Zero-Emission Bus Conversion Report
TR § 7-406(f)(1)
SB 61/Ch. 463, 2022

A Report to the Maryland General Assembly

Senate Budget and Taxation Committee

Senate Education, Energy,

and the Environment Committee,

House Appropriations Committee

and

House Environment and Transportation Committee

Maryland Department of Transportation

Maryland Transit Administration

MSAR #13941

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Introduction

The Maryland Transit Administration (MTA) offers this report in response to the following language contained in Senate Bill 61, Chapter 463, Acts of 2022:

> *(f)(2) The annual report shall include:*
>
> *(i) A schedule for converting the Administration's State transit bus fleet to zero–emission buses;*
>
> *(ii) An evaluation of the charging infrastructure needed for the Administration to create and maintain a State transit bus fleet of zero–emission buses;*
>
> *(iii) A plan for: 1. Transitioning any State employees adversely affected by the conversion from a diesel–powered State transit bus fleet to a zero– emission State transit bus fleet to similar or other employment within the Administration or Department that has commensurate seniority, pay, and benefits; 2. Ensuring that no duties or functions of State employees are transferred to a contracting entity as a result of the conversion from a diesel–powered State transit bus fleet to a zero–emission State transit bus fleet; and 3. Ensuring that any entity other than the Administration that operates or maintains zero–emission buses on behalf of the Administration provides employee protections equivalent to the protections required by the plan;*
>
> *(iv) A certification that the Administration is adhering to the plan required under item (iii) of this paragraph;*
>
> *(v) In coordination with other appropriate State agencies, an estimate of the reduction in the amount of carbon dioxide emissions, measured in pounds, that will be obtained through the use of zero–emission buses each year until the State transit bus fleet is converted to zero–emission buses; and*
>
> *(vi) A financial analysis: 1. Of the projected cost of purchasing, maintaining, and providing charging infrastructure for the zero–emission State transit bus fleet each year until the fleet is converted to zero–emission buses; and 2. Comparing the projected cost under item 1 of this item to the projected cost of continuing to operate a diesel–powered State transit bus fleet."*

In 2016, The Maryland Greenhouse Gas Reduction Act Reauthorization[1] set a 40 percent reduction target for statewide emissions by 2030 from 2006 levels. The MTA subsequently established a goal to convert 50 percent of its Core Bus fleet in the Greater Baltimore region to zero emission buses (ZEBs) by 2030. This goal was also included in the 2020 Central Maryland Regional Transportation Plan (CMRTP), along with a longer-term goal to convert 95 percent of

[1] 2030 GGRA Plan Executive Summary (https://mde.maryland.gov/programs/Air/ClimateChange/Documents/2030%20GGRA%20Plan/2030GGRAPlanExSum01272021.pdf)

the Core Bus fleet to zero-emission buses by 2045. The passage of Senate Bill 137, Chapter 693 (2021) confirmed that MTA is prohibited from entering into new procurements for non-ZEBs beginning in Fiscal Year 2023.

This report primarily reflects MTA's progress in advancing the ZEB program as of October 2023. In December 2023, a reduced capital budget was proposed to close a gap in project Transportation Trust Fund revenues. This reduced budget includes reductions to ZEB funding, necessitating that MTA adopt a slower transition pace. The preliminary impacts of this change are discussed in the "December 2023 Budget Impacts" section of this report.

In 2020, MTA commenced a two-phase Zero-Emission Bus (ZEB) Transition Study that evaluated facility upgrades, utility infrastructure, rolling stock, and charging infrastructure needed to achieve the 2030 transition goal. Since then, MTA has undertaken extensive work toward preparing charging infrastructure, developing workforce training and procedures, and procuring zero-emission buses.

In 2022, MTA contracted for its first zero-emission buses. These vehicles, seven New Flyer battery-electric buses (BEBs), arrived in Baltimore between July and September 2023. Utility upgrades were completed to power vehicle chargers at the Kirk Bus Division, and implementation of a training program to upskill staff to work with these new vehicles has occurred. Additionally, MTA has advanced engineering and operational planning for the subsequent phases of the zero-emission bus transition. Requests for Proposals (RFPs) for a new multiyear zero-emission bus contract, and for a bus depot and electrification partner to install and support chargers, were issued in the Fall of 2022. The MTA continues to explore options for future zero-emission bus contracts.

According to CALSTART, an industry research organization, approximately 5 to 10 percent of the U.S. transit fleet currently consists of ZEBs. In light of decarbonization mandates, policy targets, and grant funding that supports ZEB fleets, transit agencies will be implementing larger ZEB fleets in the immediate future. Agencies are facing fast learning curves as they integrate ZEBs into their fleets. Technological advancements, such as battery capacity, are beginning to improve vehicle efficiency but these innovations will take time to thoroughly test and evaluate as ZEBs continue to enter transit service.

Despite technological advancements, the full lifecycle cash cost of a transition to BEBs is still higher than the cost of continuing operations of clean diesel buses. Fuel costs are lower for BEBs than for clean diesel buses, but overall costs for BEBs are higher than for clean diesel buses. The high capital costs of BEBs, their batteries, and charging infrastructure offset any fuel savings. However, operating cost benefits are highly dependent on factors that are continually evolving as BEBs are deployed in transit service.

Global supply chain issues will constrain delivery timeframes from vehicle and infrastructure manufacturers for the next few years. Vehicle production lead times, as well as charging infrastructure and utility support equipment, are strained by material sourcing delays and can be more than12 months. Transit agencies nationwide are concurrently placing large ZEB orders, placing strain on a diminishing pool of manufacturers that serve the U.S. transit market. As ZEB

technology is constantly changing, warranty terms for buses and chargers are critical to ensure transit service to the Greater Baltimore region is not disrupted. Where possible, MTA is preparing contingency plans to mitigate external risk factors, including vehicle and charger delivery delays.

Background

MTA's Phase II Transition Study (2020-2021) evaluated the feasibility of implementing BEBs and fuel-cell electric buses (FCEBs) in the Core Bus fleet. Results from the study recommended that MTA pursue BEBs for an initial pilot program to assess their performance. The study also recommended that BEBs be chosen as the propulsion type for the first few years of ZEB-only procurement from 2025-2030.

The recommendation to operate BEBs instead of FCEBs from 2025-2030 was based on several findings. First, BEBs are more widely available and have been deployed in greater quantities in the U.S. transit market, compared to FCEBs. Second, BEBs have lower initial capital costs for both rolling stock and charging infrastructure (depending on scale) compared to FCEBs. Finally, many of MTA's operating divisions are incompatible with existing fire safety codes that regulate the distance between hydrogen storage tanks, vehicles, and buildings.

The state of MTA's four bus depots was key to forming a reasonable transition plan. Kirk Division was chosen to host the pilot program and initial BEB deliveries due to its shorter service blocks (the group of daily assignments for an individual bus) and minimal construction risk, followed by a portion of Northwest Division. Eastern Division, which has exceeded its useful life, was slated to undergo a full reconstruction to become one of North America's first purpose-built BEB depots. Bush Division, a historically protected site that houses many of MTA's bus maintenance shops, was slated for conversion after 2030 to allow time for the agency to glean lessons learned from facility projects and bus performance.

Furthermore, service modeling during Phase II of the Transition Study found that BEBs can complete a majority of MTA's existing service blocks, given current range capabilities and conservative operating assumptions. These assumptions incorporate weather, gross vehicle weight, and battery availability. Inputs to this service modeling included assumptions that factored in:

- Greater Baltimore's topography
- MTA service and schedule data from General Transit Feed Specification (GTFS) data, representing pre-pandemic operations
- Gross Vehicle Weight of BEBs, based on vehicles available on the market in 2020
- Assumed temperature of winter months, to utilize as conservative an assumption as possible.

The facility transition schedule (**Table 1**) was developed based on a service block completion analysis. Due to its short service blocks, MTA identified Kirk Division as the most suitable location for the pilot program and the initial full-facility BEB retrofit.

This study, which provided the framework for MTA's fleet conversion through 2030, recommended that the integration of FCEBs remain under evaluation for future facility

transitions. Specifically, FCEBs will be considered for facility transitions at Northwest Division due to the division's longer service blocks that may exceed currently available BEB range capabilities, as well as its ample space to accommodate the required setback requirements for hydrogen infrastructure in relation to buildings.

The MTA completed a Hydrogen FCEB Fuel Study in 2023 to evaluate the feasibility of hydrogen production, delivery, storage, and fueling at MTA, focusing on portions of Northwest Division. This study recommended that MTA pursue a FCEB pilot program, testing these vehicles to inform facility design and bus procurement decisions for Northwest and other locations to support post-2030 vehicle deliveries. The MTA is currently in the planning phase for this effort and anticipates commencing this pilot program in 2026.

The MTA is currently conducting a Phase III ZEB transition planning assessment, which focuses on determining specific plans for vehicle propulsion type(s), charging/fueling and maintenance locations, and service integration beyond 2030, including an assessment on the need to commission a fifth bus division to support transit service in the region.

Budget Impacts

In December 2023, a reduced capital budget was proposed to close a gap in projected Transportation Trust Fund revenues. This reduced budget includes reductions to available ZEB funding, necessitating that MTA adopt a slower pace of transition. This section describes the preliminary plan MTA has developed to align with the available budget. This revised schedule reduces annual ZEB purchases from 70 to 20 buses per year from 2025 through 2027, with the remaining 50 bus purchases consisting of diesel vehicles. This schedule also assumes, due to this funding shortfall, that the construction of Eastern Bus Division be postponed to 2027, with a reopening date of 2031.

Changes to the Maryland Zero-Emissions Bus Transition Act are required to align with this slower ZEB transition. While necessitated by the lack of available funding, the slower pace of ZEB transition is more consistent with broader transit industry practices. Many agencies are struggling with long and unpredictable delivery lead times for buses and charging equipment, challenging facility upgrades for charging, evolving safety and manufacturing standards, workforce training considerations, and the expense of ZEB-related improvements. The slower transition is expected to reduce risk that ZEBs and/or required charging equipment (EVSE) cannot be provided to support reliable bus service throughout the ZEB transition.

Table 1 indicates the revised fleet procurement and ZEB fleet transition schedule, to reflect proposed budget reductions. This plan anticipates that MTA will annually procure 20 ZEBs and 50 clean diesel buses from 2025 through 2027, and the purchase of 35 ZEBs per year beginning in calendar year 2028. While MTA is planning for a hydrogen FCEB pilot program to commence in approximately 2026, this fuel-cell bus procurement is in preliminary phases, is only partially funded, and is not included in the fleet transition schedules and cost modeling reflected in this report.

Table 1: Preliminary Annual Deliveries and ZEB Fleet Percentage Schedule

	2023	2024	2025	2026	2027	2028	2029	2030[4]
Zero-Emissions Bus Deliveries[5]	7	0	20	20	20	35	35	35
Total ZEBs in Core Bus Fleet	7	7	27	47	67	102	137	172
Total Fleet Size (Year-End)	807	771	778	807	877	850	849	849
Fleet Share of ZEBs (End of Year)	0.9%	0.9%	3.5%	5.8%	7.6%	12%	16.1%	20.2%

Fleet Transition Schedule

The MTA previously developed a transition schedule for which facilities will be partially or entirely retrofitted to support ZEB deliveries from 2025-2030. More detailed transition planning analysis is ongoing, which will yield a quarterly phasing of charging infrastructure installation and vehicle delivery. As a result of the December 2023 budget reductions, and as MDOT continues to review fiscal constraints, the MTA continues to explore options for future zero-emission bus contracts to advance the fleet's transition.

Several initiatives are underway to advance the upcoming phases of MTA's zero-emission bus transition. A Charge Management Study, completed in March 2022, provided detailed recommendations for how much energy will be consumed, how much on-site power is needed, and how many BEBs may be required to complete existing service requirements. The MTA is currently preparing to onboard a developer to support the design, construction, operations, and maintenance of BEB charging infrastructure at Kirk and Northwest Divisions, in an innovative arrangement that will provide turnkey bus charging, allowing MTA's workforce to maintain focus on operating service and maintaining the bus fleet. For Eastern Division, which will be reconstructed into one of the first bus divisions purpose-built for BEBs in the U.S., a construction manager for pre-construction services was brought on board in fall 2023 to support construction activities.

Contracting lead times, material shortages and delivery delays, and permitting are examples of potential delays that MTA may encounter with facility charging schedules that precede vehicle delivery. MTA is incorporating risk management strategies where possible to maintain its schedule and avoid service impacts throughout the transition to ZEBs.

ZEBs require infrastructure to be constructed, installed, and tested at the divisions before the vehicles can begin operating. Work needs to begin on bus procurements three or more years in advance to mitigate risks from production backlog and supply chain issues that have worsened in recent years. Several manufacturers have exited the U.S. transit bus market or had their production capacity significantly reduced due to financial challenges and compliance issues with Buy America requirements that apply to vehicles purchased with Federal funding. Reduced production output has resulted in cost increases due to increasing demand for ZEBs.

Options are further limited for certain vehicle configurations; as of October 2023, New Flyer Industries is the only manufacturer that will be selling an articulated zero-emissions bus to Federally funded transit agencies after 2024. Some manufacturers are eliminating or reducing extended warranty options, setting the stage for peers to follow suit and forcing transit agencies to bear the responsibility and cost of mid-life overhauls and battery replacements.

Transit properties nationwide are initiating large orders of zero-emissions buses to comply with State and local policies or targets, a trend that has been accelerated in light of the Inflation Reduction Act's expansion of Federal grant funding to support zero-emissions fleets. Concurrently, supply chain delays that arose during the COVID-19 pandemic and have been compounded by nationwide staffing shortages and geopolitical conflict in regions with key materials, continue to impact vehicle and infrastructure production timing and costs.

The MTA is currently evaluating the number of spare vehicles needed for maintenance purposes, training, and other special uses where "bus bridges" are deployed, such as rail replacement service or special events. As the ZEB fleet grows, MTA is working to ensure that consistent levels of reliable service can be delivered by ZEBs throughout the transition. The MTA will assess fleet transition needs beyond 2030 in a third phase of the Transition Study that is currently underway and anticipated to be completed in 2024.

Evaluation of Charging Infrastructure

The Phase II Transition Study evaluated various types of BEB charging infrastructure, including overhead pantograph charging, ground-mounted and overhead plug-in charging, and inductive charging.

Currently, MTA intends to provide all BEB charging at the operating divisions where buses are stored and maintained while not in revenue service. However, the Administration continues to evaluate in-route fast charging stations and the viability and value of installing these at certain locations within the region.

Overhead pantograph charging was determined to be the optimal charging infrastructure method for the BEB pilot and initial facility conversions at MTA. In this type of charging, the pantograph on the bus is automatically deployed to begin charging when the bus parks and the emergency brake is engaged. Overhead pantograph charging provides the fewest disruptions to the existing site, is the least restrictive to future modifications, and minimizes additions to operations and maintenance staff workloads. As transit agencies nationwide begin to scale up their BEB fleets, overhead pantograph dispensers are becoming increasingly selected among the larger transit agencies due to the aforementioned benefits.

Ground-mounted, plug-in charging stations can reduce the number of BEBs that MTA can store at facilities in which they are used, due to the additional ground space that they occupy. Due to their in-ground power distribution, these units are less flexible for redeployment upon shifts in fleet composition and expose staff to additional efforts and risks to plug in the buses. The MTA has procured and installed several plug-in charging stations for the Kirk Pilot program due to significant delays in the procurement and delivery of pantograph charging equipment and intends to install additional plug-in units at Kirk and Northwest Divisions to ensure battery-electric buses

to be delivered in 2025 and 2026 can be charged in the event of continued supply chain delays that may impact pantograph charger deliveries.

Overhead plug-in charging stations, where charging cords connect from ceiling-mounted dispensers, require staff to physically connect and disconnect the plugs to the buses and may present a safety hazard to staff.

Inductive charging, which wirelessly connects the bus to a charging unit embedded in the pavement, is considerably more expensive and complicated to install than plug-in or overhead charging. Inductive charging is disruptive to deploy and presents additional maintenance challenges and expenses associated with pavement upkeep.

The MTA has also procured smaller chargers for maintenance shops, which must be connected to a 480V welding socket but can be moved around the bays on a small, wheeled cart. These units provide a slower charge but are valuable to restore charge to buses during maintenance activities.

Figure *1* provides an overview of hardware that will need to be installed at MTA operating divisions to power BEBs and depicts the flow of electricity from transformers to overhead pantograph chargers, where it is dispensed to the bus.

Figure 1: Battery-Electric Charging Infrastructure Overview

Utility Upgrades

New, large-scale electrical service will be required to install the new charging stations. The new electrical loads are more than 10 times greater than the existing electrical loads at the sites and will require significant investments by MTA to support electrical service upgrades to each facility. The voltage and capacity of that service will be determined by Baltimore Gas and Electric (BGE), according to the power demand required by the new equipment. The MTA holds bi-weekly working sessions on all bus facilities with BGE and has filed several applications for new electrical service upgrades at various sites, which can be entered into BGE's planning process approximately two to three years in advance of the requested service commencement date. Upon receipt of the application, BGE reviews the available capacity on the overhead and/or underground circuits, and BGE substations. BGE also conducts surveys (manholes and ducts) to identify future pathways of new service feeders and presents the available alternatives and options for installing the new services. BGE has started engineering designs for various facilities.

Installation plans will be site dependent. While the enhancements required for the seven-bus Kirk BEB Pilot included a new utility pole, transformer and conduit, as well as some earthwork to level land, larger load enhancements later in the transition may require significantly more construction work to accommodate the additional equipment and redundancy required to support larger BEB fleets. The MTA and BGE are coordinating on long-term energy load planning for all three divisions that includes the scaling of utility infrastructure based on anticipated demand. Optimizing utility infrastructure sizing to align with daily service requirements, as opposed to total connected load, which will never be fully used, may save millions of dollars in capital investment at each depot.

Table depicts the unit cost estimates of charging infrastructure as accounted in MTA's Lifecycle Cost Analysis. For initial deployments, MTA is planning to utilize a ratio of two pantograph dispensers per every one charging cabinet.

Table 2: Approximate Unit Costs of Charging Equipment (2023)

	Unit Cost
Cost per cabinet	$120,084
Cost per pantograph dispenser	$27,920
Cost per one cabinet and one dispenser	**$148,005**
Resiliency Infrastructure - Equipment	$17,285
Charging Equipment Installation	$34,212
Charging Infrastructure cost per bus	**$199,501**

The MTA is evaluating alternate energy systems, such as solar energy and microgrids, to ensure the resilient power supply needed to maintain 24/7 transit operations. MTA will collaborate with BGE and the Maryland Public Service Commission (PSC) to determine innovative solutions that are appropriate for this purpose. Alternative energy systems will allow MTA to benefit from cost savings and will enable reliable power during times of the year when the local utility is straining to supply power to its customers, such as during heat waves or serious storms.

While hydrogen FCEB fueling infrastructure will not be used for larger ZEB facility conversions between 2025 and 2030, MTA is planning for a pilot deployment of FCEBs to test vehicle performance in fueling, with an intended commencement date of 2026 to inform subsequent fleet and facility planning decisions. The MTA has assessed various configurations to operate FCEBs, including delivery of fuel as well as on-site generation. Either configuration will require power upgrades to the facilities to support fueling infrastructure. Liquid delivery configurations require slightly less power than plug-in chargers, and on-site hydrogen generated via electrolysis will have a comparable power requirement to that required by BEB chargers.

State Employee Transition Plan

Senate Bill 61, Chapter 463 (2022) includes the following language concerning workforce development and training relating to the ZEB transition:

> *(d)(1) The administration shall provide safety and workforce development training for its:*
> *(i) operations training workforce; and*
> *(ii) maintenance workforce in a manner that enables the maintenance workforce to safely repair and maintain:*
> *1. The administration's zero–emission buses and all their components; and*
> *2. The charging infrastructure for the zero–emission buses.*
>
> *(d)(2) The training required under paragraph (1) of this subsection shall include registered apprenticeships and other labor–management training programs to address the impact of the transition to zero–emission buses on the administration's workforce.*

The MTA will retain its current workforce throughout the transition to a ZEB fleet through a training and retraining program. This program is currently being implemented and draws upon best practices from large transit agencies that have been operating BEBs, industry groups, and vehicle manufacturers. The MTA has coordinated with the local chapter of the Amalgamated Transit Union (ATU), the International Leadership and Training Center (ILTC), and other U.S. transit agencies that have begun training their workforce to support ZEB maintenance to ensure that MTA's training program incorporates best practices from peer deployments and is developed with the needs of MTA's workforce in mind. Training and Standard Operating Procedure (SOP) development is a significant investment within the overall fleet transition plan, as the new fleet will impact thousands of employees and multiple departments within MTA.

The MTA has created a draft ZEB Workforce Development Plan to provide a roadmap for implementing training. For example, maintenance activities will need to adjust, as some components of conventional buses and ZEBs differ. Additionally, these vehicles require new maintenance functions and training, such as high-voltage safety education. **Table 3** lists the required training modules for the transition.

Table 3: Proposed MTA ZEB Training Program Modules

Training Module	Source
BEB 101 Overview	MTA
Operator Orientation	OEM
High Voltage Safety Basics (part of BEB 101)	MTA
Maintenance Orientation	OEM
Entrance and Exit Doors	OEM
Wheelchair Ramp	OEM
Coolant Loop Fill Procedures	OEM
Towing/Recovery	OEM
Propulsion & ESS Familiarization/High Voltage Safety	OEM
Propulsion & ESS Systems Trouble Shooting	OEM
Siemens Propulsion Troubleshooting	OEM
XALT ESS Troubleshooting	OEM
Troubleshooting for Dispatchers/Starters/Supervisors/BOCC	MTA
CPR & AED	MTA
Multiplex Systems	OEM
Suspension and Steering	OEM
Electric Fan Drive	OEM
Articulate Joint	OEM
HVAC Maintenance	OEM
First Responder Training for BEB	MTA
Schedulers/Planners	MTA/Third Party
Charger Basics (as part of BEB 101)	MTA/Third Party
Depot Charger Familiarization (all brands and types)	OEM
Depot Charger Troubleshooting & Repair (all brands and types)	OEM
Charge Management	OEM
Charge Management Advanced	OEM
Mobile Charger Familiarization	MTA/Third Party
First Responder Training for Charging Infrastructure	MTA/Third Party

The workforce development training provided by MTA will include registered apprenticeships that comply with the 2022 amendment to the Maryland Zero-Emission Bus Act. The *Maryland Apprenticeships in Transportation Workgroup*, a group including MDOT and the Maryland Department of Labor, has convened monthly since August 2022 to collect and share data on establishing apprenticeships programs across MDOT modal administrations. In collaboration with the TBUs, the group produced a report on the qualifications, structure, limitations, and advantages of apprenticeship programs in skilled trade areas within MDOT.

In an important milestone, on July 11, 2023, MTA registered an apprenticeship program to help meet ZEB transition training needs, developed in conjunction with ATU Local 1300. This program, led by MTA's Bus Maintenance Division and supported by MTA Training and a local community college, will hire, train, and retain a qualified workforce. The MTA's Apprenticeship Program will provide a structured way for workers to gain the skills and experience necessary to work with new zero-emissions vehicles. The program directly responds to the challenges identified, including:

- **Training and Education**. MTA's Apprenticeship Program will provide on-the-job training and related classroom instruction, giving workers a comprehensive understanding of new zero-emissions technologies. The program will help workers learn how to operate, maintain, and repair these new technologies, as well as the safety protocols associated with them.
- **Recruitment and Retention.** The program will be used to recruit, develop, and retain workers with the necessary skills and expertise to work with new zero-emissions technologies through mentorship and training. The program will help MTA develop a pipeline of skilled workers who are committed to staying with the agency long-term.

In addition to offsetting the workforce impacts of the transition, the program seeks to promote equitable creation of employment opportunities for Baltimore City's vulnerable and underserved communities. In 2022, the estimated annual unemployment rate in Baltimore City was 5.1 percent, notably higher than the Maryland rate of 3.2 percent and national rate of 3.6 percent. Similarly, 21.2 percent of Baltimore City's residents live below the poverty line, almost double the national rate of 11.6 percent.

In partnership with ATU, MTA has developed the Standards of Apprenticeship (SoA), a document outlining the recruitment, selection, employment, and training requirements for Bus Maintenance Mechanic apprentices. This was developed in a collaborative process that spanned from 2018 to 2023. The SoA establishes the minimum training standards that an apprentice must meet to complete the program and become a journey worker. To ensure that the apprenticeship program provides high quality training, these standards have been developed in conjunction with MD DOL Apprenticeship and Training Program and MTA Training, using nationally recognized guidelines set by the U.S. Department of Labor's Office of Apprenticeship, and The International Transportation Learning Center - Transit Workforce Center. In addition to containing classroom instruction and on-the-job training, the program will have a dedicated curriculum that addresses ZEB technology safety, maintenance, and repair.

Apprentices will be partnered with an incumbent union employee trainer and mentor to support them while in the program. They will be paid a progressive wage during their matriculation through the program and will be permitted to join an international labor union. The program will recruit eight apprentices per year over a period of four years, for a total of 32 apprentices for the duration of the program. Recruitment and selection of mentor/trainers are to begin fall 2023, and recruitment for apprentices will begin in early 2024.

Estimate of Carbon Dioxide Reduction

Transitioning MTA's bus fleet to ZEBs with a 50 percent fleet conversion to BEBs will reduce carbon dioxide emissions by an estimated 457.9 million pounds over the lifecycle of BEB operations. This calculation was developed based on current grid power supply assumptions and projected a partial transition to renewable sources by the existing utility provider. Emissions reduction estimates are being updated as the ZEB transition revised to reflect the December 2023 budget reduction and slower pace of transition.

Upstream emissions include considerations of diesel production through conventional petroleum refining and supply to the region for diesel buses, and of the production of electricity, based on current grid power for BEBs.[2]

Tailpipe emissions include estimates of CO_2, NO_X, SO_X, PM_{10}, $PM_{2.5}$, and VOC for clean diesel vehicles, as well as PM_{10} and $PM_{2.5}$ emissions attributed to brake and tire wear. For BEB emissions, MTA has considered PM_{10} and $PM_{2.5}$ attributed to brake and tire wear.

Emissions data was derived from the U.S. Department of Energy's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) model, the Argonne National Laboratory's Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (GREET) model, and the EPA MOVES 2014b model. Emissions were compared and refined to incorporate actual operational experience from comparable transit agencies. Resulting per-unit emissions values were applied to MTA's fleet and operating environment with considerations of average vehicle efficiency and annual miles.

Financial Analysis

MTA conducted a lifecycle cost analysis (LCA) to compare MTA's capital and operating expenses for fleet acquisition, operation, and maintenance associated with vehicles purchased between 2025 and 2030 under the ZEB transition schedule planned prior to December 2023. The LCA compared a "Moderate Case" of two "Build" scenarios[3] in which MTA operates a ZEB fleet consisting of 70 or 77 BEB deliveries per year and economic, operational, and cost conditions are based on baseline market conditions. The analysis also includes a "Renewable Electric Case" of two additional "Build" scenarios where MTA operates a ZEB fleet consisting of 70 or 77 BEB deliveries per year and economic, operational, and cost conditions are based on renewable energy rate for BEBs. Lastly, the LCA includes a "No-Build" scenario[4] that assumes the existing diesel bus fleet will be replaced by 70 similar models each year. This analysis is being updated and revised to reflect the December 2023 budget reduction and slower pace of transition.

Overall, the cost analysis showed that the full lifecycle cash cost of a transition to BEB is approximately 90 percent higher than the cost of continuing operations of clean diesel buses. The analysis will be updated to reflect a revised ZEB transition schedule in 2024. While fueling costs are lower for BEBs than for clean diesel buses, overall operating costs for BEBs are higher than for clean diesel buses. Notably, the high capital costs of BEBs, their batteries, and charging infrastructure offset the fuel savings. However, the operating cost benefits are highly dependent on factors that are continually evolving as BEBs deploy in transit services. Current market conditions have resulted in a shortage of parts and increasing lead times, which have caused price increases due to spiking BEB demand. Operating costs are anticipated to decrease in future years when market conditions and supply chains stabilize.

The industry in North America is still in the preliminary stages of development. Changes in tax breaks, grant programs, discounts, and incentives that are currently available for BEB acquisition

[2] Maryland State Law (Md. Code, Public Utilities Sec. 7-703) and MTA 2020 Sustainability Report
[3] Both "Build" scenarios include the delivery of 7 BEB pilot buses in 2023.
[4] Does not include the delivery of 7 BEB pilot buses in 2023.

and associated charging infrastructure may impact the capital expenditure required from MTA to stand up its zero-emissions fleet. Additionally, MTA will continue to monitor supply chain challenges that have significantly delayed vehicle and component production. For example, delays for parts such as microchips may impact vehicle delivery timeframes and pricing.

The range of BEB models available for varying operating and climate conditions continues to evolve. The costs for batteries may decline with continued development of more efficient technology and lower production costs resulting from economies of scale. Some potential future cost reductions, however, may be slightly or drastically offset through increases in the cost of acquiring the primary battery components, specifically lithium or other alternative materials.

The costs of diesel fuel and electricity also strongly impact the lifecycle benefits of BEBs. While utility prices are historically less volatile than diesel prices, there is still the potential for utility price fluctuations, specifically increases to cover the cost of capital investments and rehabilitation. MTA pays approximately $0.10/kWh for electricity and is not charged taxes on this rate as a state entity. BGE is currently holding discussions on whether a separate rate class will be developed for and charged to transit fleets.

Conclusion

This report outlines MTA's approach to achieving zero-emissions fleet conversion goals. Initial ZEB procurements will focus on BEBs, as this technology is poised to deliver the majority of MTA's service and has been more widely used in U.S. transit service than FCEBs.

FCEB fueling remains under evaluation for divisions that have adequate space to satisfy safety regulations and host service blocks that may exceed BEB range. MTA is beginning to organize a pilot program of FCEB buses to deploy in approximately 2026, informing future facility and fleet planning decisions.

The MTA commenced a seven-bus BEB pilot in January 2024, which will inform the Administration's subsequent zero-emissions bus procurements.

The MTA will retain its current workforce through its newly-registered apprenticeship program and trainings for staff in maintenance and operating procedures that are required for ZEBs.

Overall, the financial analysis shows that the full lifecycle cash cost of a transition to battery electric buses is higher than the cost for continued reliance on a clean diesel fleet. While fuel savings are anticipated for a BEB conversion, the high capital costs of BEBs, their batteries, and charging infrastructure may offset the savings. However, the operating cost benefits are highly dependent on factors that are continually evolving as BEBs deploy in transit services. The transition to ZEBs will result in a large reduction of tailpipe emissions in the Greater Baltimore region.

The MTA's key ZEB transition accomplishments in 2023 include:

- Arrival of seven new pilot BEBs
- Installation and commissioning of Kirk Pilot BEB charging infrastructure
- Development of implementation and data measurement plans for the Kirk Pilot

- Registration of apprenticeship program
- Development of a BEB contract for BPW review, to support 2025-2030 bus deliveries
- Completion of a hydrogen FCEB Fuel Study
- Solicitation and progress towards the award of a developer to electrify two bus divisions, Kirk Division and Northwest Division
- Advanced designs for Eastern Division reconstruction plans
- Solicitation and award of a construction manager for Eastern Division pre-construction activities
- Conducted outreach activities to raise local awareness of the ZEB transition plan.
- Continued regular coordination with BGE on specific utility enhancements needed for facility retrofits later in the transition

The budget implications, outlined in the FY 2024 – 2029 Consolidated Transportation Program and released in January 2024, reflected a slower transition to ZEBs. MTA will continue the ZEB transition and throughout 2024, will be revising the facility transition plan and updating lifecycle costs and emissions analyses. The slower transition is a result of budget constraints but is also more consistent with the practices across the transit industry.

Zero-emissions vehicles represent a new technology that is still changing rapidly. The MTA is closely following industry developments, including the experiences of peer transit agencies that have begun operating ZEBs. The MTA continues research and analysis to refine its preliminary plans to scale up the ZEB fleet and understands the need to remain flexible and adapt as needed to new technology and market conditions. Furthermore, MTA is building a strong coalition of project stakeholders to ensure all aspects of the fleet transition and associated impacts are carefully considered to avoid risks during integration. The MTA's primary goal is to maintain reliable service for passengers throughout the duration of the zero-emissions transition.