to new areas (Figure 20). This scenario includes on-route charging. HFCBs are used for longer blocks to avoid purchasing multiple BEBs to serve the same route(s). Finally, there is an interim goal to end all diesel purchases starting with FY 2027 for the existing fleet; for new routes or to expand existing services. BEBs will be purchased starting in FY 2023.

Figure 20 Scenario 5 Overview



4.6.1 Fleet

For a scenario in which a combination of BEBs (94 percent) and HFCBs (6 percent) is utilized with on-route charging, 394 vehicles would be needed. Vehicles that could not be replaced 1:1 with either HFCB or BEB would be replaced with BEB vehicles. If on-route chargers were implemented and a combination of BEB and HFCB were used, 334 blocks could be replaced with a 1:1 BEB and an additional 24 with 1:1 HFCB (Table 9). This leaves 42 blocks that would require a 2:1 replacement or greater, requiring 99 BEBs. Table 9 outlines the blocks and vehicle requirements by fuel type. Two percent of HFCBs and 78 percent of BEBs would be operated out of RIPTA's Providence Campus and the remaining buses would operate out of the Newport facility.

Table 9 Scenario 5 Block Vehicle Replacement Needs

Replacement	BEB Blocks	HFCB Blocks	Total Blocks
1:1	334	24	357
2:1	42	0	42
Total Blocks	376	24	399
Total Vehicles Needed	377	17	394

4.6.2 Facilities

In Scenario 5, RIPTA's active fleet requires 394 vehicles to implement TMP service levels, adding 169 buses to the current fleet. These buses can be accommodated on RIPTA's Providence Campus, using 325 Melrose Street as a new storage and charging facility. On-route charging at 39 locations is needed to support select BEBs in this scenario.

4.6.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,395 employees by 2042. The conversion to BEBs for most vehicles complemented with HFCBs to support a small share of longer routes has a smaller overall fleet size requirement than the baseline (Scenario 1). Transportation staff needs increase by about 333 staff between 2022 and 2042, and about 156 additional maintenance staff are needed in this scenario. Other departments with double-digit staffing growth needs over this 20-year period are paratransit (+21), street supervision (+16), training (+18), and customer service (+10). Total staffing in Scenario 5 grows from 814 staff in 2022 to 1,395 in 2042.

4.6.4 Cost

Under Scenario 5, a combination of BEBs and HFCBs will be purchased to meet TMP goals. ICE buses will need to be purchased in FY 2023 to FY2025. By FY 2037, the existing fleet will have transitioned to ZEBs and by FY 2042, the fleet will reach its maximum size of 394. On-route charging optimizes asset utilization, requiring fewer BEBs to meet the service growth projections; a total of 39 on-route chargers are needed in this scenario. HFCBs also reduce the need for additional BEBs on blocks longer than the BEBs range.

Fleet-related costs total $1,525 million (YOE) between 2023 and 2042. Of this total, $1,157 million is associated with capital costs, $169 million is associated with fuel costs, and $199 million is associated with maintenance.

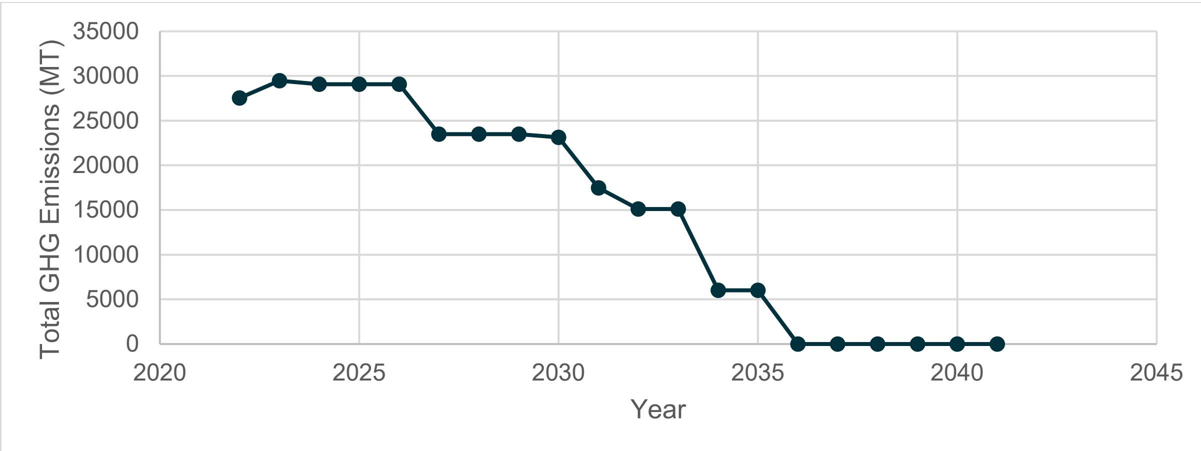
Facilities-related costs total $202 million, including:

- Building out 325 Melrose Street to include BEB charging infrastructure and a parking deck for employees
- Retrofitting 269 Melrose Street, 265 Melrose Street, 750 Elmwood Avenue, and 350 Coddington Highway for ZEB infrastructure

Staffing increases needed to facilitate fleet growth and the transition to ZEBs total $1,721 million (YOE) between 2023 and 2042.

Scenario 5 totals $3,448 million (YOE) for the 20-year time horizon. By 2042, Scenario 5 results in zero annual on-road GHG emissions (Figure 21).

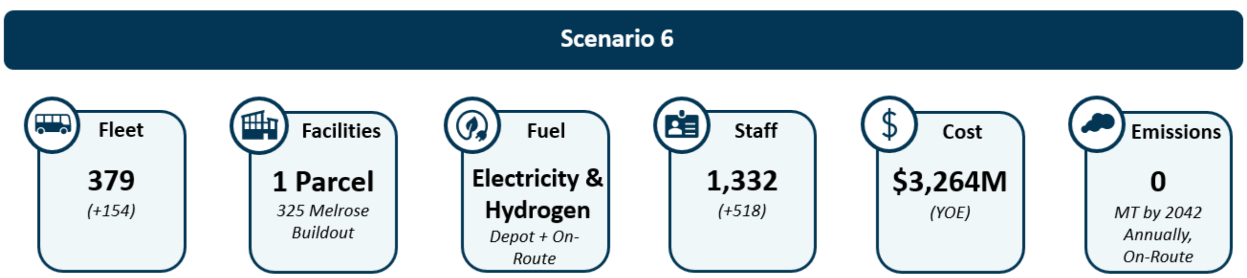
Figure 21 Scenario 5 On-Road GHG Emissions per Year (2023–2042)



4.7 Scenario 6

Scenario 6, "BEB/Higher HFCB Combination," assumes a combination of BEB and HFCBs are purchased to replace the existing fleet at the end of the useful life, improve existing services and expand services to new areas (Figure 22). This scenario includes on-route charging; however, there is a higher proportion of HFCBs compared to Scenario 5. HFCBs are used for longer blocks in order to avoid purchasing multiple BEBs to serve the same route(s). Finally, there is an interim goal to end all diesel purchases starting with FY 2027 for the existing fleet; for new routes or to expand existing services. BEBs will be purchased starting in FY 2023.

Figure 22 Scenario 6 Overview



4.7.1 Fleet

Scenario 6 examines a combination of BEBs (71 percent) and HFCBs (29 percent), with on-route charging. Vehicles that could not be replaced 1:1 with BEB would be replaced with HFCB vehicles. If on-route chargers were implemented and a combination of BEBs and HFCBs was used, 334 blocks could be replaced with a 1:1 BEB and an additional 23 with 1:1 HFCB. This leaves 42 blocks that would require a 2:1 replacement or greater, utilizing 84 HFCBs. Table 10 outlines the blocks and vehicle requirements by fuel type. Fourteen percent of HFCBs and 68 percent of BEBs would be operated out of RIPTA's Providence Campus and the remaining buses would operate out of the Newport facility.

Table 10 Scenario 6 Block Vehicle Replacement Needs

Replacement	BEB Blocks	HFCB Blocks	Total Blocks
1:1	334	23	357
2:1	0	42	42
Total Blocks	334	65	399
Total Vehicles Needed	278	101	379

4.7.2 Facilities

Scenario 6 differs from Scenario 5 in that fewer total vehicles are needed to meet TMP service levels because there is a higher proportion of HFCBs in the fleet mix. As such, Scenario 6 only requires RIPTA's current fleet to grow by 154 buses. RIPTA's Providence Campus has the capacity to store and charge the additional vehicles at 325 Melrose Street, without needing to acquire additional parcels. However, 29 on-route chargers would need to be installed along select routes to charge BEBs.

4.7.3 Staffing

Expanding service to align with RIPTA's TMP goals will require 1,332 employees by 2042. Scenario 6 is similar to Scenario 5 except with a higher share of the fleet being hydrogen fuel cell buses, resulting in a somewhat lower fleet size need. Transportation staff needs increase by about 333 staff between 2022 and 2042, and about 93 additional maintenance staff are needed in this scenario. Other departments with double-digit staffing growth needs over this 20-year period are paratransit (+21), street supervision (+16), training (+18), and customer service (+10). Total staffing in Scenario 6 grows from 814 staff in 2022 to 1,332 in 2042.

4.7.4 Cost

Under Scenario 6, a combination of BEBs and HFCBs will be purchased to meet TMP goals. ICE buses will need to be purchased in FY 2023 to FY 2025. By FY 2037, the existing fleet will have transitioned to ZEB and by FY 2042, the fleet will reach its final size of 379 vehicles. This scenario requires 15 fewer buses and 10 fewer on-route chargers than Scenario 5, making the total fleet-related costs $1,458 million (YOE) for 2023 to 2042. The $67 million difference in fleet costs between Scenarios 5 and 6 is because fleet size primarily drives cost in the absence of the cost of hydrogen infrastructure. Of the fleet-related total, $1,066 million is associated with capital costs, $183 million is associated with fuel costs, and $209 million is associated with maintenance.

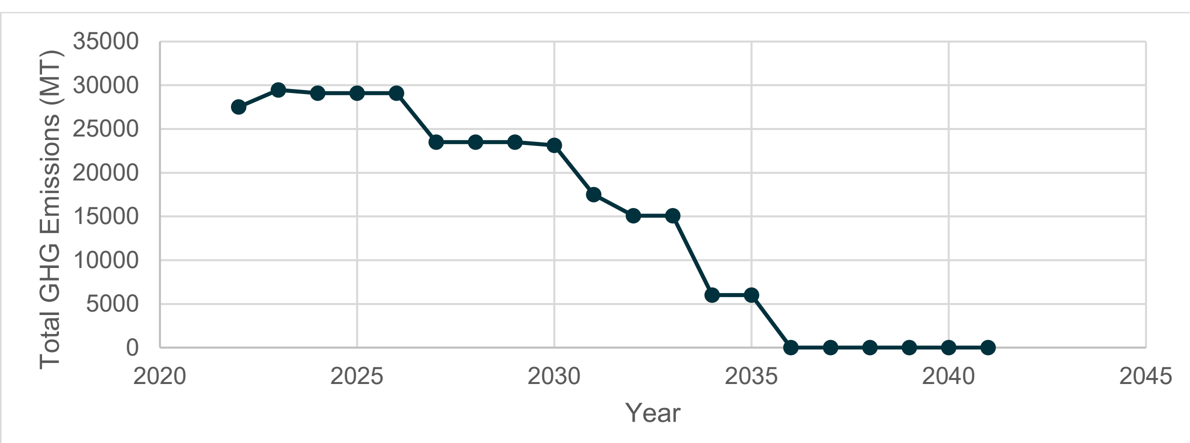
Facilities-related costs total $188 million (YOE) for Scenario 6, including:

- Building out 325 Melrose Street to include BEB charging infrastructure and a parking deck for employees
- Retrofitting 269 Melrose Street, 265 Melrose Street, 750 Elmwood Avenue, and 350 Coddington Highway for ZEB infrastructure

Staffing costs for Scenario 6 total $1,605 million (YOE) 2023-2042, as RIPTA must hire 518 additional employees.

The total cost for Scenario 6 is $3,264 million (YOE) over the 20-year period. By 2042, annual on-road GHG emissions will be zero metric tons (Figure 23).

Figure 23 Scenario 6 On-Road GHG Emissions per Year (2023–2042)



5. Workforce Development

Transitioning from diesel vehicles to ZEBs will require staff growth, additional training, and procedural change across maintenance, administrative, safety, and training staff, as well as operators. The tables below denote workforce development by department based on lessons learned from early and widespread adopters' experiences with ZEB deployment.

5.1 Maintenance Department

Training needs for the Maintenance departments are likely to change depending on levels of ZEB deployment. IndyGo, as reported through TCRP Synthesis 130, noted that minor issues may be perceived as big issues during early levels of deployment. Management may need to become familiarized with new systems before diagnostic procedures can be established. IndyGo chose to receive ongoing support from the bus OEM (Complete Coach Works), which provided a resident trainer for mechanics and guided a team dedicated to BEB maintenance.[10]

The Maintenance departments are likely to require extensive coordination with both RIPTA's Training department and collaboration with OEMs. In the short term, it is common for an agency to rely heavily on OEMs to provide instructions and training on new technologies. An example of the kinds of OEM support that may be available from OEMs is in the relationship that Canton, Ohio's Stark Area Regional Transit Authority (SARTA) has with Air Products, which maintains ownership of the hydrogen storage equipment and compressors used in SARTA's HFCBs. SARTA compensates Air Products in exchange for maintenance and operations of the fuel, which Air Products delivers from a production facility approximately 300 miles away.[11]

Table 11 notes workforce development needs for RIPTA's maintenance team.

Table 11 Maintenance Workforce Development

Training	New or Expanded Procedures	Additional Personnel
• ZEB-specific components and failure response procedures • Facility maintenance/ troubleshooting	• Expanded inventory of spare parts necessary to service ZEBs and charging/fueling infrastructure • Expanded inventory of maintenance equipment necessary to service ZEBs (such as scaffolding)	• Grows due to additional garages and vehicles • Additional training personnel in early stages of transition to ZEB fleet • Additional electricians needed for BEB scenarios

5.2 Administrative Staff

Several of RIPTA's administrative departments will be particularly impacted by the transition to ZEBs. The Planning department will likely need to pursue more grants to support large capital ZEB purchases. Project Management will be required to learn new technical requirements associated with ZEB deployments (i.e., obtain some level of training on all ZEB-related topics for other departments) and coordinate closely with all departments to ensure these requirements are followed.

The Procurement department will have ongoing responsibilities to fulfill grant requirements associated with supplementing funding for low or no emission vehicles, as well as issuing Request for Proposals

[10] CTE, TCRP Synthesis 130: Battery Electric Buses: State of the Practice, 2018, https://nap.nationalacademies.org/catalog/25061/battery-electric-buses-state-of-the-practice.
[11] UC Davis, Workforce Implications of Transitioning to Zero-Emission Buses in Public Transit, 2022, https://escholarship.org/content/qt3jb4b73d/qt3jb4b73d.pdf.

(RFPs) for buses and charging/fueling infrastructure. New technologies are also accompanied by new local, state, and federal regulations that will also apply to RFP documents. This department may also face additional responsibilities as a result of ongoing coordination with local utilities. As a state with a competitive energy market, retail energy suppliers are able to compete on the price of electricity generation (electricity distribution costs continue to be set by local service area providers). While this arrangement provides cost savings on variable energy demands, it may also require a high administrative burden.

Table 12 notes workforce development needs for RIPTA's administrative departments.

Table 12 Administrative Workforce Development

Training	New or Expanded Procedures	Additional Personnel
• Project management must learn technical requirements associated with ZEB deployment • Some level of proficiency in training topics necessary for all other departments	• Procurement tasked with developing contract requirements that reflect higher level of ongoing support from OEMs in at least training and maintenance • Greater level of coordination with local utilities • New deployment plans to accommodate BEB's reduced range when compared to legacy technology	• Grows due to additional vehicle revenue hours as service increases • Does not change with new technology

5.3 Safety Staff

With zero emission bus deployment (both BEB and HFCB), Safety departments will at a minimum require additional training in order to understand hazards and safe handling of batteries, hydrogen fuel cells, and battery chargers (Table 13). Some new procedures will be required as a result of work with energized components as specified within the Code of Federal Regulations Title 29, Part 1910.

In addition to training, new emergency management procedures will also apply. It is a best practice to document procedures associated with actions to take to avoid an emergency, locations of emergency cut-off switches and fire response equipment, and incident response procedures. Safety departments are likely to require a high level of coordination with emergency responders such as police and fire agencies to conduct ZEB component overview, high-voltage safety training, and share information on emergency shutdown procedures. There may be an opportunity to incorporate BEBs' ability to serve as an emergency backup power source through various Vehicle-Grid Integration technologies.

Table 13 Safety Workforce Development

Training	New or Expanded Procedures	Additional Personnel
• Understanding of BEB and HFCB hazards • Safe handling and deactivation of high-voltage components • Training in operation and testing • Pressure relief systems (HFCB) • Fire and leak detection systems (HFCB) • Control of Hazardous Energy, Title 29, CFR Part 1910.147 (HFCB) • Personal protective equipment (PPE)	• Emergency response procedures (considering both needs of BEB/HFCB, but also emergency backup power opportunities with BEB) • Hazard and Operability Study (HAZOP) to ensure that appropriate risks are identified	• Security department personnel grows with the number of bus maintenance facilities • No changes are expected with vehicle propulsion technology changes

5.4 Training Staff

RIPTA's Training department spearheads all employee training, including on-boarding, diversity and sensitivity training, and leadership development. With the zero emission vehicle deployment, training demand for each department will require an increase in personnel in RIPTA's Training department, especially in the early stages. To meet the request for zero emission bus, trainers at a minimum are required to have knowledge of high-voltage safety requirements, personal protective equipment, and new techniques on zero emission buses such as the regenerative braking techniques (

Table 14). Besides in-house training, RIPTA can also collaborate with OEMs or local educational institutions on training staff.

Table 14 Training Department Workforce Development

Training	New or Expanded Procedures	Additional Personnel
• Expert level of proficiency in training topics for all other departments	• High levels of coordination between agency and OEMs • Outreach and training for local first responders to support incident response (if not OEM responsibility) • More regular training for all staff • More interactive training techniques for operators learning new propulsion systems • Greater emphasis on incentive program for operators based on training needs • Validate that OEM training meets requirements of all departments	• Additional personnel will be necessary to provide extensive training requirements for all departments

Training	New or Expanded Procedures	Additional Personnel
	• Incorporate 'train-the-trainer' materials provided by the OEM (if required under contract agreements)	

5.5 Operators

Operators are one of the most critical groups of employees for successful ZEB deployment, particularly for BEB deployment. Foothill Transit, one of the first agencies in the country to transition to BEB, found that many low-voltage starter batteries on several of the buses had to be replaced as a result of a driver training issue. Operators who were used to hearing an engine running would fail to shut down a bus at the end of the shift.[12] Similarly, Antelope Valley Transit Authority found that two operators on the same route under the same conditions could experience a 4 kWh/mile difference in efficiency due to driving technique, equal to a reduction in range from 220 miles to 80 miles.[13] Operators at Ohio's SARTA reported a high degree of range anxiety even with high-range HFCBs in deployment, and stopped to refuel more often than necessary.[14] These examples illustrate how critical it is that operators be trained on all aspects of the new propulsion systems in order to avoid additional unnecessary costs and experience the full benefit of new propulsion systems. Approximately 70 percent of the agencies surveyed for TCRP Synthesis 130 received training from a bus OEM for operators. Most agencies rely on bus OEMs to provide driver training. Table 15 notes the workforce development needs for operators.

Table 15 Operator Workforce Development

Training	New or Expanded Procedures	Additional Personnel
• General familiarization • Regenerative braking (BEB) • Silent operations (ensuring that buses are off when not in use, pedestrian danger) • Understanding notifications on the dashboard • Condition reporting and road calls	• Transitioning refueling mentalities • New channel for complaints related to learning new ZEB operations separate from complaints driven by failures • Procedures for low battery management or requirement to fuel	• Grows due to additional vehicle revenue hours as service increases • Does not change with new technology

6. Risk

Introducing new propulsion systems, whether BEBs or HFCBs, into service carries certain risks for the agency not unusual for a highly complex program. Failure to mitigate these results may result in additional costs, substantial delay, inefficiencies, and negative customer impacts. This chapter details a high-level overview of the most pertinent foreseeable risks facing RIPTA APEG implementation.

[12] NREL,, Foothill Transit Battery Electric Bus Demonstration Results, 2016, https://rosap.ntl.bts.gov/view/dot/36135.
[13] CTE,, TCRP Synthesis 130: Battery Electric Buses State of the Practice, 2018,
[14]UC Davis, Workforce Implications of Transitioning to Zero-Emission Buses in Public Transit, 2022, https://escholarship.org/content/qt3jb4b73d/qt3jb4b73d.pdf.

6.1 Methodology

Risks were identified and evaluated based on a review that included the 2022 Transit Asset Management Plan update (required per 49 CFR 625), data from Michael Baker International developed for RIPTA, interviews with RIPTA staff, a review of public records provided to the National Transit Database, and final plans for transit agencies undergoing similar transformations. Additionally, the project team conducted interviews with staff from other transit agencies and consulted with subject matter experts at AECOM and Cambridge Systematics.

The risks that were identified were then further evaluated for impact (ranging from very high to very low and probability of occurring (expressed as a percentage). These ratings are subject to change with additional refinement from RIPTA.

Risks for the ZEB program are divided into 11 general risk categories, including insufficient resources, governance/decision making/policy, internal/external stakeholders, funding, operational, data/information availability, process maturity/goal setting, legal/compliance, mission/priority changes/errors, communications, and financial. For each general risk category, specific risks and comments are included.

The consequences of failing to manage various risks generally fall into three categories: impacts to schedule, cost, and/or scope. Scope impacts can last the entire life of the assets, and thus particular care must be taken to identify and mitigate them.

6.2 Key Findings

Mitigation strategies have been developed for many identified risks, while for others, further development will be required as the ZEB program proceeds. In addition, the formation of an internally dedicated program team, with consulting support, to manage and execute the program will also allow RIPTA to mitigate common project risks such as governance, stakeholder management, staff burnout, quality assurance and control, cross departmental coordination, and communications. Table 16, below, identifies key risks.

Table 16 Identified Key Risks

Risk	Suggested Mitigation
A dedicated program team is not currently in place (staffing is assumed in planning but not yet assigned).	Establish and empower dedicated program team and form a formal ZEB Program Management Office (PMO), cognizant not to pull resources from current work to start "just one more project." Ensure Two PMO Offices (Bus and Engineering) are also in place that report into the overall program PMO. Establish and define how program complexity will be managed, including defining methods to be used, documenting what is known, initiating project activity to explore options, addressing feasibility questions, and eliminating critical knowledge gaps. Establish a document management system that is utilized from Program kick-off through completion.
State/federal/local funding for the complete ZEB implementation remains unclear at this time. State partners may not have the funding available to contribute to service and/or equipment.	Work with state and federal partners to get a detailed understanding of current financial conditions. Is RIPTA confident in its ability to obtain liquidity to cover upfront costs until state/federal costs arrive? If so, detail plans and actions to reduce risk to the program.
Some bus fleets are near or beyond their useful life.	Develop simulations/models to better understand wear and tear on existing fleets. Include detailed legacy bus Decommission Plan and Transition Plan. Increase equipment inspections.
Current operations may be impacted when modifications are made to existing facilities and terminals/yards.	Engage stakeholders, including subject matter experts, to develop detailed requirements and construction staging plans. Implement a phased construction approach and explore potential for new facilities instead of modifying existing facilities.

Risk	Suggested Mitigation
Grid buildout and redundancies are not available for power needs.	Engage with RI Energy to understand its capital program for both existing and new power infrastructure buildout. Include the needs of RIPTA in those plans and assist with any funding applications to the utility buildout. Regular meetings should be held once locations of new facilities have been determined and site acquired. Existing networks should be evaluated for capacity, reliability, and redundancy by RIPTA to ensure a stable source of power. Prioritization planning efforts that consider the impacts of power outage so that RIPTA can provide services in case of an emergency event and transit buses are called upon.
The impact of temperature on equipment over time is uncertain.	Drivers should be trained on seasonal variability, as it effects operations. Additionally, due to reduced range, BEBs may require a weather-dependent spare ratio.
Thermal runaway in bus batteries may result in physically unsafe conditions[15].	Continue to converse with transit operators on thermal events and work to develop mitigation procedures.
Variable electricity costs threaten the financial sustainability of BEB adoption.	Opportunity to work with state entities to cap electricity rates (or create a new rate classification) prior to an electric fleet being commissioned. Opportunity for RIPTA to build its own power generation source to provide electricity to bus, facilities, and infrastructure. Explore opportunities for Power Purchase Agreements to purchase electricity directly from producers.
New bus operation requirements for ZEBs require documentation and staff training.	Ensure specification of the buses includes provision to automate provisions that are not associated with diesel bus operation. For example, if the bus is stationary for more than 'xx' minutes the bus should turn off automatically. Drivers should be trained in efficient driving. Driver behavior should be tracked in metrics.
There are significant bus storage constraints at Newport, 269 Melrose Street, and the yard on Cadillac Drive.	With the buildout of new facilities and increasing the service delivery footprint, it is reasonable for RIPTA to also deploy and house ZEBs to several facilities and not have all stored in one location. This will also mitigate any unforeseeable risks regarding storm events, or special circumstances where ZEBs could be deployed to help the community.

The *Action Plan for Electrification and Service Growth: Risk Register Technical Memorandum* details the most common risks for a program of this type and corresponding recommended mitigation strategies.

[15] Thermal runaway of a battery is caused by a failure of the battery's cells – often, as a result of physical damage to the battery, manufacturer defects, short-circuiting, overheating, or overcharging – resulting in a rapid increase in internal temperature. The heightened temperatures can cause chemicals in the battery cell to break down, which may result in toxic gas emission, fires, and/or explosions.

7. Recommendations

To meet *Transit Forward RI 2040* service expansion goals, RIPTA's fleet, staffing, and facilities must grow. The scale of growth will be directly influenced by the propulsion type of future vehicles, as will the costs of expansion.

Scenario 1 – baseline growth to meet the TMP's expansion goals with a diesel fleet – is projected to cost $2.96B (YOE) from 2023-2042 (Table 17). Meeting *Transit Forward RI 2040* goals with diesel-electric hybrid, BEBs, or HFCBs is projected to cost up to $1.24 billion more. In exchange for more investment in decarbonization adoption, total on-road GHG emissions per year could fall from 47,203 metric tons to zero (Figure 24).[16]

Table 17 Baseline Scenario Comparison

Scenario	Description	Fleet	New Facilities	Staffing	YOE Cost (millions)	On-Road Annual Emissions by 2042 (MT)
1	Diesel	388	1	1,292	$2,961	47,203
1A	Hybrid	+0	+0	+0	+$330	-14,487
2	BEB Depot Charging	+280	+1	+189	+$1,247	-47,203
3	BEB On-Route Charging	+30	+0	+80	+$518	-47,203
4	100% HFCB	+1	+0	+21	+$188	-47,203
5	94% BEB, 6% HFCB	+6	+0	+103	+$486	-47,203
6	71% BEB, 29% HFCB	-9	+0	+40	+$303	-47,203

FTA's Low or No Emission Vehicle Program 5339(c) provides funding to support state and local efforts to procure vehicles, retrofit facilities, and support workforce development. In FY 2022, $1.105 billion was awarded to 100 projects[17] and $1.2 billion is available for funding in FY 2023.[18] Though Low or No Emission Grant funding is at a historic high, the total dollars are not distributed evenly among grantees (Figure 25). In 2022, approximately one-third of total funding was awarded to three transit agencies: the Metropolitan Transportation Authority in New York, the Massachusetts Bay Transit Authority, and the Los Angeles County Metropolitan Transportation Authority in California. Nearly three-quarters of awardees received $10 million or less.

Due to funding uncertainties, RIPTA should continue to implement zero emission bus adoption pilot projects while replacing retiring diesel buses with low emission hybrid vehicles in their fleet. In tandem, RIPTA should work to improve capacity for the transition to a zero emission fleet by bringing facilities to SOGR, developing the workforce, and collaborating with partners to ensure the viability of any future fleet electrification. Specific recommendations are outlined below.

[16] For discussion of total GHG and criteria pollutant emissions, see *Action Plan for Electrification and Service Growth: Financial Projections for Vehicle Replacement and Fleet Growth Technical Memorandum.*
[17] FTA, FY22 FTA Bus and Low- and No-Emission Grant Awards, 2022, https://www.transit.dot.gov/funding/grants/fy22-fta-bus-and-low-and-no-emission-grant-awards.
[18] FTA, Low or No Emission Vehicle Program – 5339(c), 2023, https://www.transit.dot.gov/lowno.

Figure 24 On-Road GHG Emissions per Year Across Scenarios (2023–2042)

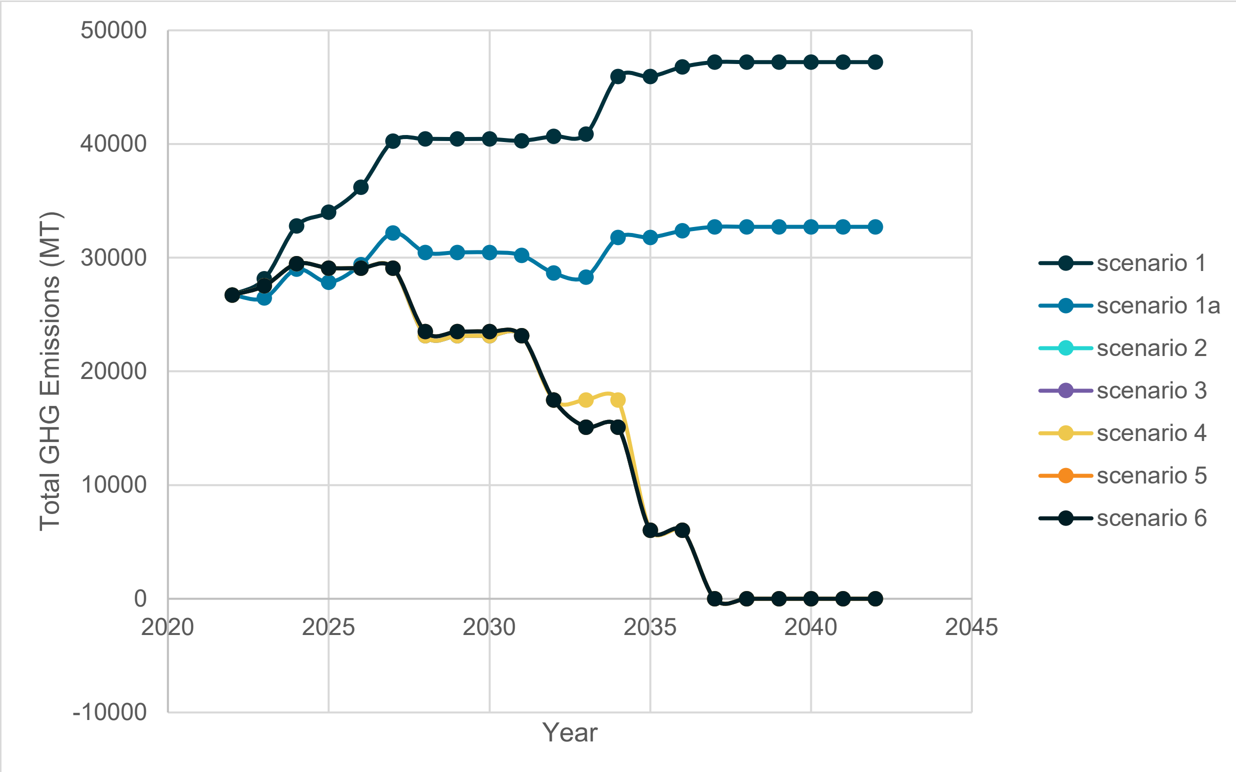
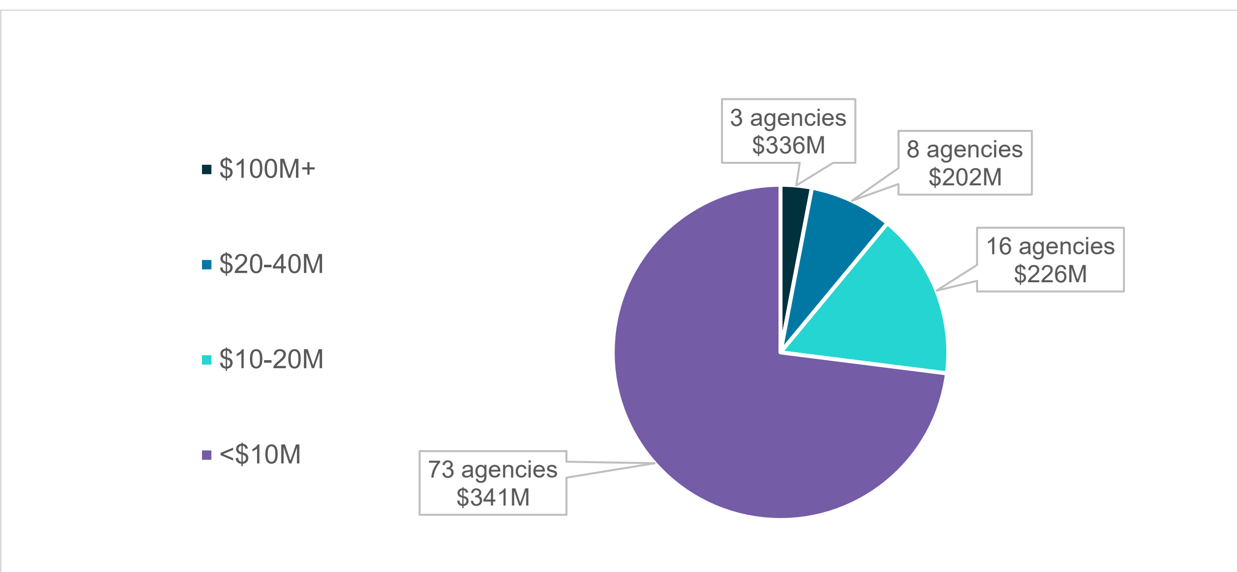


Figure 25 FY 2022 Nationwide FTA Low or No Emission Grantees by Award Amount



Fleet:

- Continue implementation of ongoing zero emission bus pilot programs (R-Line, Aquidneck Island)
- Evaluate pilot results as a basis for determining future bus procurements
- Ramp up gradually but steadily toward all zero emission vehicle procurements, focusing on hybrid-electric buses in the near term
- Engage with community of transit agencies nationwide on decarbonization efforts
- Monitor developments in zero emission technologies
- Consider scoping a hydrogen fuel cell bus pilot within the next 2-5 years

Facilities:

- Bring all facilities up to a State of Good Repair
- Rehabilitate and expand 265 Melrose Street
- Begin facility reuse planning for 325 Melrose Street
- Continue working with RI Energy on grid and substation capacity
- Continue working with the Division of Public Utilities and Carriers on rate accommodations

Staffing:

- Continue recruiting additional operators to restore existing service and allow for gradual service growth
- Increase facilities and maintenance staff to handle charging infrastructure needs and support additional vehicles
- Grow training staff capacity and increase investment in training programs

***Transit Forward RI 2040*:**

- Continue implementation of transit master plan recommendations as resources allow
- Continue to pursue sustainable, long-term capital and operational funding for transit master plan