MASSACHUSETTS BAY TRANSPORTATION AUTHORITY

BUS ELECTRIFICATION PLAN

May 2022

A LETTER FROM OUR GM

The MBTA is embarking on the most dramatic transformation of its bus system since the streetcar rail network began to be converted to rubber-tired vehicles in 1922. The MBTA is working to convert our entire bus fleet to battery electric buses by 2040—one of the most aggressive electrification timelines in the U.S. This ambitious effort aligns with the MBTA's longstanding goal of providing a better rider experience, advancing equity in the region, and improving our system's sustainability while achieving the Commonwealth's 2050 decarbonization goals.

For more than 200 years, the Boston region has led innovations in public transit. From the stagecoaches of the early 1800s, to the first subway tunnel in North America in 1897, and then with the formation of the first regional transit system in the U.S. in the 20th century, the MBTA has a proud history of tackling challenges and preparing for the future.

Today, the T is continuing our legacy of innovation. As described in the following sections of this document, the MBTA Bus Electrification Plan, this bold effort will address the urgent need to ensure reliability and enhance the rider experience while improving livability for the entire region by eliminating bus emissions.

Our approach positions the MBTA as a leader in fleet electrification, both within the Commonwealth and nationally. This transition will not be easy or inexpensive, but the T looks forward to continuing to work with community partners to make progress on these fronts. Together we can move our riders in a way that leverages the best, most reliable green technology and protects our environment.

Figure 1: Horse-drawn Omnibus in Cambridge, early 1880s

Figure 2: A battery-electric bus 2022

Steve Poftak
General Manager

CONTENTS

1 Confronting Our Challenges & Investing in the Future

The Massachusetts Bay Transportation Authority (MBTA) is driven by a powerful vision of improving lives for the people and communities of the Boston region. The MBTA aims to be reliable, robust, and resilient in order to achieve the goals of sustainability, livability, equity, economic competitiveness, and prosperity for Boston-area communities. On the following pages, the MBTA Bus Electrification Plan explains how the MBTA will implement its long-term vision for a cleaner, modern bus fleet and a more livable and equitable community. This document outlines the specific steps that the MBTA will take in its ambitious transition to a zero-emissions bus fleet by 2040.

The MBTA has one of the most ambitious fleet transition timelines in the nation with plans to electrify its entire fleet of 1,150 buses by 2040. In the meantime, the MBTA will continue to purchase a mix of battery-electric and hybrid buses, with the last hybrid purchase planned for 2027. As the MBTA adds to the battery-electric bus (BEB) fleets, we also intend to modernize facilities depot by depot, prioritizing the facilities with the most potential to dramatically reduce tailpipe emissions in Boston-area communities in alignment with the goals of sustainability and equity. This coordinated process will allow the MBTA to continue providing reliable bus transportation to the riders who depend on that service, while upgrading and modernizing the entire system. Throughout this process, MBTA plans to steadily transition to BEBs while also meeting Federal Transit Administration (FTA) minimum useful life requirements.

ABOUT MBTA

The Massachusetts Bay Transportation Authority (MBTA) is the largest transit provider in New England and one of the largest in the country, providing 1.26 million passenger trips each day (FY 2019). The MBTA operates or contracts service across seven modes: heavy rail, light rail, bus rapid transit, fixed-route bus, commuter rail, ferry, and paratransit. The total service area is made up of 175 communities, with impacts extending across the 4.9 million-person Boston Metropolitan Statistical Area (MSA).

Bus Electrification Transition Goals

The MBTA aims to achieve the following goals through the bus electrification transition:

1. Convert the entire bus fleet to zero-emissions technology and implement associated facility investments in support of the Commonwealth of Massachusetts's ambitious carbon reduction goals.

2. Modernize all bus maintenance facilities to accommodate zero-emissions technology and improve conditions for the workforce to support their efforts to keep bus service competitive and reliable for MBTA passengers.

3. Transition to a more uniform bus fleet replaced on a predictable, annual timetable to reduce capital, maintenance, and operations costs and support fleet reliability for passengers.

4. Allow for an increase in bus fleet size to position the MBTA's Bus Network Redesign to meet the needs of growing ridership.

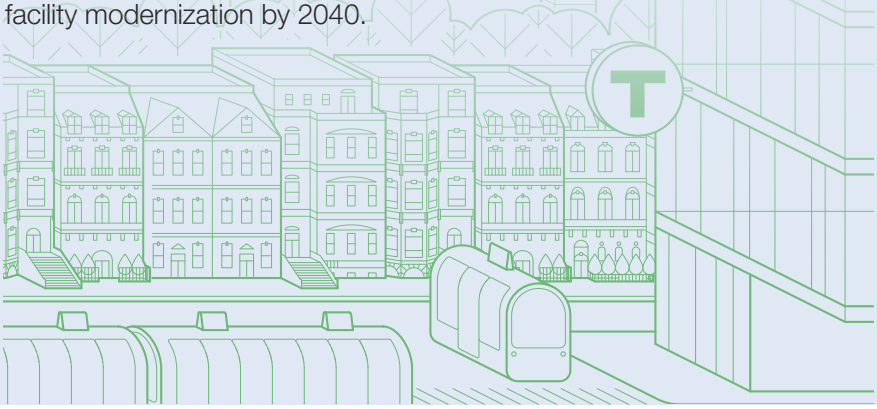
The MBTA Bus System Today

The Bus Electrification Plan aligns with, and advances, an effort begun in 2018 to elevate MBTA's bus service and center it around the rider experience. The Better Bus Project, is a key element of MBTA's $8 billion, 5-year capital investment plan to modernize and upgrade every aspect of the transit system. The Better Bus Project lays out a vision to achieve a better, faster, lower-emissions service, supported by all-door boarding and exclusive busways, that is aligned with where riders live, work, and travel. The transition to zero-emissions vehicles and facilities aligns with the Better Bus Project and will support those initiatives.

FOCUS 40
The 2040 Investment Plan for the MBTA

Focus40, the MBTA's long-range capital plan, released in March 2019, positions the MBTA to meet the transit needs of Greater Boston through 2040. The plan offers a roadmap for the capital investments needed to achieve the MBTA's goals, as well as priority areas for new or improved service. The goals outlined in Focus40 provide a framework for the fleet and facility transition: sustainability, livability, equity, and economic competitiveness and prosperity. All of the activities outlined in this document support one or more of those organization-wide goals.

The MBTA identified bus fleet and facility modernization as a key area of investment and established a goal to complete the fleet transition and facility modernization by 2040.



Buses: the MBTA's On-Street Workhorse

The MBTA bus network is the foundation of all the transit services provided by the T. It serves both dense urban corridors and outlying areas, and makes critical connections to commuter rail, heavy rail, and ferry services. Before the COVID-19 pandemic, MBTA buses carried nearly half a million passengers on an average weekday—about 30% of all MBTA trips. Buses serve 170 routes across 44 cities and towns in the Boston region. Pre-pandemic, ridership on the MBTA bus system alone was higher than the total ridership of all but seven American public transit systems. Modernizing the bus system is therefore critical to meeting all of the MBTA's Focus40 goals.

With equity a top priority for the organization, the MBTA is committed to making key bus system upgrades, including electrification. The bus network is especially crucial for low-income and minority MBTA passengers. The bus system serves a much greater share of minority and low-income riders than other modes. Based on MBTA ridership survey data, 47% of systemwide bus riders are considered minorities and 42% are low-income. By comparison, less than 30% of MBTA rapid transit riders are minority or low-income. Less than 14% of MBTA commuter rail riders are people of color and only 8% are low-income.

Like many transit agencies, MBTA has experienced considerable challenges during the COVID-19 pandemic, as ridership has dropped and transit operators continue to face health and safety risks. Yet, the bus network has proved to be the most resilient of MBTA's services. As of April 2022, bus ridership was up to 73% of prepandemic levels. MBTA's bus network remains essential to providing access to jobs and opportunities for low-income and disadvantaged communities across the region.

The MBTA Bus System Tomorrow

Transitioning this critical component of the MBTA system to a sustainable, emissions-free future will be a complex process. It is crucial for MBTA to achieve this transformation without disrupting the daily riders who depend on the service. The MBTA also recognizes the importance of constructing or retrofitting bus facilities that respect the needs and desires of neighboring residents and that provide a modern and safe working environment for MBTA employees, both of which allow the T to support the Focus40 goals of livability and reliability. In order to manage all of these priorities, the MBTA bus fleet and facilities strategy includes the following two major components, which will be implemented concurrently:

1. Investing in new, clean bus technology that will eliminate emissions and harmful pollutants from Boston and Boston-area communities.

2. Modernizing the T's aging bus maintenance facilities so that they can support BEBs and accommodate future fleet growth.

The T will deploy BEBs as it upgrades its nine bus maintenance facilities to modernize working conditions, expand capacity for buses, and incorporate charging infrastructure. As new facilities come online, the MBTA will fill them with BEBs, starting with a retrofit to North Cambridge in 2023 (35 buses), a new facility in Quincy in 2024 (120 buses), and a new facility in Boston at Arborway in 2027 (200 buses). By the beginning of 2028, nearly 30% of the MBTA bus fleet will be electric. By 2030, more than 50% will be electric with the completion of facilities at Wellington and in Lynn. The remaining facilities are targeted

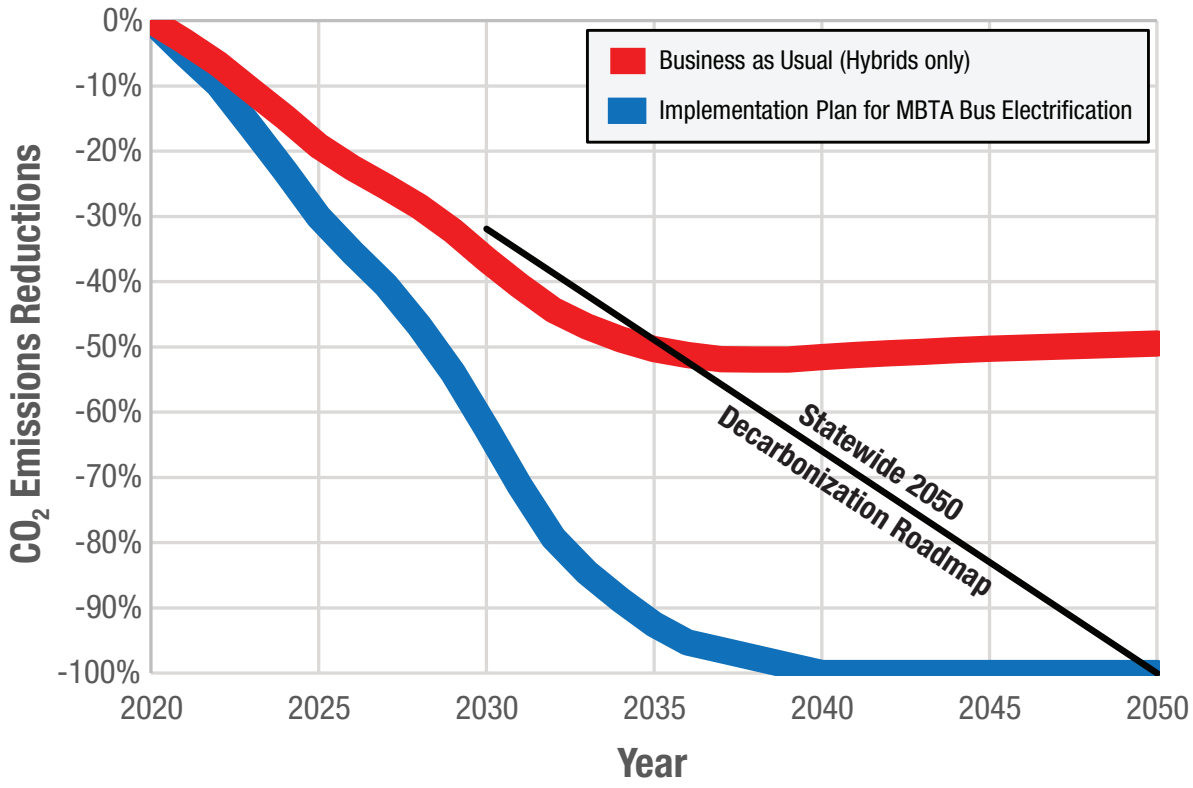


Figure 3. Electrification Plan and Carbon Reduction Progress Chart

for completion every 2 to 3 years and will enable the T to steadily reduce bus fleet emissions to zero by 2040 (Figure 3).

Over the next 5 years, the MBTA plans to procure efficient hybrids whenever space is not available at new BEB-equipped facilities to replace the oldest, most polluting diesel buses and support reliable service for bus riders. Based on the facilities plan, the MBTA expects to receive the last round of hybrids in 2027, upon the completion of the 5year contract beginning in 2022.

Throughout this period, the MBTA is also implementing a Bus Network Redesign, changes to bus routes and frequencies that will better meet demand, making transit a better mobility choice for people across the region. In addition to the noise and air quality benefits of BEBs, these transformational changes will help drive an increase in ridership and reduce reliance on single-occupancy vehicles throughout the region.

Funding this ambitious undertaking will be a challenge that we at the MBTA are planning for, along with creating and fostering partnerships with local and regional stakeholders that will make this effort a success. Funding is discussed in detail in Section 6 of this document, Costs and Funding Options. The following sections detail the plans for transitioning the fleet and modernizing facilities.

A NET-ZERO COMMONWEALTH BY 2050

In 2021, the Commonwealth enacted legislation setting emission reductions targets of 50 percent by 2030 and net-zero by 2050. MBTA's fleet and facility transition plan will help the Commonwealth achieve these ambitious targets and create a healthier environment for all our residents.

2 Bus Fleet Transition

The scale of MBTA's bus fleet transition goals is immense, and the strategy for this transition to electric-powered buses is inextricably linked to the facility modernization plans described in the next section. The current bus fleet is composed of both 40- and 60-foot buses that use a mix of propulsion types, including diesel, diesel hybrid, Compressed Natural Gas (CNG), battery-electric, and dual-mode electric trolley buses. Through the implementation of this plan, MBTA's bus fleet will be transitioned to one that is entirely battery-electric.

The Current Bus Fleet

Propulsion type	# of active buses
Diesel	368
Hybrid	568
CNG	175
Battery-Electric	5
DMA (Dual Mode)	32
Total number of active buses	**1,148**

With almost 1,150 buses, the MBTA has one of the largest public transit bus fleets in the U.S. While the mix of vehicle types serves many different operational needs, it is more expensive and logistically challenging to reliably maintain this many fleet types.

Battery-Electric Buses

MBTA determined that to advance the bus fleet transition in a way that best meets the needs of its passengers, the new fleet should be:

- **Uniform:** In order to maximize flexibility and efficiency, the selected technology should be replicable across the entire bus fleet.
- **Compatible:** In support of a smooth transition, and since the fleet conversion will happen over many years, the selected technology should work with the existing operating practices and procedures.
- **Cost Effective:** In order to transition the bus fleet as quickly as possible, the selected technology should minimize life cycle costs (for both vehicles and infrastructure) and generate broad interest from manufacturers.

In line with these goals, the MBTA has determined that long-range BEBs most effectively meet our service and passenger needs. In the short term, these buses will also be equipped with auxiliary

SILVER LINE PILOT PROGRAM

The MBTA has already begun its transition to a zero-emission fleet with the deployment of five battery-electric buses for the Silver Line route in 2019. The pilot demonstration project included the installation of three 150kW plug-in chargers at the Southampton bus garage and has provided valuable lessons for the T that will inform its future fleet transition plans.

heaters until battery technology improves, allowing a conversion of buses that minimally impacts the service schedule.

The MBTA has used a modeling software program to evaluate operational feasibility of BEBs under a range of scenarios. We used the model to test a range of possible fleets, including different battery capacities, use of auxiliary heaters, and charging capacity at garages and in the field. The modeling accounts for a number of variables, including passenger loads, topography, and temperature. As a result of the modeling, we have determined that focusing on adding charging infrastructure to facilities while adding auxiliary heaters in the short term will allow a gradual transition of the bus fleet with fewer changes to operations that could affect customers. In the future, the MBTA will explore on-route charging options, and the T will aim to phase out auxiliary heaters while gradually building out that infrastructure. Adding auxiliary heaters combined with charging at bus depots was a more practical approach than installing on-route charging. Although the technology is still developing, at this time, on-route charging complicates route planning and scheduling because it requires long layovers and may not work across all bus routes, especially as routes are changed to accommodate new employment

ELECTRIC TROLLEY BUSES (ETB)

The MBTA has a long history of operating electric vehicles: until recently, we operated a small fleet of 28 electric trolley buses (ETB). The decision to replace the ETBs was due to several factors, and the many benefits of catenary-free electric vehicles were impossible to ignore. Most importantly, the lifecycle cost of BEBs is considerably lower than that of ETBs and the associated catenary infrastructure. In addition, ETBs encounter operational challenges, such as when roadway blockages impact their routes, or when catenary systems experience a failure. In these instances, buses are often replaced with diesel hybrids (15-18% of trips). In addition, removing the overhead catenary wire system will create more design flexibility in the high-priority corridors where ETBs have been located, including opportunities for separated bike lanes, dedicated bus lanes, and transit priority infrastructure. While trolleybuses that can go off-wire are available on the market, the cost and complexity of stringing wire over dozens (and potentially hundreds) of miles of Boston's already limited Right of Way (ROW) would cause us to miss the 2040 target for a fully zero-emission fleet. Finally, the increased flexibility of the BEB fleet without catenary wires will allow for increased reliability for bus riders through BEBs' more flexible technology and provide more equitable service while reducing vehicle emissions.

ZERO-EMISSION VEHICLES ADVANCE EMISSION REDUCTION GOALS

Battery-electric buses will help reduce the MBTA's carbon footprint and contribute to the plans outlined in the Massachusetts 2050 Decarbonization Roadmap with calls for net zero emissions across the Commonwealth by 2050. These targets include emissions from all sources – transportation, buildings, electricity generation, and others.

and population centers. The MBTA expects on-route charging to play a role as BEBs become the standard vehicle type in the fleet, and we have initiated planning work to prioritize pilot locations and develop a systemwide on-route charging deployment strategy.

Hydrogen technology, although promising, requires significantly more physical space at maintenance facilities for fueling, making them a less practical choice for an urban transit T where space is at a premium and the cost of upgrading facilities is already substantial. In addition, few manufacturers can provide large fleets of FCEBs at this time. Waiting for manufacturers to produce enough FCEBs to serve all of MBTA's routes would potentially delay the transition to zero-emission buses well beyond the 2040 timeline.

Implementation Plan

MBTA will replace an initial retirement of 250 diesel buses with a combination of BEBs and Enhanced-Electric Hybrid buses to serve the new Quincy bus maintenance facility and the North Cambridge facility in late 2023 and 2024, among others.

Following these deliveries, we will continue to purchase 80 to 100 buses each year, depending on the milestones reached with facility upgrades and replacements, until the entire bus fleet is transitioned to BEBs by 2040. The last purchase of diesel hybrids will occur in 2027,

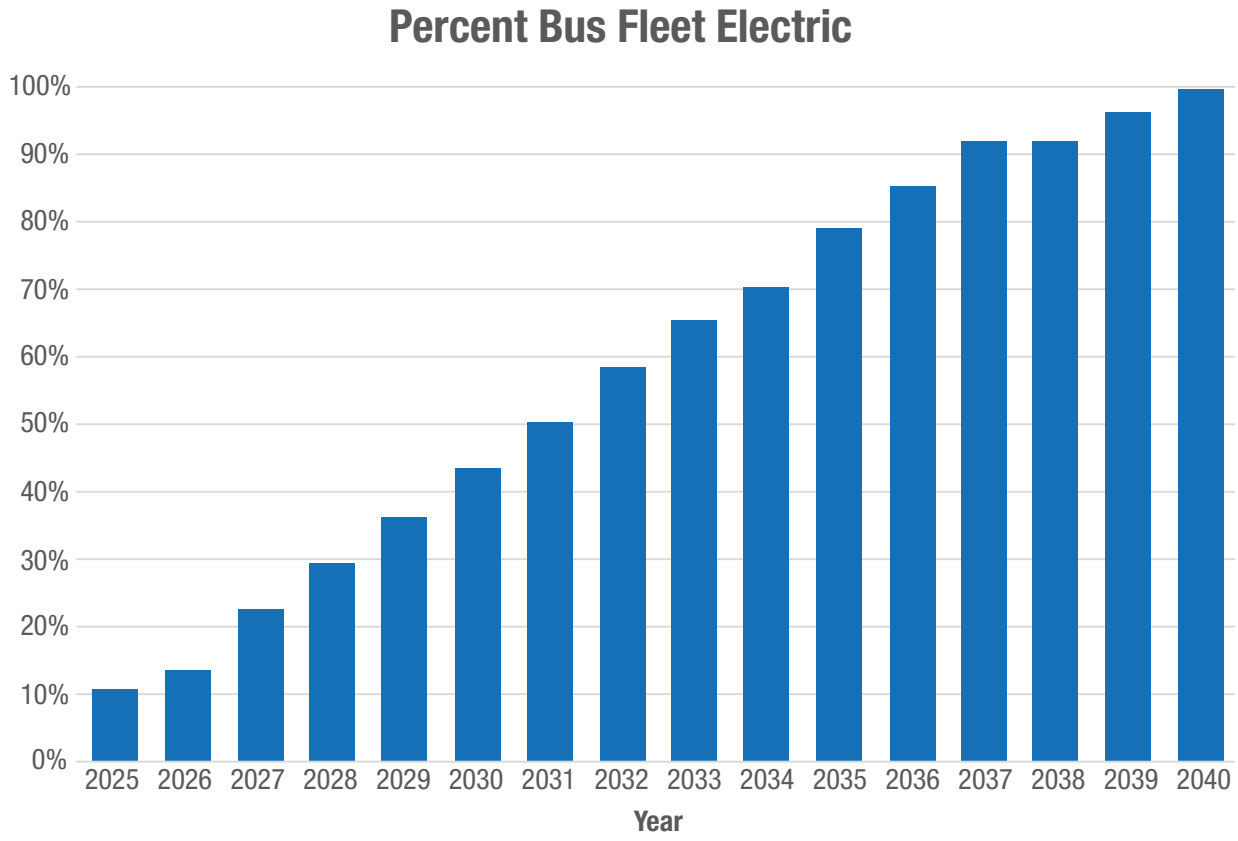


Figure 4. Percent Bus Fleet Electric

provided the Arborway bus facility remains on track to open in that year. Figure 4 illustrates the planned delivery of BEBs.

Policy and Legislative Impacts

An array of federal, state, and local policies will influence the ultimate implementation of this plan. MBTA works closely with its local, regional, and federal partners, and will continue to monitor policy changes and legislative developments as they arise.

Among the policies that impact zero-emission bus deployments, the Commonwealth of Massachusetts, along with seven other states, has led a Multi-State Zero-Emission Vehicle Action Plan to increase zero-emission vehicles and establish appropriate refueling infrastructure. Currently, Bill S.2130: An Act to Convert the MBTA Bus Fleet to Zero-Emission Vehicles is under consideration in the Massachusetts Senate. That act would require that MBTA purchase only zero-emission vehicles beginning in 2030 and convert the entire bus fleet to zero-emission vehicles by December 31, 2040. While implementing this policy could be complicated by the ongoing FTA requirement to retain vehicles purchased with federal funds for at least 14 years, the MBTA Bus Electrification Plan currently aligns with these possible requirements.

3 Facility Modernization

Upgrading MBTA's bus facilities is a critical first step for the deployment of zero-emission bus fleets. Although often unseen by the general public, bus maintenance facilities are essential to reliable bus system operations and a positive transit customer experience. As one of the oldest transit agencies in the U.S., MBTA has nine bus maintenance facilities in widely varying conditions. None has been retrofitted with the charging and maintenance infrastructure required for a full fleet of BEBs, and many have no available capacity for fleet expansion. Through the Bus Facility Modernization Program, the MBTA has developed a practical plan to deliver a portfolio of state-of-the-art bus maintenance facilities that will support MBTA ridership growth and deliver comfortable, reliable, high-frequency, and emission-free service.

The MBTA Vision for Battery-Electric Bus Facilities

As the MBTA upgrades or replaces each bus facility in the network, we will ensure that every new facility is modern, safe, energy-efficient, and capable of meeting customer needs now and in the future. We will regularly revisit plans and evaluate new technologies to ensure that all facilities are designed for future flexibility.

Each state-of-the-art, sustainable, and modernized facility will include:

› Overhead charging to simplify and automate the charging process and support worker safety, with a focus on adapting to new technologies as they are developed

› Indoor facilities to protect our employees and fleet from the elements, an essential feature for BEBs, while minimizing noise and disruption for nearby residents and businesses

› Capacity to house enough buses to expand our fleet and support potential increased ridership

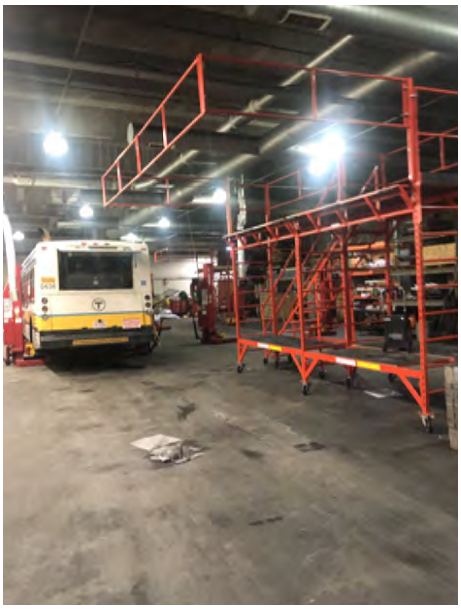
› Many facilities will also have innovative electric heat systems, meaning all fossil-fuel emissions from facilities will be eliminated along with tailpipe emissions

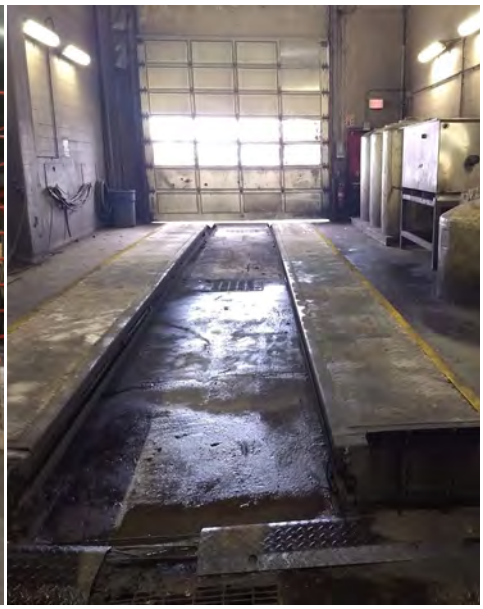
The MBTA is closely coordinating with the utility providers to upgrade building system needs, discussed in detail Section 5, Public Engagement, Partnerships, and Stakeholders. Each of these elements will be crucial to support the maintenance and operation of BEBs. In addition, while we are starting with charging infrastructure only at bus facilities, we will add in on-route charging as needed and continue to explore and adapt to new charging technologies as they evolve.

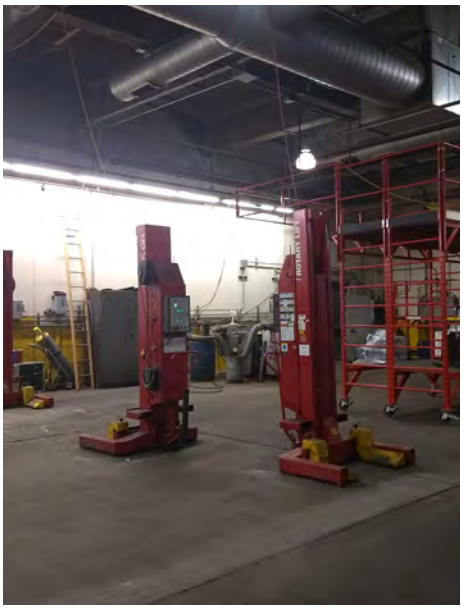
Necessity of Bus Facility Upgrades: Fleet Emissions Analysis

The MBTA is charting a path to meet the Commonwealth's goals through its bus fleet and facility plans. In support of this work, the T completed a fleet emissions analysis for bus electrification efforts, shown in Figure 4.

The analysis shows that the MBTA's electrification efforts provide a long-term vision that reduces bus fleet emissions while staying ahead of statewide emissions targets in most scenarios. However, as the figure on the next page shows, there are scenarios in which MBTA could fall behind the Commonwealth's target. The pace of facility upgrades to support BEBs represents the largest risk to the vision of an emissions-free fleet. In order to meet the 2040 zero-emissions bus fleet target, we will need to ensure facilities are not a bottleneck to BEB adoption. Additionally, the MBTA will seek out technological opportunities







to enhance the T's vision over the decades to come.

The following four scenarios are represented in Figure 5:

Unconstrained Scenario – This scenario illustrates the limit on how fast the MBTA can electrify the bus fleet without violating FTA guidelines for useful vehicle life. When a bus reaches the end of its useful life in this scenario, it is replaced by a BEB. This scenario does not take into account the facilities' capacity to support BEBs with charging infrastructure or technology readiness.

Business as Usual – This scenario represents the resulting emissions if the MBTA were to buy hybrid buses indefinitely without moving toward a full electrification. While this is not a planned scenario, it illustrates the worst case for bus fleet emissions for the MBTA and provides a useful baseline for comparison.

Bus Electrification Scenarios – This analysis spans scenarios that vary facility build rate and battery technology readiness. The resulting shaded area illustrates the range of emissions outcomes if new BEB facilities are built every 2 to 5 years. Based on this analysis and an evaluation of existing facilities, the MBTA identified the prioritized sequencing and target timeline for facility reconstructions as its Implementation Plan.

Statewide 2050 Decarbonization Roadmap – This represents the statewide emissions targets laid out in the Massachusetts 2050 Decarbonization Roadmap. The MBTA bus fleet currently makes up 0.1% of statewide emissions. While the MBTA is not explicitly given a target in the state roadmap, we will demonstrate leadership in reducing carbon emissions by outpacing the statewide guidelines. Note that the emissions guidelines shown

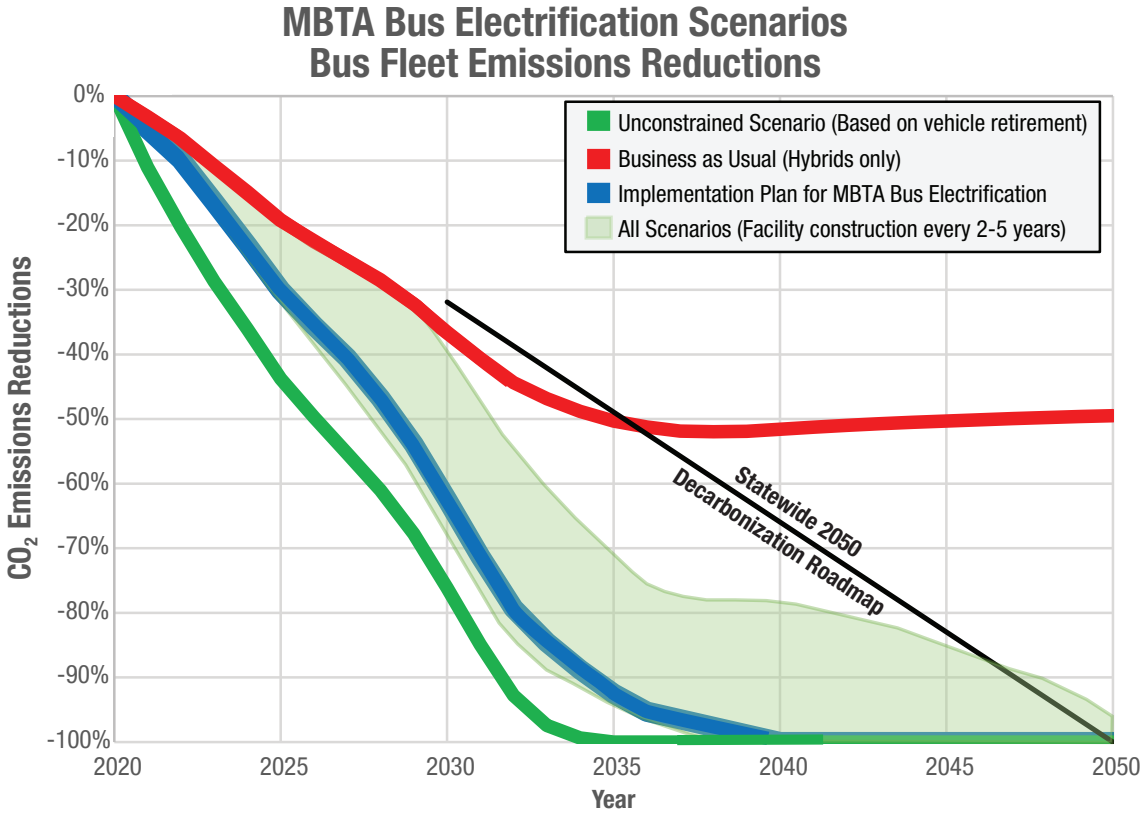


Figure 5. Potential bus electrification and emissions reduction scenarios

in the figure have been translated from a 1990 baseline to a 2020 baseline. These guidelines reflect the reduction in 1990 emissions levels with a target of 45% reduction by 2030 and net-zero emissions by 2050.

Current Facilities

Currently, the MBTA operates our bus fleet from nine legacy bus storage and maintenance facilities (also known as "depots" or "garages") of various sizes in Boston, Cambridge, Malden, Lynn, and Quincy. All nine facilities present challenges that already inhibit current operations and limit both future growth and the transition to electric buses.

Quincy, Fellsway, and Lynn are the oldest facilities in the MBTA's network, and they are among the most constrained, with North Cambridge having the smallest capacity. Charlestown, Cabot, and Southampton are the largest facilities and are also the most centrally located within the region served by the MBTA bus network. Some facilities, including Arborway, are partially or even almost entirely outdoors, which exposes employees and vehicles to the elements and leads to elevated noise levels for neighbors. These outdoor facilities

Nine maintenance garages house **1,150 buses**, with a **limit on expansion** and **zero facilities** that accommodate a full BEB fleet.

1904
Quincy Opens

1925
Fellsway Opens, Quincy to Bus

1936
Lynn Opens

1941
Albany Opens

1975
Cabot + Charlestown Open

1979
North Cambridge Opens (ETBs)

2002
Southampton Opens (60-ft only)

2004
Arborway (temporary facility)

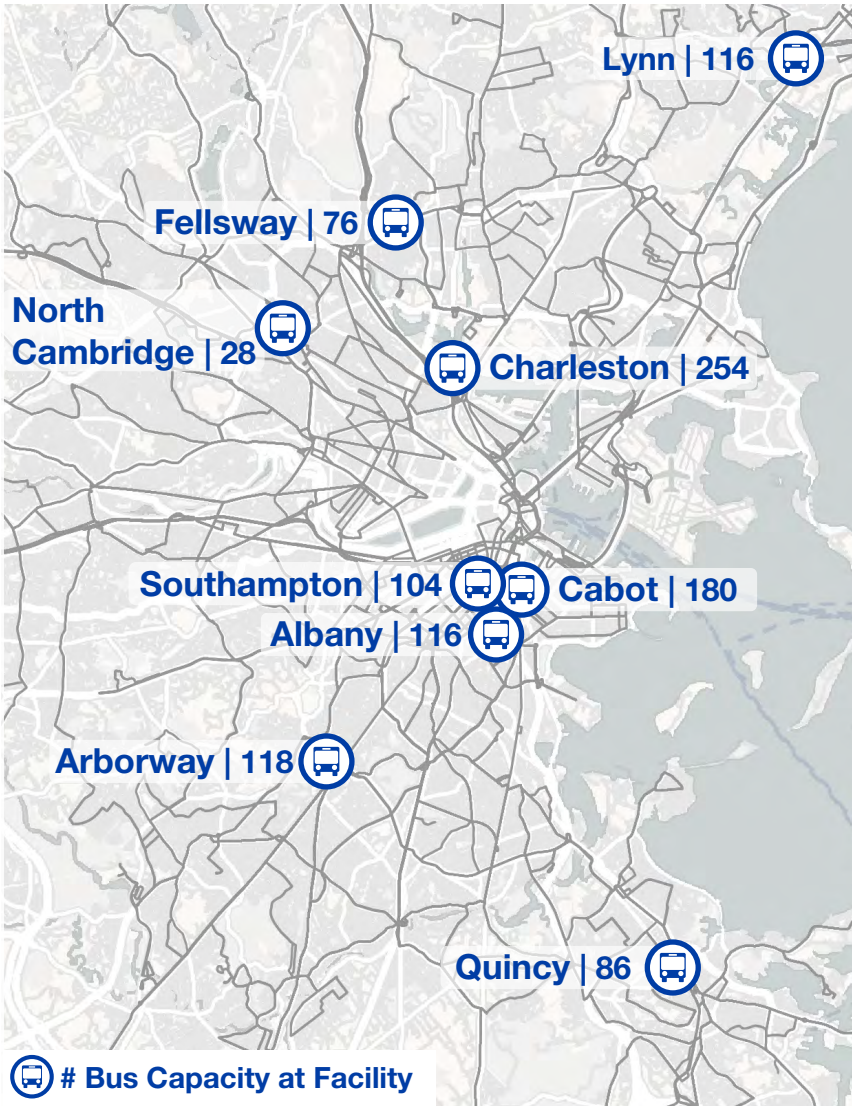


Figure 6. Number of bus capacity at each MBTA facility

would be especially problematic for electric vehicles, which benefit from indoor storage, charging, and maintenance to perform at a satisfactory level on the road.

Integrated Bus Fleet & Facilities Planning Process

In 2017, MBTA launched a comprehensive condition assessment to provide facility improvement recommendations for all nine bus maintenance facilities, as well as facilities supporting other modes. We have identified upgrades that will be needed over the next 15 years to modernize these critical facilities.

Facility Investment Prioritization & Implementation

Recognizing the tremendous scale of investment needed to upgrade each bus maintenance facility, MBTA has performed a detailed evaluation and prioritization analysis to guide the scale and sequencing of related capital investment decisions. This prioritization is closely tied to the rollout of BEBs: each time a new bus facility opens, it will open with BEBs, so all of the routes that the facility serves will be zero-emission routes from day one.

New facilities are slated for construction every 2 to 3 years, allowing for a phased adoption of electric buses and the completion of the entire emission-free bus fleet transition process by 2040. To align with MBTA goals of equity and sustainability as well as reliability and resilience, we have used the following criteria to determine the sequencing of facility upgrades:

- **Transit-Critical Communities** – We have prioritized facilities that will provide electric buses on routes that serve a high percentage of people of color and low-income households. This analysis takes into account the demographics of the populations served by existing facilities, as well as seeking opportunities to design new facilities that can absorb nearby transit-critical routes where operationally feasible and accelerate the deployment of zero-emission buses in areas that have been overburdened by pollution impacts in the past.
- **Ridership** – The MBTA has prioritized upgraded facilities when they support bus routes that serve a greater share of MBTA bus ridership. This includes assessing the ridership served out of existing facilities and seeking opportunities to design new facilities that can absorb nearby high-ridership routes where operationally feasible.
- **Current Facility Conditions** – Identifying and replacing or upgrading facilities that are currently at the end of their useful life and not up to modern standards is a priority for the MBTA. Facilities that no longer support any modern bus fleets or are in poor condition will be replaced first.
- **Relocation Feasibility** – Replacing facilities that could be moved to a new location first is a priority factor, as this practice opens up temporary space ("swing space") that can be used while other facilities undergo reconstruction at the same location. This practice will allow for operational efficiencies and reduce service disruptions for riders. The MBTA's largest and most centrally located facilities are in the urban core, where land is scarce and expensive. We will prioritize rebuilding in place at these locations, which requires them to be modernized last.

Table 1 shows the full results of the prioritization analysis based on the implementation plan. As part of the implementation plan, some routes will be moved to different facilities, while others will be combined or renamed. This table reflects those future changes.

Table 1. Prioritization Analysis Results

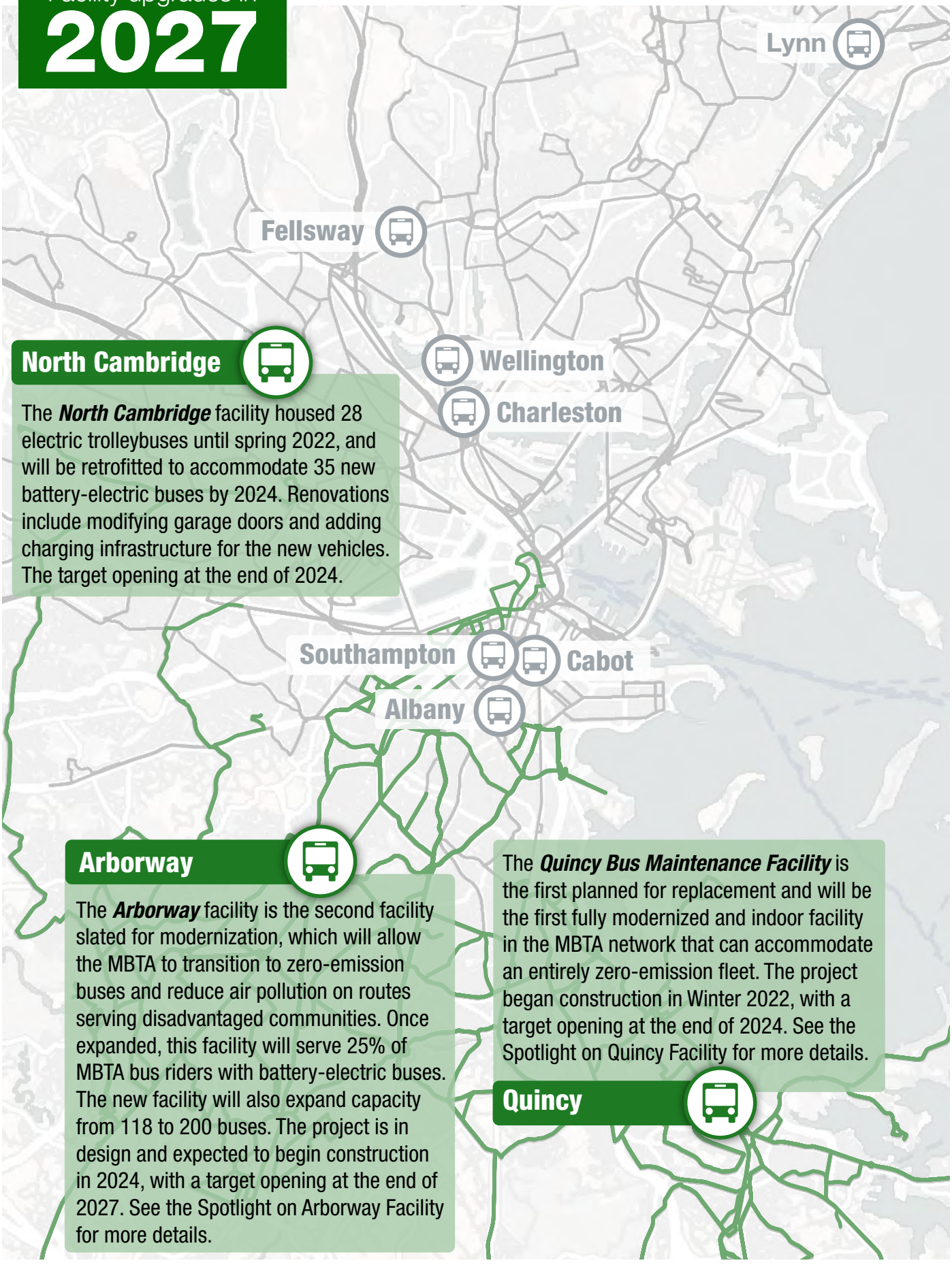
FACILITY	EQUITY	RIDERSHIP*	CONDITION	RELOCATION FEASIBILITY
Quincy	Medium	4.3%	Obsolete	Feasible
Arborway	High	24.3%	Poor	Feasible
Wellington (former Fellsway)	Medium	20.5%	Poor	Feasible
Lynn	High	3.8%	Poor	Feasible**
West (Albany/N Cambridge)	Low	7.9%	Poor	Feasible
Cabot	High	20.3%	Fair	Extremely Difficult
Southampton	High	4.7%	Good	Extremely Difficult
Charlestown	Low	13.5%	Fair	Extremely Difficult

** Based on percent of total bus ridership for the average weekday in fall 2021.*

***Lynn must follow Wellington, as several routes from Lynn will move to Wellington, and Lynn will be reconstructed as a smaller facility.*

The following maps illustrate the rollout of new facilities between now and 2040, including details on the current plans for each of MBTA's nine facilities that will be addressed in our depot-by-depot approach to the zero-emission bus fleet transition.

Facility upgrades in 2027



North Cambridge

The ***North Cambridge*** facility housed 28 electric trolleybuses until spring 2022, and will be retrofitted to accommodate 35 new battery-electric buses by 2024. Renovations include modifying garage doors and adding charging infrastructure for the new vehicles. The target opening at the end of 2024.

Arborway

The ***Arborway*** facility is the second facility slated for modernization, which will allow the MBTA to transition to zero-emission buses and reduce air pollution on routes serving disadvantaged communities. Once expanded, this facility will serve 25% of MBTA bus riders with battery-electric buses. The new facility will also expand capacity from 118 to 200 buses. The project is in design and expected to begin construction in 2024, with a target opening at the end of 2027. See the Spotlight on Arborway Facility for more details.

Quincy

The ***Quincy Bus Maintenance Facility*** is the first planned for replacement and will be the first fully modernized and indoor facility in the MBTA network that can accommodate an entirely zero-emission fleet. The project began construction in Winter 2022, with a target opening at the end of 2024. See the Spotlight on Quincy Facility for more details.

Figure 7: Phased electrification of routes based on facility upgrades in 2027

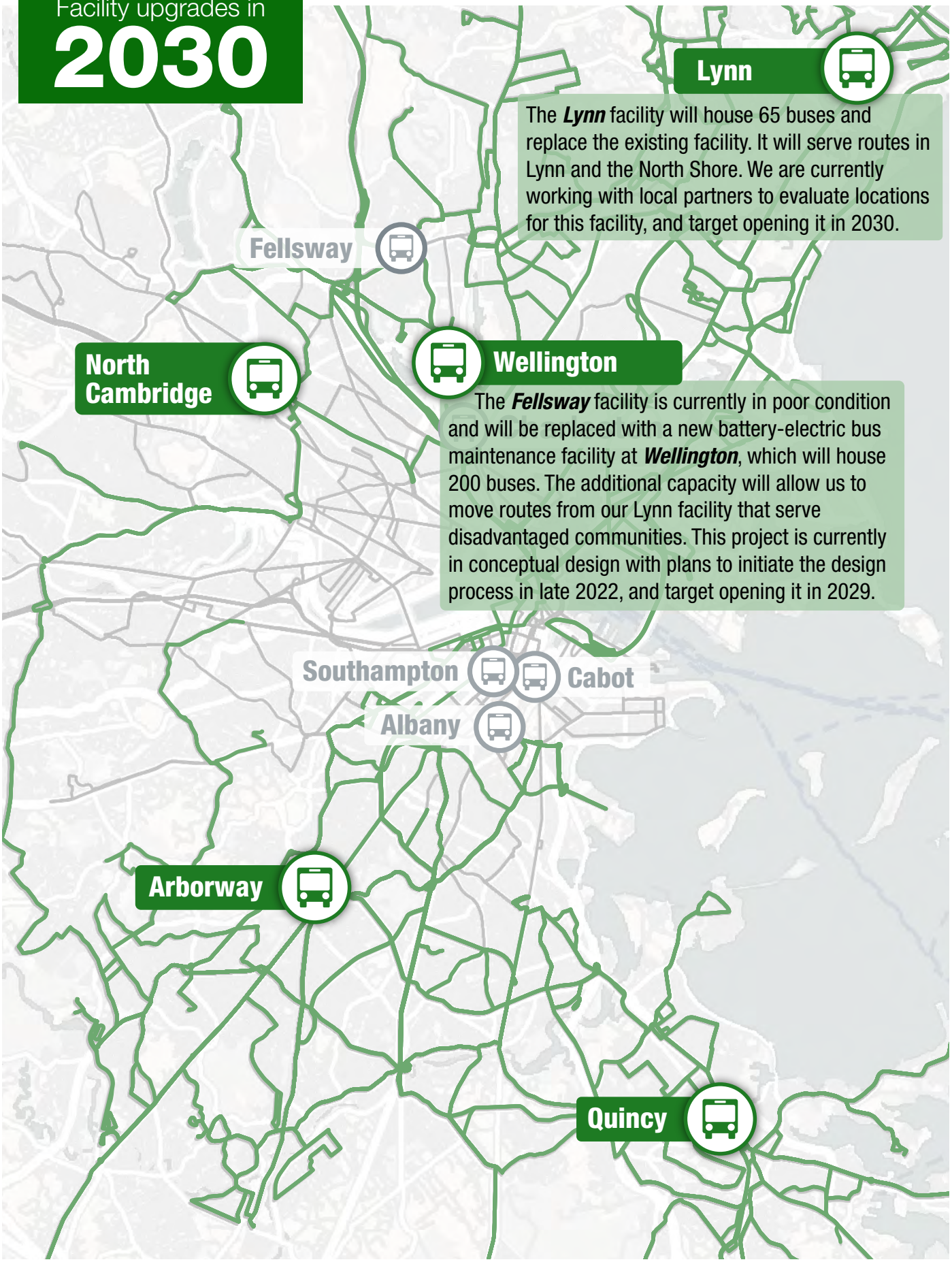


Figure 8: Phased electrification of routes based on facility upgrades in 2030

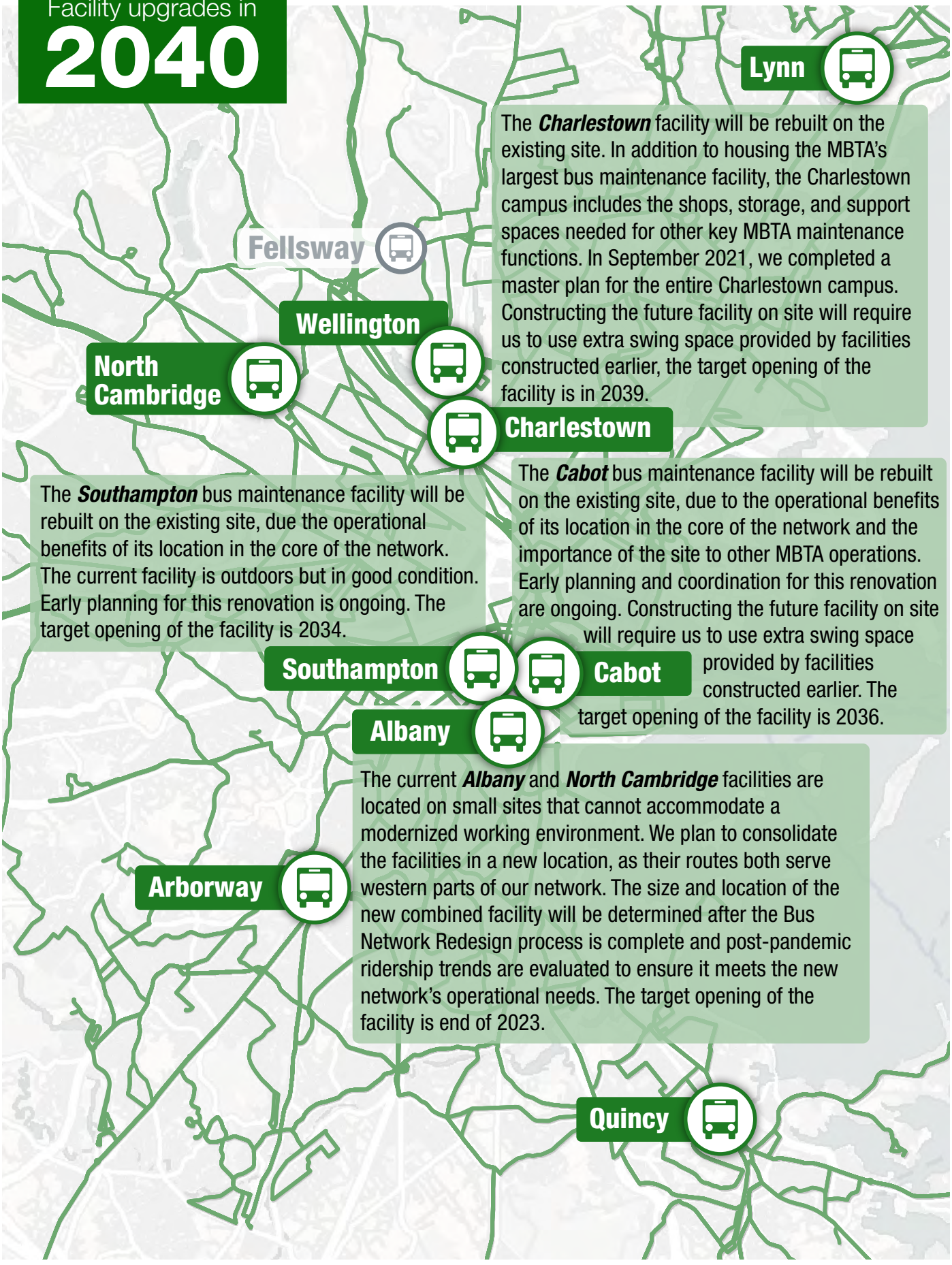


Figure 9: Phased electrification of routes based on facility upgrades in 2040

SPOTLIGHT ON QUINCY FACILITY

Constructed in 1904, at 118 years old, the Quincy bus maintenance facility is the oldest facility in the MBTA system. Although upgrades were made in the 1930s and 1970s, several building elements date back to the early 1900s, making the facility well beyond its useful life, with many obsolete features that make it inadequate for maintaining the current fleet and incapable of being used to maintain more modern bus fleets. Due to low ceiling heights and other constraining building features, the facility can only accommodate MBTA's oldest, least efficient, and most polluting diesel buses, and at only 44,000 square feet, the facility can barely house the 86 diesel buses that are assigned to it. In addition, the buses must be parked outdoors, which is not practical for battery-electric vehicles. These buses have already reached the end of their useful lives, but because of the constraints at the Quincy facility, no other bus type (battery-electric or even hybrid) can be housed or maintained there. In addition, the existing facility provides insufficient working conditions.

The new Quincy facility will be constructed 2 miles from the current garage. Quincy will be the first bus facility in the MBTA network that can accommodate an entirely battery-electric fleet. When the facility opens in 2024, the 86 buses currently housed there, which are at the end of their useful lives, will be replaced by 90 new buses. Half (45) of the new buses will be hybrids, while the other half (45) will be battery-electric, zero-emissions models. Eventually, Quincy will house 120 BEBs.

MBTA's robust public outreach effort as part of the Bus Facility Modernization Program resulted in an opportunity for community members in Quincy to shape the design of the new facility. Community input led to the development of a shared-use path that will be built as part of the facility, allowing residents who live behind the new garage to access the Quincy Adams T Station, just across Thomas Burgin Parkway from the facility.

SPOTLIGHT ON ARBORWAY FACILITY

The Arborway bus maintenance facility dates back at least to 1917 when the site was first used for streetcar storage. Today, the facility contains only outdoor storage for a limited number of buses, and the outdoor storage and temporary buildings result in substandard conditions for our workforce. The facility only supports CNG buses, and the current CNG fleet is expected to reach the end of its useful life starting in 2028. The Washington Street frontage of the current site – now used for bus storage – would be much better suited to community uses such as housing and other services.

The MBTA has sequenced the Arborway facility for replacement after the Quincy facility, with construction of a replacement facility expected to begin in 2024. The construction of the new facility will allow us to expand the Arborway fleet from 118 CNG buses to 200 BEBs, and the new facility will be able to house both 40-foot and 60-foot vehicles. The new facility will provide for two levels of bus operations when it is complete in 2027 and eliminate almost all emissions from buses in southern neighborhoods of Boston, including in some of the lowest-income communities. These routes will provide zero emissions bus service to 25% of MBTA's bus riders across the system.

Finally, the new Arborway facility will be constructed on a parcel adjacent to the current facility, thereby freeing up approximately 8 acres of land along Washington Street for community-driven development.

Photo Credit: David Wilson, www.flickr.com/photos/davidwilson1949/11504375843/in/photostream/

4 | Equity & Workforce Considerations

The MBTA has centered our decision making for its Bus Electrification Plan on equity. It is essential that zero-emission buses and the health benefits they provide are directed to communities with disadvantaged populations that have historically borne a disproportionate share of negative environmental and health impacts.

Equity Analysis

In determining which neighborhoods would receive the first investments in zero-emission buses, typical measures of community vulnerability were necessary but not sufficient. We first identified overburdened communities using the Massachusetts environmental justice screening tool. After completing this analysis, we learned that nearly every bus route in the MBTA system serves at least some overburdened communities. In order to prioritize facilities and routes for the zero-emission transition, we needed to go further in our analysis and considerations.

MBTA's methodology considered the household income and demographics within a defined area around each bus route in the network, given that not only riders but all households near a bus corridor benefit from the reduction in tailpipe emissions that will result from BEB deployments. Routes that served areas with higher proportions of low-income households and communities of color were sorted and averaged by bus depot, in recognition of the fact that BEB deployment will be implemented across an entire bus facility at once.

The final step in the prioritization process was to consider equity alongside other critical factors, such as the requirements to replace certain bus facilities

in place compared to constructing entirely new facilities. For example, Southampton and Cabot serve the greatest number of people of color and low-income households, but are also located ideally in the core of the network where it would be difficult to find large enough swaths of land to replace these facilities on new sites. Therefore, each of these facilities must be reconstructed only after new, larger facilities for BEBs have been completed elsewhere in the network. This will allow the MBTA to fully or partially close each of these facilities during their reconstruction and operate their service uninterrupted out of other facilities in the network where there is extracapacity.

To accelerate emissions reductions for low-income communities, we will move high-ridership routes currently served by the Cabot and Southampton facilities to the new Arborway facility, which also serves a large percentage of low-income households and people of color. We have prioritized Arborway and moved these routes out of facilities that will be completed later in order to ensure that the communities that have faced the highest environmental burdens receive the benefits of bus electrification first.

Table 2 shows the results of the equity analysis.

Table 2. Equity Analysis Results

AFTER FACILITY	% PEOPLE OF COLOR IN SERVICE AREA	% LOW-INCOME HOUSEHOLDS IN SERVICE AREA	PRIORITIZATION
Southampton	54%	41%	High
Cabot	55%	39%	High
Arborway	54%	35%	High
Lynn	40%	34%	High
Wellington (Fellsway)	39%	29%	Medium
Quincy	40%	28%	Medium
West (Albany/N Cambridge)	37%	28%	Low
Charlestown	38%	25%	Low

Commitment to Our Workforce

MBTA is committed to the safety of our employees, as well as to providing job training and other opportunities to ensure that our skilled mechanics, technicians, and bus facility staff benefit as much as our riders will from the transition to BEBs. Currently, MBTA workers in maintenance and transportation operations are familiar with fossil-fuel buses and traditional bus facilities. Driving and maintaining a fossil-fuel-powered bus can present different challenges than driving and maintaining a BEB. In addition, power and facilities staff will face new challenges with bus chargers and all-electric heating systems in facilities. The transition to BEBs also presents new safety challenges, given the introduction of new, high-voltage charging infrastructure. The MBTA is committed to closely monitoring and evaluating safety hazards and mitigations as the fleet is rolled out and becomes operational.

Partnering with Our Workforce on Facility Design

At each facility design milestone, we engage maintenance employees and facility staff in design workshops where they provide input and take part in a collaborative process to plan the new facilities. Our frontline workers know our facilities and operational processes better than anyone else. Already, they have suggested improvements that will make the facilities operate more safely and efficiently. Our design team has incorporated these changes into facility plans and will continue to do so as the design process progresses.

Prioritizing Worker Safety

We also convene a Safety Management Working Group that meets regularly with the design team to complete and review the findings from the safety certification process, jobs hazard analysis, and any other concerns raised through the design process. During construction and commissioning of the facility, the safety certification process ensures that every aspect of the facility is designed with worker safety in mind.

Partnering with Our Workforce on Operational Changes

To proactively address workforce training and retention in the context of the zero-emission bus fleet transition, we are convening a steering committee and working group to identify the breadth of potential operational impacts associated with the deployment of BEBs and the construction of new, modern facilities. This team includes all the departments and representatives needed to assess the potential impacts and to identify operating budget, process changes, or resources needed to support planning and scheduling service, managing charging software, operating and maintenance of charging equipment, and other activities. Specific challenges for this team include determining staffing needs to support new charging and bus assignment processes and maintain charging infrastructure and determining the types and duration of training that will be required to adapt to these new processes.

In addition to the concerns listed in the previous paragraph, we will work collaboratively with our employees to address the following upcoming challenges and changes with a focus on innovation and continuous improvement:

Workforce Processes:

› Identify and define new roles and responsibilities related to charging and charge management, especially for maintenance staff who currently fuel buses and prepare facilities for morning pull out.

› Quantify the number of additional staff needed in the power department to support the maintenance of charging infrastructure.

Operational Processes:

› Integrate battery ranges into scheduling.

› Develop standard operating procedures for operations and maintenance staff in responding to low battery or no battery bus situations or chargers breaking down.

- Determine how the charge management system will orchestrate charging given bus parking location and service needs, as well as how this system will integrate with existing MBTA fleet management and scheduling systems.
- Assess the type and level of support required from the charger and charge management system vendor.

Supporting Upskilling

The transition to zero-emission vehicles and facility modernization will present opportunities for MBTA employees to gain new skillsets and take on interesting, challenging work that will be transferable to other green economy jobs. Workforce strategy is therefore a critical component of the bus fleet and facilities transition planning process. We are already planning for this shift in work processes and required skillsets with a workforce development program currently underway.

As we order BEBs and chargers, specifications include extensive training requirements for manufacturers to directly train MBTA staff and provide training materials in a format compatible with the MBTA e-learning system. In addition, the Bus Maintenance Department will develop continuous and refresher training to transition the workforce to the new technologies.

In the longer term, additional workforce training may be required as the MBTA adds new technologies such as on-route charging infrastructure to continue to improve zero-emission bus operations. Scheduling and operational adjustments may also be necessary at that point to adapt to new technologies. We will use a similar approach to addressing those changes as the one outlined above, including engaging operations staff at all levels with the implementation process.

Collaborating with Our Employees to Identify Training Needs

In addition, the BEB Operational Transition Steering Committee and Working Groups include members from all relevant departments working together to develop a robust training plan and identify training budget and resource gaps. These teams are meeting biweekly from March through September 2022 and may convene again in the future as the Bus Facility Modernization Program and bus electrification transition continues.

DEPARTMENT	KEY NEW ROLES AND NEEDS (NON-EXHAUSTIVE)
Bus Operations and Dispatch	› Training operators on driving techniques to support battery range › Assigning buses based on state of charge › Developing protocol for low/no-range emergencies while in service
Bus Maintenance	› Replacing fueling workflow with charging workflow › Maintaining buses with additional software and larger batteries
Planning and Scheduling	› Integrating battery range into bus scheduling
Power Department	› Maintaining chargers and pantographs (preventative, corrective, breakdowns)
Asset Management	› Collecting lifecycle data on new assets (e.g., charging infrastructure)
IT	› Supporting installation and operation of charge management system
Safety	› Developing protocol for new high-voltage working conditions › Developing protocol for potential thermal event
Environmental	› Incorporating charging into power-demand management and contracts with utilities › Assessing plans for battery recycling

5 | Public Engagement, Partnerships, & Stakeholders

The MBTA is taking a facility-by-facility approach to public engagement to line up with the overall electrification strategy. Each step of the MBTA's Bus Electrification Plan has been guided by the input of a wide range of community members and regional stakeholders. For each facility design, we have followed a robust public and stakeholder engagement process from the very beginning, with outreach to the community and public meetings at each design milestone. Regular meetings with municipalities and state agencies are also included in the design process for each facility. Relevant municipalities and agencies depend on the specific facility but include the City of Quincy, City of Boston, City of Lynn, Department of Conservation and Recreation, and Massachusetts Department of Transportation, among others. These ongoing public and stakeholder meetings result in feedback on design details, planning approaches, and additional ways for partners to collaborate on new facility and fleet implementations.

Direct community engagement is critical to the process, and we hold small group meetings for critical stakeholders, including abutters and groups representing bus riders affected by the transition to BEBs at each facility. In the case of Quincy, this process resulted in a number of modifications to benefit the community, such as changing a sidewalk to a shared-use path to accommodate bicycles and adjusting the design of fencing based on neighborhood input. Our productive working relationship with the community and other public entities has also led to community benefits resulting from the Arborway project, including the transfer of a large parcel of land to the City of Boston for a potential mixed-income housing development.

PARTNERING WITH UTILITY PROVIDERS TO POWER OUR NEW ELECTRIC FLEET

Providing for the electrical infrastructure needed to power BEBs is essential to the success of the bus fleet and facility transition. Most bus charging will take place at the maintenance facilities, but on-route charging will also be deployed on certain routes. Ensuring that the Boston region's electric grid can supply this needed power is a top priority for MBTA and its partners.

To ensure the successful deployment of the new BEBs and maintenance facilities, MBTA meets at least quarterly with the two utility providers in the bus service area – Eversource and National Grid. This collaboration focuses on the power needs associated with each facility, which are driven both by bus charging and the facility operation (Arborway, for example, is planned to be 100% electric in accordance with **Massachusetts Clean Energy and Climate Plan** goals around building heating systems).

The goal for MBTA is to identify how much power is needed to operate service while incorporating strategies to manage peak load. The MBTA collaborates with the utilities to understand their peak load drivers and the potential strategies to provide mutual benefits.

6 Costs and Funding Options

The bus electrification transition is an ambitious effort that will take decades to complete. Current cost estimates for completing a new bus maintenance facility every 2 to 3 years until each facility is replaced are in the range of $300 million or more, plus escalation per each facility over the next 15 years. These estimates could change significantly due to price volatility in construction materials, new technologies, and labor. In addition to construction costs, these projects include a range of additional costs. For example, design contracts and design oversight support (per Massachusetts General Law) can cost from $30 million to $40 million per each facility, depending on site and building complexity. Real estate can also be a significant cost and create uncertainties; therefore, we intend to minimize real estate purchases whenever possible. Upgrades to electrical services are required at the facilities in order to meet power demands for charging a full fleet and operating a sustainable, fully electric building. We expect these upgrades to cost approximately $10 million per facility. In addition, the MBTA tracks its internal costs to the capital budget so as not to burden the operating budget with capital expenditures. Internal project support including project management/administration, inspections, and operational support to deliver and commission the buildings is expected to cost between $10 and $20 million per facility.

While facilities will be the largest line item in the bus fleet transition program, there are other significant capital costs. The expected budget is $100 million per year in zero-emission bus purchases for approximately 80 to 100 new BEBs annually. Currently, the price point for electric buses is higher than comparable diesel or CNG vehicles, in part due to battery changes as they become degraded due to prolonged use. However, prices may change

relative to other vehicles as the technology is more widely adopted and production increases. With the uncertain future of transit ridership, it is difficult to predict the future size of the MBTA fleet in 2040, the final year of the transition. However, we expect that the total cost of vehicle purchases will be between $1.5 and $2 billion, or about 30% higher than purchasing an equivalent number of diesel, hybrid, or CNG vehicles. Some of these costs are due to modernizing out of date facilities and not electrification specifically

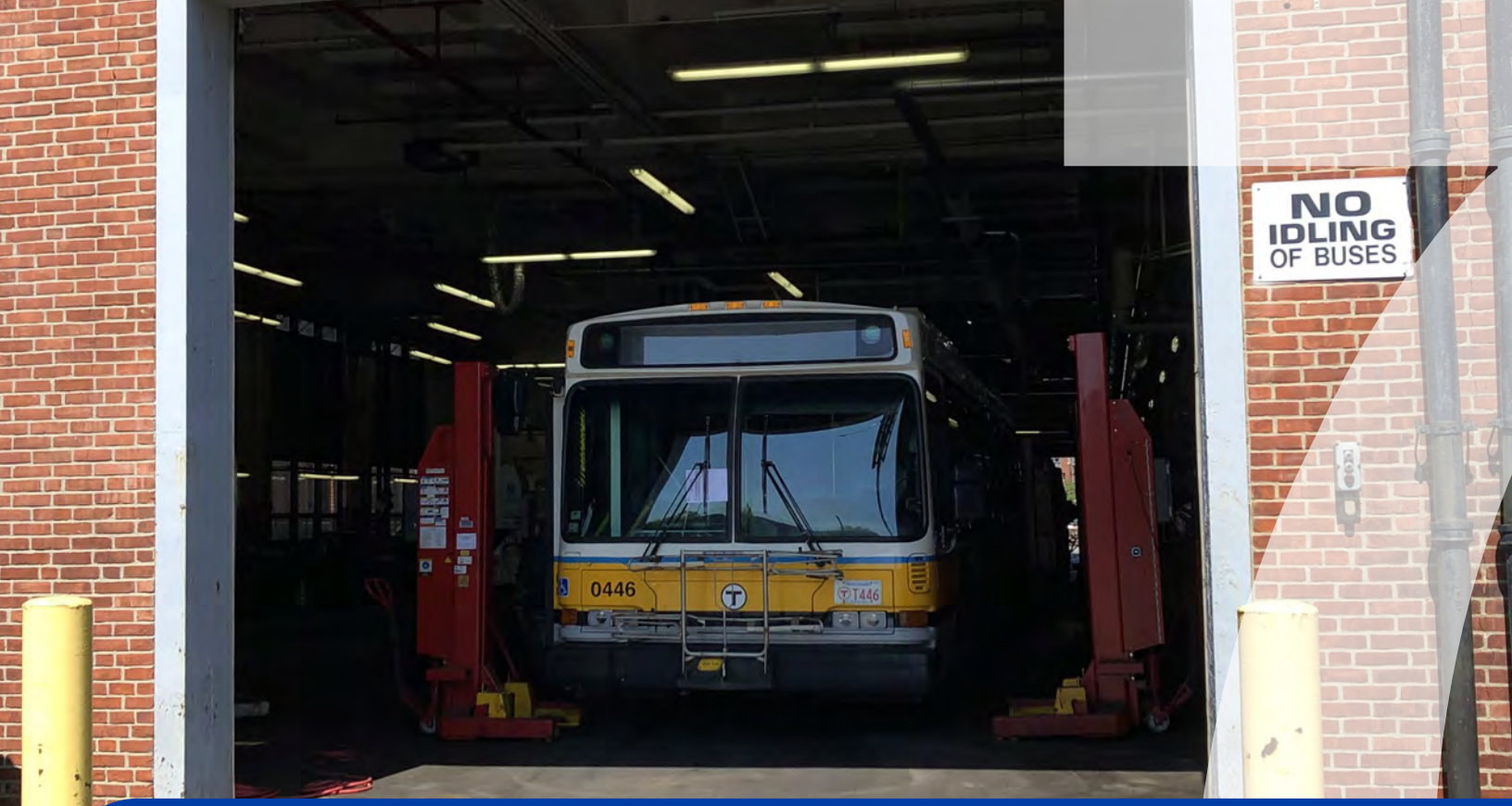
There will be some operating costs incurred during the transitional period as well. Training and upskilling both current maintenance employees and new hires will be a further cost, although employee retention could also increase due to better working conditions and the challenge of working on a new technology. Operators also may need to adjust driving styles to maximize mileage from electric vehicles, at least until technology improves and range is less of a concern, which will add another training-related cost in the near term. Training costs will be a short-term investment in the early years of the transition, as new hires will be working solely with BEBs rather than juggling multiple fleets of different types of vehicles. In some cases vendors will provide training, and service contracts will also factor into the cost of the transition.

In the long term, the new fleets may come with savings that will partially offset the costs. Electricity may be a more affordable source of energy than diesel or CNG, especially as new renewable energy sources become available, and the contract is 100% offset by renewables. In addition, maintenance costs could go down as electric vehicles potentially require fewer parts and supplies.

Currently, the first steps in the MBTA bus fleet electrification process are fully funded. This includes the Quincy bus maintenance facility through construction, preliminary design, and planning for all facilities; design for the Arborway BEB facility; and the purchase of 80 BEBs, which is in the 2023-2027 Capital Investment Plan currently under review by the MBTA Board. However, as much as several billion dollars of the construction and vehicle costs detailed in the previous paragraphs are not yet funded.

Funding Options to Support the Transition

Potential funding sources to address the high costs of transitioning to a zero-emission bus fleet include federal grant programs such as discretionary low or no-emission vehicle grants, which saw a significant increase in funding in the recently passed Infrastructure Investment and Jobs Act. We will also explore opportunities for joint development and public private partnerships on our sites to help offset costs and support compatible uses in areas with high land costs. The MBTA is exploring FTA Bus & Bus Facilities grants to help with the cost of new, indoor facilities that will be ready for electric vehicles. State funds may also be available to help move the program forward. The Massachusetts Clean Energy Center also provides grants to promote zero-emission transportation options including the DeployMass grant program for public agencies. Congestion Mitigation and Air Quality Improvement Program grants may also cover some of the expenses of transitioning to an all-electric bus fleet.



7 Next Steps

Implementing the ambitious transition to a zero-emission bus fleet will come with additional challenges and opportunities. We envision working collaboratively with our employees and the community to work through facility design, workforce development, and operational challenges to make the transformation a reality.

The MBTA is looking forward to working with our partners, stakeholders, funding agencies, workforce, and customers to make our bus fleet and facility transition a reality. We are committed to leading the way to a cleaner, emission-free future benefitting our entire region and all of the communities we serve.

As we continue on our journey to full bus fleet electrification, updates and opportunities for comment and participation will be available on our website.


NOT IN SERVICE