2023

MTA Zero-Emission Transition Plan

Metropolitan Transportation Authority

Contents

Executive Summary

In 2018, the Metropolitan Transportation Authority (MTA) committed to a momentous endeavor – transitioning its entire bus fleet and non-revenue vehicles to zero-emission vehicles by 2040. Such an accomplishment demands unparalleled investment and transformative changes across several key facets of bus operations. This report, which incorporates the latest developments in vehicle and battery technology as well as findings from an assessment of MTA's existing facilities and infrastructure, serves as a vital resource for understanding the challenges, opportunities, and best practices in the transition to zero-emissions. The path forged by the MTA and its partners and stakeholders will resonate far beyond the boundaries of New York City, mitigating the impacts of climate change, improving air quality, and fostering healthy communities.

Zero-Emission Transition Strategy

The MTA is committed to leading the way in decarbonizing its bus fleet and transitioning to zero-emission vehicles. The MTA's goals are reflected throughout the transition plan: prioritizing environmental justice, maintaining excellent customer service, minimizing operational constraints, reducing costs, and empowering its workforce. The plan serves as a foundational step for the MTA and is part of an ongoing, dynamic process; further refinements and updates will be made as the transition progresses.

Goals

Prioritize environmental justice

The MTA recognizes the importance of prioritizing historically underserved communities and areas most affected by air pollution and climate change. To support this commitment, the MTA has developed an Environmental Justice (EJ) Scoring framework that incorporates EJ priorities into the deployment phasing process and supports a more sustainable and inclusive transit system.

No impact on customer experience

Throughout the zero-emission transition, the MTA is committed to maintaining high-quality bus service for its customers. New Yorkers and bus riders should enjoy improvements in air quality and quieter bus rides without negative impacts on bus comfort, reliability, speed, or overall experience. The MTA will ensure that the newly deployed zero-emission fleet offers equal or enhanced functionality compared to the current fleet.

Limit constraints on operations

The transition to zero-emission vehicles will not significantly hinder current bus operations and service. The MTA will provide its service with a similar number of buses as today, ensuring minimal disruptions to scheduling and route planning. The agency is committed to minimizing additional requirements for depot operations related to charging, fueling, and maintenance of zero-emission buses. Charging operations will be designed to maintain operational flexibility and real-time adaptability.

Reduce implementation cost and complexity

The MTA will pursue technology alternatives and implementation plans that reduce its total capital and operating burden without limiting operational functionality or impacting the transition timeline. Pilot programs are one way the agency can test new technologies and learn important lessons.

Empower our workforce

MTA will ensure that our workforce is competently trained and supported to undertake the operation and maintenance of zero-emission buses in a seamless and safe manner.

The plan is organized into three major sections: fleet, facilities, and workforce. The MTA's transition is also coordinated to align with the MTA's five-year capital planning process. Each successive five-year plan will coincide with a new stage of zero-emission transition. By adopting this phased approach and focusing on learning at scale, the MTA sets the foundation for a successful zero-emission transition, emphasizing environmental justice, operational feasibility, and workforce empowerment. More detail regarding the plan for each stage is provided in the Chapter "Zero-Emission Transition Strategy."

1

Stage 1 - Learning at Scale

2015-2019 and 2020-2024 Capital Programs

During Stage 1, the MTA will purchase and deploy 560 battery-electric buses. Fifteen buses have already been deployed and another 60 have been purchased with delivery expected in 2024. The remaining 485 buses are expected to be purchased before the end of 2023 and delivered 2025 through 2026.

2

Stage 2 - Expansion Challenge

2025-2029 Capital Program

Stage 2 will roughly double the number of purchases from Stage 1 with an expected total of 1,000 zero-emission buses. This stage is expected to include the first purchase of zero-emission express buses. Most purchases are expected to be battery-electric, though some hydrogen fuel cell purchases will be considered. During this stage the MTA will switch to 100% zero-emission fleet purchases.

3

Stage 3 - Steady Growth

2030-2034 Capital Program

Stage 3 will once again almost double the number of zero-emission bus purchases from the prior stage, from 1,000 up to 1,970. All new buses purchased in this stage will be zero-emission. One-third of the fleet will switch to zero emissions, bringing the overall zero-emission fleet share up to 60%.

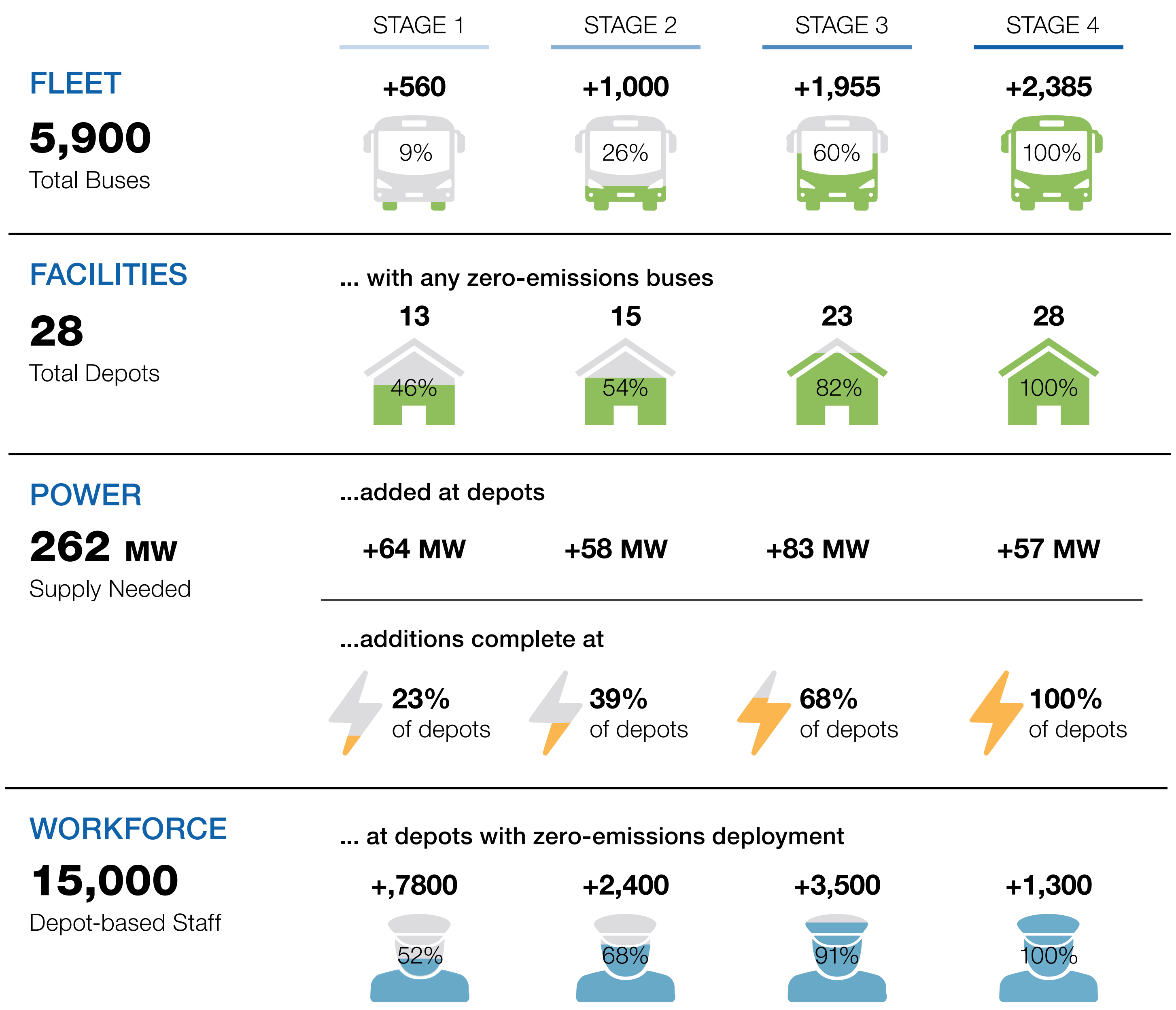
4

Stage 4 - Final Push

2035-2039 Capital Program

Stage 4 will complete the transition. An expected total of 3,300 zero-emission buses will be purchased; as in Stage 3, the propulsion type of these purchases will depend on experience to date. A projected 2,385 remaining buses that are non-zero-emission will be retired and replaced.

Figure i: MTA Zero-Emissions Transition Plan Conceptual Rollout



**Represents one possible version of zero-emissions fleet rollout. Actual final rollout plans likely to be different to reflect further input from the power utility, experience from ongoing deployments, updated operatinal plans, and future technology improvements*

Experience and Progress Update

The MTA began its experience with zero-emission buses through a pilot of ten battery-electric buses starting in late 2017. The agency's first non-pilot zero-emission buses (15 articulated buses) began operation in January 2020. From these early deployments, the MTA gained experience with two bus manufacturers, two bus types, different types of chargers, the overall capabilities and constraints of battery-electric technology, the operational impacts of transitioning to zero emissions system-wide, and the cost and project management challenges involved.

The MTA is now in the midst of Stage 1, carrying out the deployment in three additional projects: the deployment of 60 standard buses, the deployment of 470 buses, and new bus model testing and evaluation.

Deployment of 60 Standard Buses

This project represents several key firsts for the MTA: the first agency-owned standard 40-foot buses, the first in-depot pantograph charging installation, and the first partnership with Con Edison to expand power capacity in support of bus charging. The 60 battery-electric buses will be deployed out of five MTA depots, one in each borough. The buses are expected to enter passenger service in the second quarter of 2024.

Deployment of 470 Buses

This project will increase the MTA's battery-electric bus fleet by over 600%, representing a major step change in the scale of zero-emission deployments. The project will increase the zero-emission share of the bus fleet from 1.2% to 9.7% and increase the size of the largest deployment at any individual depot from 16 buses to 60 buses. Deployment locations will cover all five boroughs with at least two depots in each borough receiving buses, selected to prioritize environmental justice. The first buses are projected to enter passenger service in 2025.

New Bus Model Testing and Evaluation

The MTA is actively pursuing opportunities to operate small test fleets of new bus models in order to expand the pool of qualified vendors and gain real-world experience with emerging and new technologies. Up to 15 of the programmed 560 bus deployments planned for Stage 1 are targeted for these efforts.

Equity and Environmental Justice

The MTA is committed to prioritizing equity and environmental justice in the transition to a 100% zero-emission bus fleet. MTA's buses serve a disproportionate share of low-income and minority households compared to other modes of transportation, including subways. Transitioning the bus fleet to zero emissions will provide a direct air quality benefit to these traditionally disadvantaged communities. The transition will also reduce carbon emissions and help mitigate climate change impacts, which are expected to fall most heavily on traditionally disadvantaged communities.

The MTA developed a composite Environmental Justice (EJ) Score that combines equity considerations and air quality to ensure that the benefits of the zero-emission bus rollout accrue to those communities most impacted. The EJ Score is applied at both the route level and the depot level to facilitate decision-making and prioritization for the zero-emission fleet rollout.

Fleet Transition Plan

The MTA's fleet transition plan outlines the timeline of expected zero-emission bus purchases and describes the schedule feasibility of MTA bus assignments under three potential "generations" of technology. Technology generations are anchored to future dates to align with the stages of the MTA zero-emission transition:

Generation 1
Current existing technology

Generation 2
Expectations for commercially available technology in 2028, aligned with Stage 2 of the MTA transition

Generation 3
Expectations for commercially available technology in 2038, aligned with Stage 4 of the MTA transition

The MTA evaluated all existing scheduled bus assignments for compatibility with battery-electric bus operation. This exercise found that the majority of all bus assignments are already feasible using currently available Generation 1 battery-electric bus models. The MTA plans to replace existing buses with zero-emission buses on a one-for-one basis, with no increase in fleet size. Achieving this will require improvements in bus battery capacity and energy efficiency, especially in the later stages.

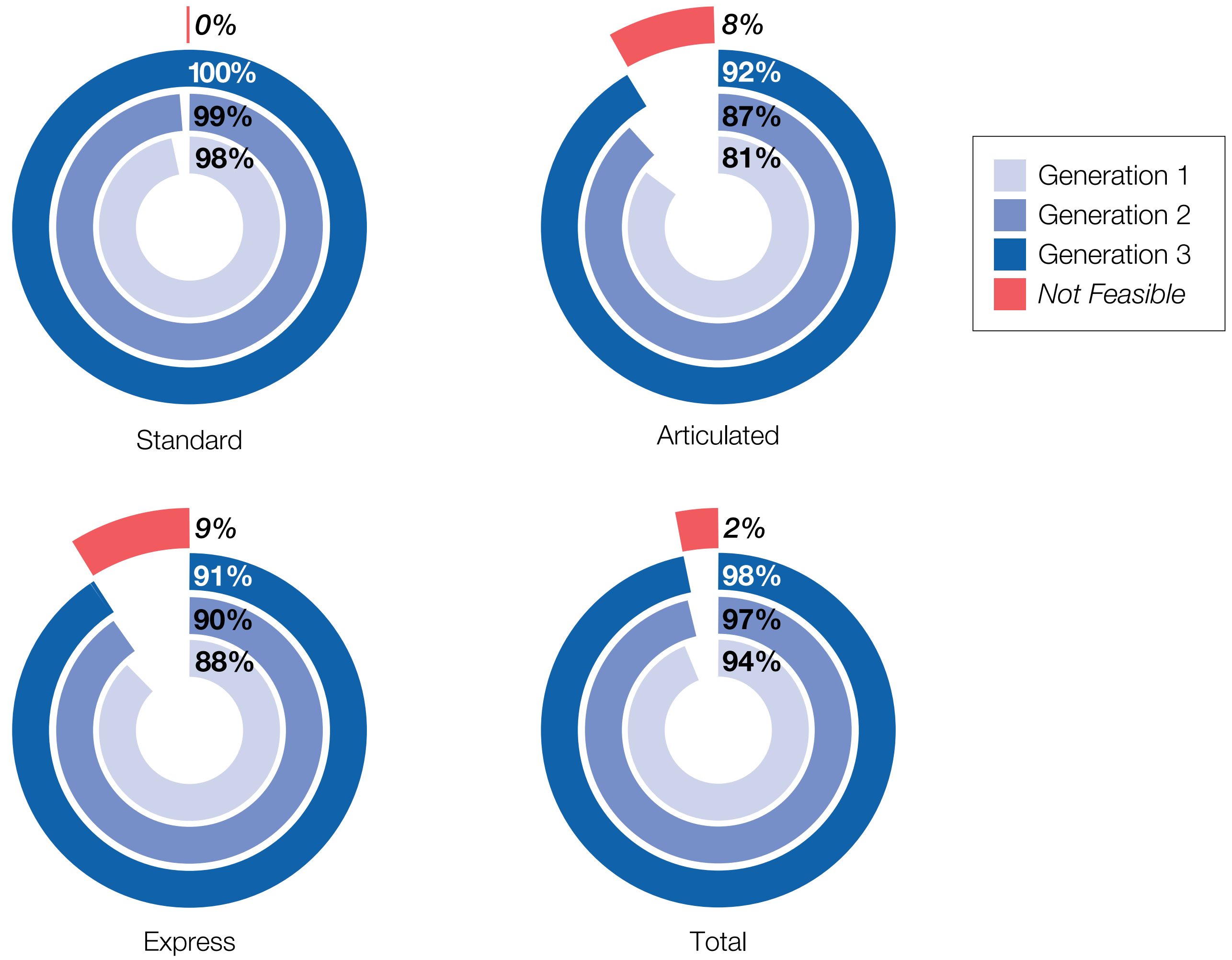


Figure ii: Summary Of Schedule Feasibility Analysis Findings*

**Express bus assignments have been estimated but are considered preliminary given the lack of MTA and industry experience with this bus type*

The transition will follow four stages (described above), aligned with the MTA's five-year capital programs. All new bus deliveries from 2029 on (Stage 3) will be zero-emission, greatly accelerating the pace of the transition.

Table i: Zero-Emission Fleet Purchase and Deployment Stages

Stage	Capital Program	New ZE Conversions**	Cumulative ZE Fleet	ZE Fleet Share
Stage 1	2015-2019	60	60	1%
Stage 1	2020-2024	500	560	9%
Stage 2	2025-2029	1,000	1,560	26%
Stage 3	2030-2034	1,955	3,515	60%
Stage 4	2035-2039	2,385	5,900	100%

***Conversions are defined as zero-emission buses replacing fossil fuel buses (but not other zero-emission buses)*

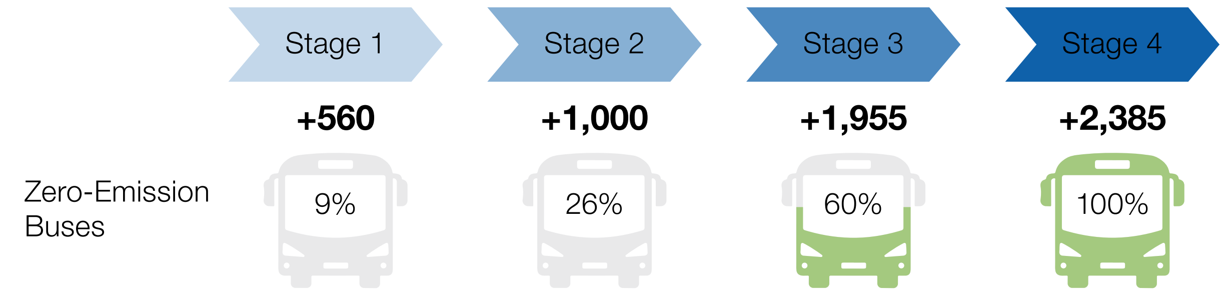
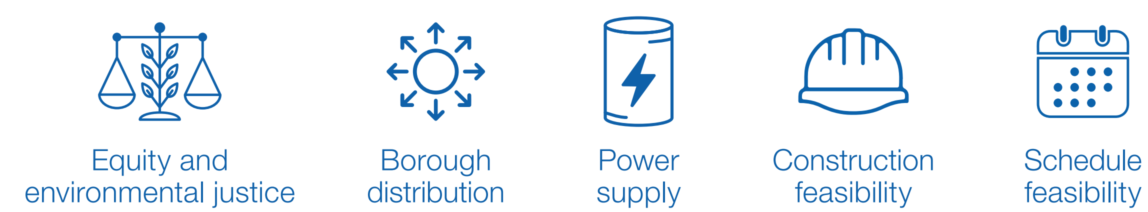


Figure iii: MTA Staged Transition Plan by Capital Program

Facility Transition Plan

The MTA's facility transition approach accounts for charging infrastructure operation and installation, required charging capacity and power supply, and supporting infrastructure upgrades and modifications. The MTA will focus on in-depot charging, particularly in the early stages, high-capacity chargers with multiple dispensers, and dedicated dispenser positions for each in-service bus. Charging and power demand projections show that MTA depots need approximately 262 MW of new power supply, a significant challenge that the agency has begun to address in coordination with the power utility Con Edison. The MTA is also evaluating several ways to reduce new power supply requirements from the grid, including on-site battery storage, solar generation.

A significant number of depots are expected to require major modifications and upgrades to accommodate zero-emission buses. In some cases, existing depot space may not be sufficient to accommodate all new equipment, and the MTA may need to expand, reconstruct, or acquire new facilities. Depot conversion and the associated rollout of bus deployments will be driven by five criteria:



Most depot facilities are expected to see bus deployments spread over multiple stages. Particularly in the early stages, deployments will consist of partial fleet deployments at depots, to avoid the risk of service disruptions from potential reliability issues and to ensure that the number of zero-emission buses is definitively less than the number of feasible schedule assignments at each location. Each bus deployment will include a supporting infrastructure project, so most depots will experience multiple infrastructure installation projects. To reduce the operational impact and complexity of repeated projects, the first infrastructure project at each depot is expected to provide all the supporting upgrades required to pave the way for full zero-emission operation, including all required depot modifications and sufficient new power supply to support full electrification. With support infrastructure in place, subsequent installation projects will focus on providing charging equipment and dispensers.

While detailed plans and exact deployment locations have not yet been established other than for some immediate deployments in Stage 1, the MTA has developed a conceptual construction phasing and deployment plan to gauge the scale and impact of the effort. This plan represents one possible scenario of infrastructure projects and bus deployments that is consistent with the agency's transition goals, prioritization approach, and fleet replacement schedule. This plan should be considered an example of one possible path. The actual rollout will likely include significant adjustments as further analysis, technology development, and operational experience are incorporated.

Table ii: Conceptual Zero-Emission Bus Deployment Plan

		Bus and Charging Equipment Deployments (share of total)			
	Depot	Stage 1	Stage 2	Stage 3	Stage 4
BROOKLYN	East New York	32%	73%	73%	100%
BROOKLYN	Fresh Pond	0	0	100%	100%
BROOKLYN	Grand Avenue	36%	36%	36%	100%
BROOKLYN	Flatbush	0%	0%	100%	100%
BROOKLYN	Jackie Gleason	20%	59%	100%	100%
BROOKLYN	Ulmer Park	16%	16%	16%	100%
QUEENS	Casey Stengel	0%	69%	100%	100%
QUEENS	College Point	0%	0%	51%	100%
QUEENS	Jamaica	23%	77%	77%	100%
QUEENS	LaGuardia	0%	0%	0%	100%
QUEENS	Queens Village	24%	24%	86%	100%
QUEENS	Baisley Park	0%	40%	40%	100%
QUEENS	Far Rockaway	0%	0%	0%	100%
QUEENS	John F. Kennedy	0%	0%	100%	100%
QUEENS	Spring Creek	0%	0%	0%	100%
STATEN ISLAND	Castleton	0%	0%	78%	100%
STATEN ISLAND	Charleston	9%	9%	9%	100%
STATEN ISLAND	Meredith Avenue	0%	0%	0%	100%
STATEN ISLAND	Yukon	4%	51%	93%	100%
BRONX	Eastchester	19%	19%	100%	100%
BRONX	Gun Hill	19%	19%	53%	100%
BRONX	Kingsbridge	10%	10%	54%	100%
BRONX	West Farms	0%	0%	57%	100%
BRONX	Yonkers	0%	0%	0%	100%
MANHATTAN	Tuskegee Airmen	0%	0%	14%	100%
MANHATTAN	Mother Clara Hale	30%	30%	30%	100%
MANHATTAN	Manhattanville	0%	0%	100%	100%
MANHATTAN	Michael J. Quill	9%	53%	53%	100%

Workforce Transition Plan

A skilled and supported workforce is essential to achieve the MTA's goal to transition to 100% zero-emission vehicles by 2040. The transition will affect the duties, responsibilities, and knowledge requirements of almost every member of the MTA operating and maintenance staff. The MTA is committed to continuously collaborating with its union partners, communicating with staff on their experience and needs, and providing robust training and support such that existing and new employees alike are capable and confident in their jobs. Preparing for this transition requires establishing new operating practices and policies and updating and expanding the training resources provided to MTA staff.

The goals of the workforce transition are:

- Safe and efficient operation
- Robust training and support
- Continuous growth opportunity
- Collaboration and communication
- Embracing ongoing innovation

The MTA has identified four major areas in which zero-emission buses will change workforce knowledge and skill requirements: safety, bus maintenance, facilities maintenance, and operations. The extent of the impact and the number of staff affected varies significantly among these categories and between specific staff members and roles. The MTA plans to approach zero-emission skill and knowledge expansion through a combination of familiarization training and specialized skills training. The early stages of the transition will require substantial training and workforce support with later stages building and expanding on this core of expertise.

Capital Cost Estimate

The MTA has estimated the capital costs to purchase battery-electric buses and charging infrastructure to achieve 100% zero-emission bus operations by 2040. Capital costs for projects in Stage 1 are funded in approved MTA Capital Programs (the 2015-2019 and 2020-2024 Capital Programs). The total projected capital cost of all battery-electric bus projects in Stage 1 is $1.7 billion. This includes roughly $868 million for the purchase of battery-electric buses and $851 million for charging infrastructure, power supply, and supporting depot modifications and upgrades.

Cost estimates for Stages 2, 3, and 4 are based on projected rollout phasing and generalized scope assumptions, both of which are uncertain, variable, and highly likely to change. The estimated total capital cost for the complete transition to 100% zero-emission bus operations is estimated to be $23.7 billion.

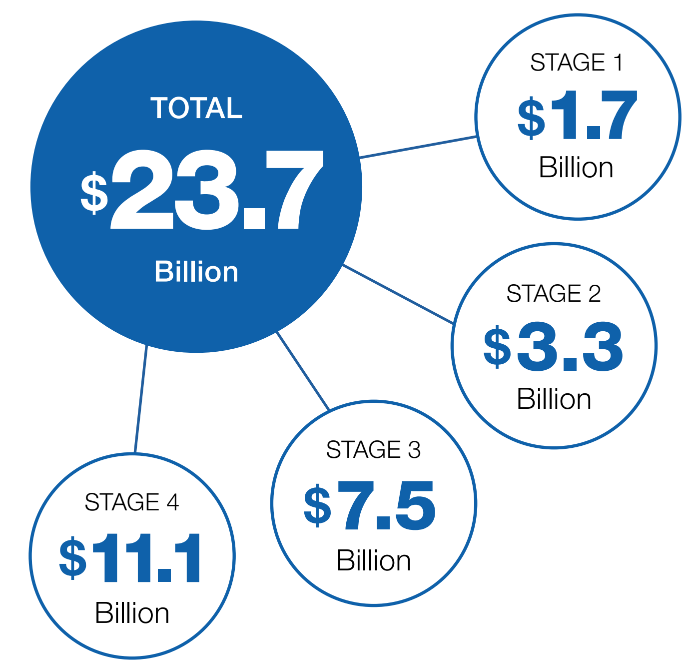


Figure iv: Capital Cost Estimate

Funding

Transitioning to 100% zero-emission buses requires a significant capital investment. To support this transition over the next two decades, an estimated $23.7 billion capital cost will need to be funded. This represents a substantial increase in investment compared to previous bus programs. This increased cost means that the MTA will need to secure additional funding from existing sources as well as explore new avenues for financial support over the next 20 years.

To meet these investment needs, the MTA is actively seeking additional funding at the federal, state, and local levels. The recent passage of the Infrastructure Investment and Jobs Act at the federal level resulted in a major increase in funding through the Low and No Emissions Grant. Furthermore, the forthcoming Central Business District Tolling program in New York City will create significant new revenue stream dedicated to MTA's capital projects. Also, the MTA is actively collaborating with state and local partners and pursuing funding from a variety of discretionary programs to accelerate its transition to zero emission.

As we work towards achieving a greener and more sustainable transportation system, the MTA recognizes that transitioning to 100% zero-emission buses is a significant endeavor. By securing these additional resources, the MTA can achieve the transition plan and realize the environmental benefits of zero-emission transportation while creating a more sustainable future.

Carbon Impacts

The MTA is committed to reducing carbon emissions from all aspects of its operations. Transitioning the bus fleet is a major aspect of this effort. MTA buses currently emit carbon dioxide from burning diesel fuel and CNG. As the MTA fleet of zero-emission buses continues to grow, total carbon emissions from MTA buses will continually decline and reach zero by 2040. Because electricity production currently generates a modest level of carbon emissions, New York State's legislative mandate to achieve 100% zero-emission electricity production by 2040 will ensure that the MTA's bus fleet is truly zero-emissions. Throughout the transition to fully zero emission bus operations, the MTA will continue to closely monitor and track carbon emissions and carbon savings.

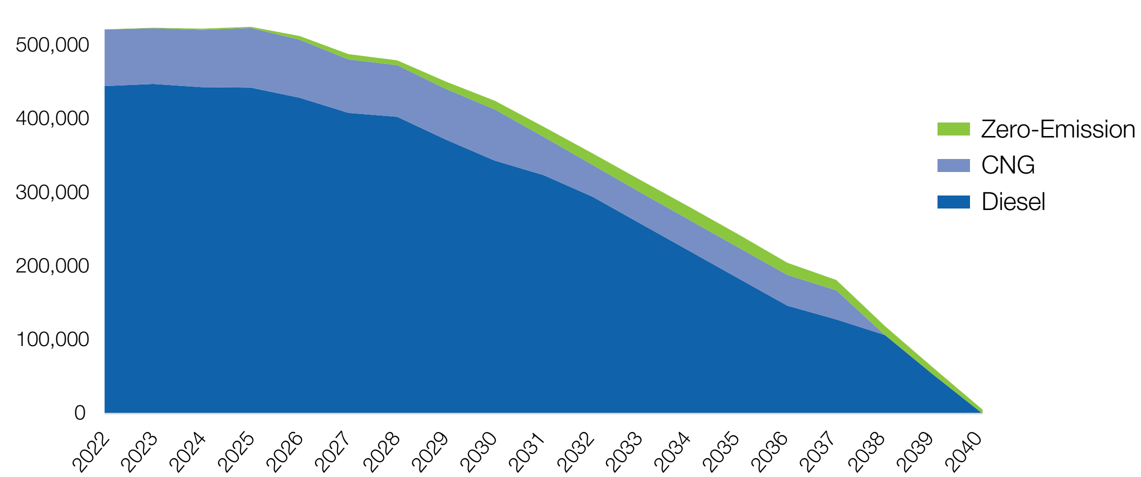


Figure v: Projected Carbon Emissions from MTA Bus Service (MT C02e)

Policy and Legislative Impacts Review

Policy and legislation at all levels of government shape the landscape in which the MTA is undertaking its transition, serving as both impetus for action and a source of funding. New York City has long been a global leader in emissions reductions from buildings, notably through the passage and implementation of the Climate Mobilization Act and its centerpiece, Local Law 97, which places caps on GHG emissions from existing large buildings. This law will help accelerate a green transition and help achieve the City's goal of carbon neutrality by 2050. The MTA's zero-emission fleet transition complements these efforts. In addition to curbing emissions from buildings, the City has already purchased more than 2,000 electric vehicles for its fleet.

At the state level, New York State's 2019 Climate Leadership and Community Protection Act (CLCPA) is arguably the most aggressive clean energy and climate agenda in the country. Achieving the emissions reductions called for by the CLCPA requires action in all sectors, including investments specific to transportation and electrification. The MTA's transition is a critical component of this overall strategy; in turn, New York State provides nearly $6 billion in direct and State authorized support for transit.

At the federal level, the Bipartisan Infrastructure Law (BIL) invests $91.2 billion to repair and modernize transit, supporting the zero-emission transition. BIL funding will be distributed both by formulas and by discretionary grants. In addition to making the best use of federal funds received via formulas, the MTA plans to pursue discretionary funding through multiple programs to accelerate its transition to a zero-emission fleet.

Introduction

As the world grapples with the increasing challenges of climate change, it becomes crucial to take bold and transformative action to reduce greenhouse gas (GHG) emissions and limit global temperature increases to safe levels. New York State stands at the forefront of this global movement, spearheading efforts to decarbonize its economy and build a sustainable future for all. The groundbreaking Climate Leadership and Community Protection Act (CLCPA), enacted in 2019, represents the nation's boldest environmental legislation, calling for a 40% reduction in statewide GHG emissions by 2030 and an impressive 85% reduction by 2050. It also sets a visionary goal of achieving net zero emissions across all sectors of the economy by 2050.

Even before the state set these ambitious targets, the Metropolitan Transportation Authority (MTA) took a stand in 2018. A year before the CLCPA, the MTA committed to a momentous endeavor – transitioning its entire bus fleet and non-revenue vehicles to zero emissions by 2040. Such an accomplishment demands unparalleled investment and transformative changes across almost every aspect of bus operations. This report, which incorporates the latest developments in vehicle and battery technology, as well as findings from an assessment of MTA's existing facilities and infrastructure, serves as a vital resource for understanding the challenges, opportunities, and best practices in the transition to zero emissions.

At the core of this commitment lies the goal of achieving 100% zero-emission bus deliveries by 2029[1]. To realize this vision, rapid scaling of zero-emission bus purchases is imperative. Moreover, each MTA bus depot must undergo infrastructure installations, facility modifications, and the incorporation of new power supply or alternative fueling systems. The transition will go beyond physical enhancements and extend to fundamental transformations in day-to-day processes such as depot operations, fleet planning, crew scheduling, maintenance, road operations, safety, and training.

The MTA boasts the largest public bus system in North America, operating 10% of all public transit buses in the United States and carrying 16% of the nation's bus passengers. Consequently, as other public bus systems nationwide contemplate their own transition to zero emissions, the path forged by the MTA will resonate far beyond the boundaries of New York City.

This plan serves as a foundation for the MTA's successful transition. It unveils the challenges and constraints associated with the shift to zero emissions, outlines a strategic approach to surmount them, and presents a preliminary implementation plan. This document is not intended to be final or static; rather, it signifies one step in a dynamic process, a building block that informs ongoing efforts to convert the MTA fleet to zero emissions.

Together, the MTA and its partners and stakeholders must embrace this momentous opportunity to build a cleaner, more sustainable future. By transitioning to zero-emission vehicles, we can mitigate the impacts of climate change, improve air quality, and foster healthier communities. New York City's steadfast commitment to this transformation sets a powerful example for the world and invites everyone to join the journey towards a greener tomorrow.

1 *Achieving a 100% zero-emission fleet by 2040 requires that the last remaining diesel and CNG powered buses in the MTA fleet be retired and replaced before the end of the year in 2040. With a 12-year useful life, that means the last year for non-zero-emission bus deliveries to the MTA is 2028.*

2023 Update

This document is an updated version of the plan initially published in April of 2022. It reflects the latest developments in the zero-emission bus industry, continued MTA experience with zero-emission deployments and updated and expanded analysis and strategic plans. The most significant changes include the addition of a Stage 1 Implementation Progress Update and major updates to the Battery-Electric Bus Technology Evaluation and Battery-Electric Bus Schedule Feasibility sections.

I.

Zero-Emissions Transition Strategy

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Goals

The MTA is committed to leading the way in decarbonizing its bus fleet and transitioning to zero-emission vehicles. This section outlines the MTA's comprehensive strategy to achieve this ambitious goal while prioritizing environmental justice, maintaining excellent customer service, minimizing operational constraints, reducing costs, and empowering its workforce.

Prioritize environmental justice

The MTA recognizes the importance of prioritizing historically underserved communities and areas most affected by air pollution and climate change. To support this commitment, the MTA has developed an Environmental Justice (EJ) Scoring framework that incorporates EJ priorities into the deployment phasing process and supports a more sustainable and inclusive transit system.

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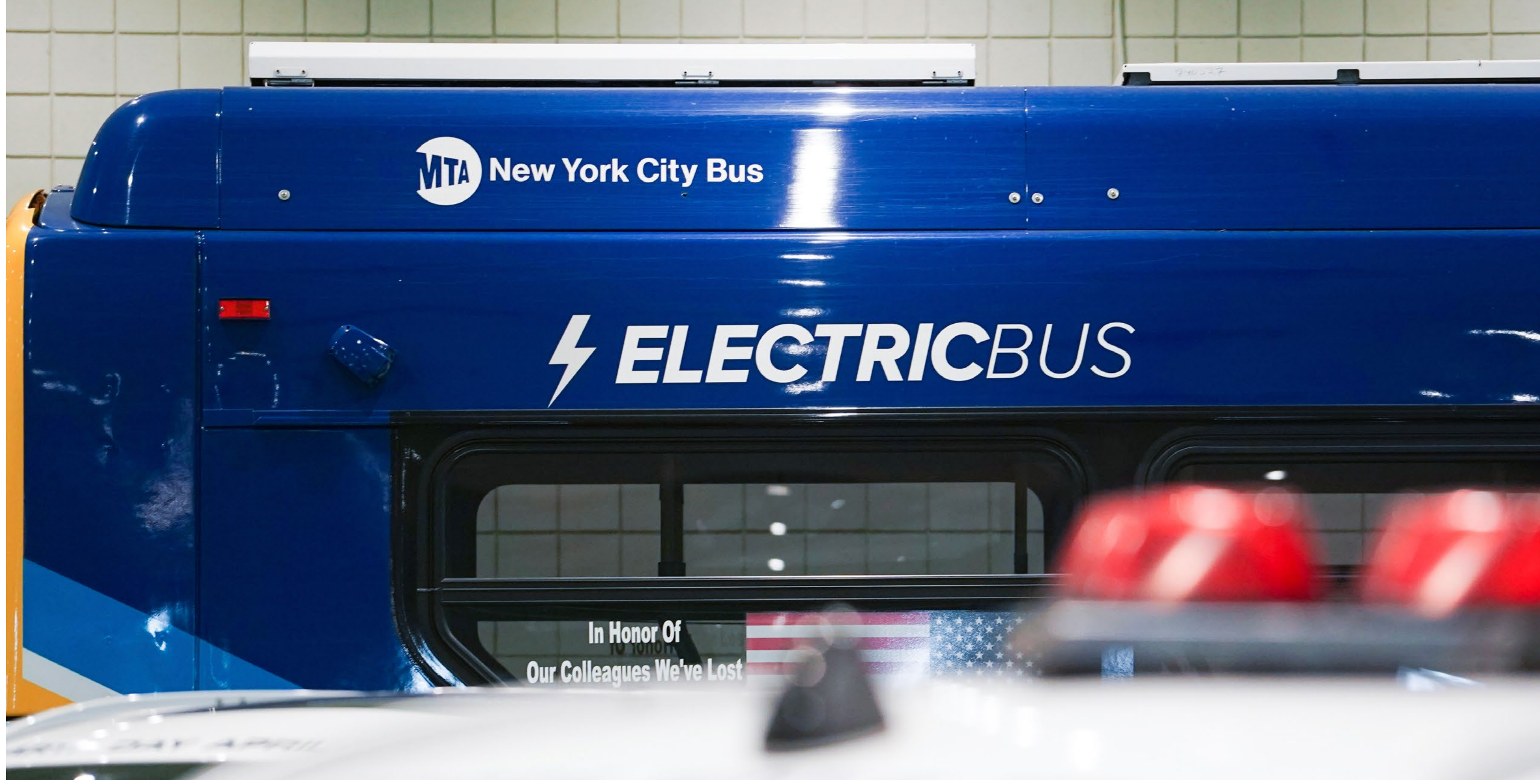


Strategy Overview and Structure

The MTA's goals are reflected throughout the transition plan. The plan is organized in three sections: fleet, facilities, and workforce. These elements are described below and elaborated on in subsequent chapters.

The ***Fleet Transition Plan*** outlines the timeline of expected zero-emission bus purchases and describes the schedule feasibility of MTA bus assignments under three potential "generations" of technology. The fleet transition plan finds that most of MTA's standard bus schedules are feasible to operate with existing zero-emission bus models. However, operating zero-emission articulated buses are more difficult, as currently scheduled, and the MTA does not yet have experience with zero-emission express buses. The MTA plans to replace existing buses with zero-emission buses on a one-for-one basis, with no increase in fleet size. Achieving this will require improvements in bus battery capacity and energy efficiency.

The ***Facilities Transition Plan*** outlines the MTA's planned approach to charging infrastructure operation and installation, projected charging capacity and power supply, supporting infrastructure upgrades and modifications, and a conceptual, staged rollout plan. The MTA's approach focuses on in-depot charging, as opposed to on-route charging. Depots may need approximately 262 MW of new power supply, a significant challenge that the MTA has begun to address in coordination with the power utility Con Edison. A significant number of depots are expected to require major modifications and upgrades to accommodate zero-emission buses. The Facility Transition Plan includes a rollout prioritization framework that emphasizes environmental justice.

The ***Workforce Transition Plan*** outlines the expected impacts to existing staff roles and responsibilities, describes new skill requirements, and lays out a plan to provide training and support. Policies and training programs around high-voltage safety is a major emphasis. Developing materials and familiarizing staff across functions with new vehicles and equipment will require significant training resources. The largest skill gaps are expected in the maintenance area and the MTA is developing a robust maintenance training and workforce development plan.

The elements of the transition plan serve as a foundational step for the MTA, providing an overview of the strategies, challenges, and preliminary next steps. This document represents one step of an ongoing, dynamic process, and further refinements and updates will be made as the transition progresses.

Rollout Plan Summary

The MTA's transition is coordinated to align with the MTA's five-year capital planning process. Each successive five-year plan will coincide with a new stage of zero-emission transition. By adopting this phased approach and focusing on learning at scale, the MTA sets the foundation for a successful zero-emission transition, emphasizing environmental justice, operational feasibility, and workforce empowerment.

1 Stage 1 - Learning at Scale

2015-2019 and 2020-2024 Capital Programs

During Stage 1, the MTA will embark on its first major deployments of battery-electric buses, with fleets of 50-100 vehicles across 13 depots. This will allow MTA to conduct and learn from extensive testing and validation of charging infrastructure technology, bus range capabilities, operational feasibility, and power supply construction. A total of 560 new zero-emission buses will be deployed, with 60 buses funded in the 2015-2019 Capital Program and 500 buses in the 2020-2024 Capital Program. At the conclusion of this stage, zero-emission buses will comprise about 9% of the total MTA bus fleet. The Stage 1 delivery primarily focuses on an in-depot overnight charging approach, and avoids the potential complexity and expenditures related to development and deployment of on-route charging infrastructure.

The deployment strategy will prioritize environmental justice by selecting locations that address the needs of traditionally underserved communities. Jamaica Depot, for example, will undergo a complete rebuild to accommodate 100% zero-emission operations. Additionally, collaboration efforts have started with Con Edison, as ensuring timely deployment of additional large-scale power capacity at target depots is instrumental for the success of the program.

Throughout Stage 1, the MTA will predominantly deploy battery-electric buses, which to date have undergone extensive testing and offer proven zero-emission propulsion. Fuel cell buses will also be tested to explore potential future options and technology alternatives. In parallel, comprehensive training and workforce development programs will be implemented across the agency to equip staff with the necessary skills and expertise to effectively operate and maintain zero-emission vehicle and infrastructure technologies. By embracing this learning phase, the MTA aims to gather valuable insights and experiences that will inform subsequent stages of the transition plan.

2 Stage 2 - Expansion Challenge

2025-2029 Capital Program

This stage will take zero-emission deployments to a new scale, with large deployments of over 100 buses at multiple depots and the first conversions of an entire depot to 100% zero-emission operation: Jamaica Depot in Queens (the highest ranked Environmental Justice locations its borough). This stage will also see the last purchases of non-zero-emission buses: all new orders starting in 2029 will be zero-emission. A total of 1,000 new zero-emission buses will bring the total zero-emission fleet share to 26%. The first zero-emission express buses are expected to be deployed in this stage. Approximately 8 to 12 depots will undergo major construction projects to install infrastructure and new power supply.

Deployment locations for the zero-emission fleet will continue to be driven by environmental justice priorities, bus schedule feasibility, and depot constructability. Most deployments are expected to be battery-electric, though moderate scale hydrogen fuel cell deployments may be implemented to prove that technology at scale. Zero-emission training will become standard for all staff in operating and maintenance positions.

3 Stage 3 - Steady Growth

2030-2034 Capital Program

This stage will see the conversion of roughly a third of the fleet to zero emissions. All 1,955 expected new bus purchases in this period will be zero-emission, bringing the zero-emission fleet share up to 60%. Accommodating this major fleet expansion will require deployments at 15 to 20 depots, with five additional depots achieving 100% zero-emission operations. By Stage 3, technology improvements are expected to eliminate most bus schedule feasibility issues resulting from battery range limitations. Battery-electric buses are expected to continue to be the primary propulsion type, though a significant portion of deployments may be hydrogen fuel cell, pending the success of earlier testing.

4 Stage 4 - Final Push

2035-2039 Capital Program

This stage will complete the transition to 100% zero-emission bus service at the MTA. The last remaining buses (approximately 2,385) of other propulsion types will be retired. The focus during this stage will be on completing any particularly challenging locations that required complete rebuilds or major modifications.

Figure 1: MTA Zero-Emissions Transition Plan - Conceptual Rollout*

	STAGE 1	STAGE 2	STAGE 3	STAGE 4
FLEET **5,900** Total Buses	+560	+1,000	+1,955	+2,385
	9%	26%	60%	100%
FACILITIES **28** Total Depots				
... with any zero-emissions buses	13	15	23	28
	46%	54%	82%	100%
... with at least 50% zero-emissions fleet	0	8	17	28
	0%	29%	61%	100%
... with 100% zero-emissions fleet	0	0	7	28
	0%	0%	25%	100%
POWER **262 MW** Supply Needed				
...added at depots	+64 MW	+58 MW	+83 MW	+57 MW
...additions complete at	23% of depots	39% of depots	68% of depots	100% of depots
WORKFORCE **15,000** Depot-based Staff				
... at depots with zero-emissions deployment	+,7800	+2,400	+3,500	+1,300
	52%	68%	91%	100%

**Represents one possible version of zero-emissions fleet rollout. Actual final rollout plans likely to be different to reflect further input from the power utility, experience from ongoing deployments, updated operatinal plans, and future technology improvements*

Completed Deployments and Lessons Learned

The MTA began its experience with zero-emission buses through a pilot of ten standard battery-electric buses in late 2017. The agency's first non-pilot zero-emission buses (15 articulated buses) began operation in January 2020. From these early deployments, the MTA gained experience and key lessons regarding vehicle performance, operations, and maintenance.

10 Standard Bus Pilot

The MTA began its experience with zero-emission buses through a pilot of ten battery-electric buses starting in late 2017. The pilot included the operation of ten buses for three years: five pilot buses from New Flyer operating in Manhattan out of MJ Quill Depot and five pilot buses from Proterra operating in Brooklyn and Queens out of Grand Avenue Depot.

Charging infrastructure was installed in the depots and on-route to support the projects. For the five New Flyer buses in Manhattan, two plug-in chargers were installed on the first floor of MJ Quill Depot and on-route fast chargers were installed at both ends of the M42 route on 42nd Street. Installation of the on-route chargers involved lengthy negotiations with multiple city and state government agencies to secure permission and design approval. The buses carried relatively smaller 150 kWh batteries designed for regular on-route charging. The buses operated primarily on the M42 and M50 routes but were also tested in service on other crosstown routes in Manhattan and throughout the system. The MTA completed the New Flyer pilot in June 2021 with over 90,000 miles in service and 172 tons of CO2 emissions avoided.

For the five Proterra buses in Brooklyn and Queens, three plug-in chargers were installed at Grand Avenue Depot and one on-route fast charger was installed at Williamsburg Bridge Plaza. The buses carried larger 440 kWh batteries designed for longer distances between charging. The buses operated on several routes out of Williamsburg Bridge Plaza, including the B60, B39, B32, B24, and Q59. The MTA completed the Proterra pilot in December 2021 with over 145,000 miles in service and 300 tons of CO2 emissions avoided.

15 Articulated Buses

The MTA made its first non-pilot purchase of zero-emission buses and gained its first experience with articulated buses in 2019 with an order of fifteen 466 kWh battery 60-foot battery-electric buses from New Flyer. To support the project, sixteen 150 kW plug-in chargers were installed at MJ Quill Depot in Manhattan. Each charger has two plug-in dispensers and is designed to support sequential charging. The buses are also compatible with previously installed on-route chargers.

Buses began operation in January 2020 and have primarily been deployed on the M14 Select Bus Service (SBS) route with occasional service on other Manhattan SBS routes. The buses have demonstrated a real-world operating range of 50-90 miles depending on weather and route conditions. Through June 2023, the fleet has operated over 348,000 miles in service, avoiding 767 tons of CO2 emissions.

Lessons Learned

From these early deployments, the MTA gained experience with two bus manufacturers, two bus types, and both in-depot plug-in chargers and on-street pantograph chargers. This experience has provided a baseline understanding of the capabilities and constraints of battery-electric technology, the operational impacts of transitioning to zero emissions system-wide, and the cost and project management challenges involved.

- **Range limitations in cold weather**

  Battery-electric buses in MTA service have shown curtailed range and high energy consumption rates, particularly in cold weather. Experienced ranges are often orders of magnitude shorter than advertised by bus manufacturers. While many MTA bus assignments can be accomplished with existing technology, closely managing range is a significant operational effort. Energy efficiency improvements will be critical to achieving 100% zero-emission bus operation without enormous cost or service impacts.

- **New demands on operations**

  Battery-electric buses have two major characteristics which make them more challenging to operate compared to traditional fleets: their range

  is limited and they require more time to charge. Shorter range means that depot dispatching staff, road service managers, and bus operators must all monitor and respond to a new variable affecting daily operations and schedules. Added charging time may require a fundamental reorganization of depot operations, creating significant logistical challenges to find charging locations and sufficient charging time for every bus required for service. Both put significant burdens on operating staff that will require new information, management systems, and training.

- **Technology challenges**

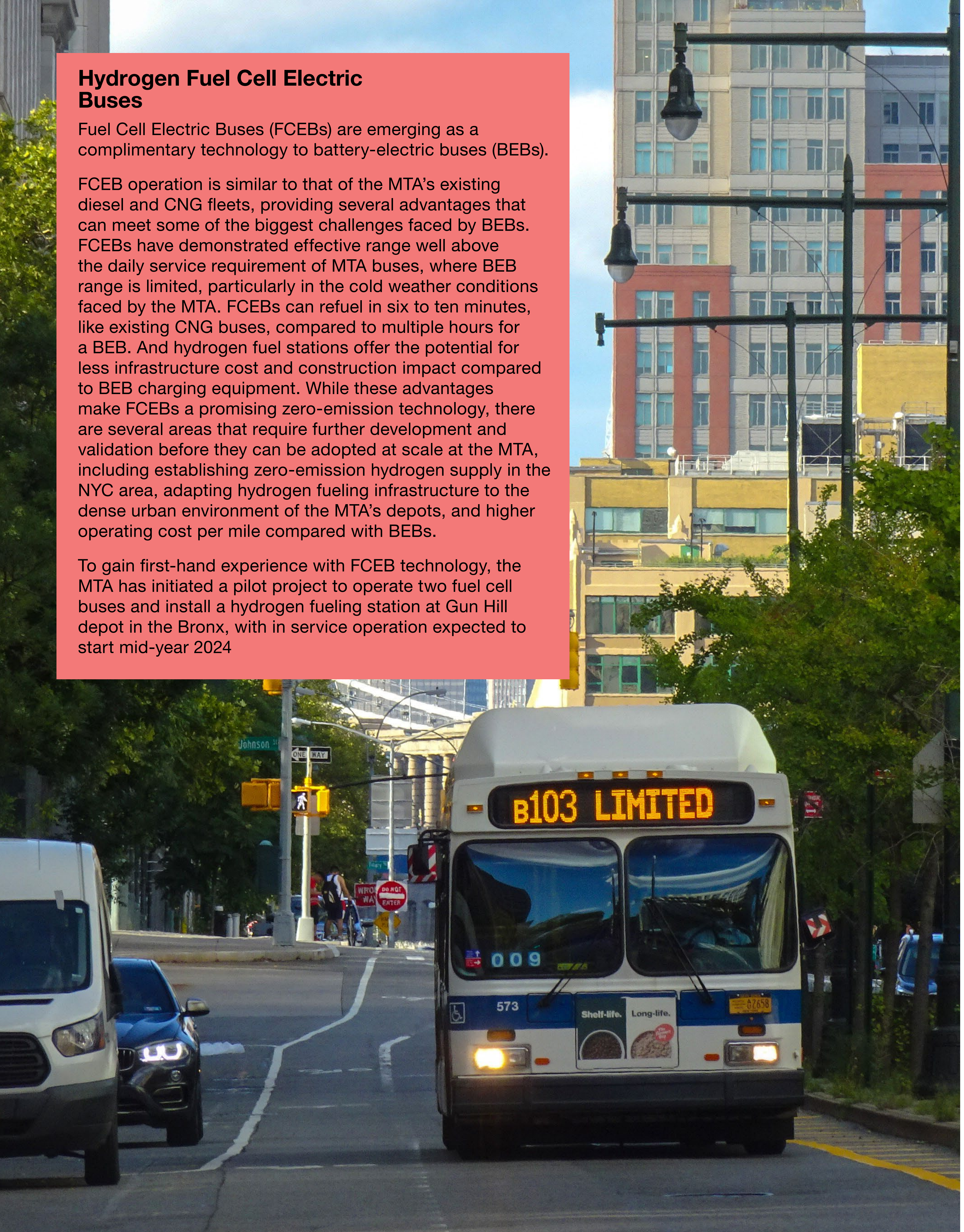
  The MTA has experienced reliability issues with both buses and chargers in its deployments to date. Battery-electric buses have much higher failure rates, lower availability, and require longer times to diagnose and fix compared to MTA's existing fleet. Chargers show similar challenges, including regular communications failures, long down times, and the failure to perform some advertised functions. This is expected for new technology systems and is expected to be mitigated with the rapid maturation of existing technology. The MTA may also include appropriate Service Level Agreements in charger deployments to help ensure that reliability issues do not impact the agency's core ability to provide transit service.

- **Uncertainty around rapidly developing technology**

  Constant change in the zero-emission bus space carries both the benefit of improving functionality and capability and the challenge of uncertainty over how zero-emission buses will operate and how depots should be modernized in the future. The range and consumption rates of vehicles, the functionality and design of chargers, and the effort required to maintain and operate them are critical variables with significant implications for how the MTA plans the capital investments and operating procedures required to transition to a fully zero-emission fleet.

- **Maintenance knowledge and staffing gaps**

  Currently neither the MTA nor bus and charging equipment manufacturers have sufficient maintenance personnel with zero-emission bus technology expertise. This causes delays in responding to and troubleshooting problems with both buses and chargers. Because few zero-emission buses have operated in service for more than a few years, there is limited industry experience with real-world failure rates, parts replacement cycles, and expected useful life.



Hydrogen Fuel Cell Electric Buses

Fuel Cell Electric Buses (FCEBs) are emerging as a complimentary technology to battery-electric buses (BEBs).

FCEB operation is similar to that of the MTA's existing diesel and CNG fleets, providing several advantages that can meet some of the biggest challenges faced by BEBs. FCEBs have demonstrated effective range well above the daily service requirement of MTA buses, where BEB range is limited, particularly in the cold weather conditions faced by the MTA. FCEBs can refuel in six to ten minutes, like existing CNG buses, compared to multiple hours for a BEB. And hydrogen fuel stations offer the potential for less infrastructure cost and construction impact compared to BEB charging equipment. While these advantages make FCEBs a promising zero-emission technology, there are several areas that require further development and validation before they can be adopted at scale at the MTA, including establishing zero-emission hydrogen supply in the NYC area, adapting hydrogen fueling infrastructure to the dense urban environment of the MTA's depots, and higher operating cost per mile compared with BEBs.

To gain first-hand experience with FCEB technology, the MTA has initiated a pilot project to operate two fuel cell buses and install a hydrogen fueling station at Gun Hill depot in the Bronx, with in service operation expected to start mid-year 2024

Stage 1 Implementation Progress Update

Stage 1 of the transition includes the deployment of 560 battery-electric buses funded via the 2015-2019 and 2020-2024 Capital Programs. Deployments in this stage and being carried out through four separate projects: 15 articulated buses, 60 standard buses, 470 buses, and new bus model testing and evaluation.

Deployment of 15 Articulated Buses

This project included the first purchase of zero-emission buses by the MTA, which began passenger service in January 2020. A description of this project can be found above in the ***Completed Deployments and Lessons Learned*** section.

Deployment of 60 Standard Buses

This project represents several key firsts for the MTA: the first purchase of non-pilot 40-foot standard buses; the first installation of in-depot overhead pantograph charging infrastructure; and the first installation of new power supply infrastructure in partnership with the power utility Con Edison. For this project, 60 battery-electric buses will be deployed out of five MTA depots, one in each of New York City's five boroughs. Supporting charging infrastructure is being installed at four of the depot locations with the fifth location leveraging charging equipment previously installed as part of the 15 articulated bus deployment. The bus purchase and charging infrastructure contracts have both been awarded and buses are expected to enter passenger service in the second quarter of 2024.

Deployment of 470 Buses

This project will increase the MTA's battery-electric bus fleet by over 600%, representing a major step change in the scale of zero-emission deployments for the agency. The project will increase the zero-emission share of the bus fleet from 1.2% to 9.7% and increase the size of the largest deployment at any individual depot from 16 buses to 60 buses. Deployment locations will cover all five boroughs with at least two depots in each borough receiving buses. Deployments were also selected to prioritize environmental justice using the ZEFT Environmental Justice Score described in the chapter "Equity and Environmental Justice." The 11 depots receiving buses include the number one ranked depot city-wide; three of top five city-wide; five of the top ten city-wide; three that are number one in their borough; and six in the top three in their borough.

The bus purchase contract has been advertised with award expected by the end of 2023. The MTA has established a partnership with the New York Power Authority to deliver charging infrastructure through a design-build process. The first buses are projected to enter passenger service in 2025.

New Bus Model Testing and Evaluation

The MTA is actively pursuing opportunities to operate small test fleets of new bus models in order to expand the pool of qualified vendors and gain real-world experience with emerging and new technologies. Up to 15 of the programmed 560 bus deployments planned for Stage 1 are targeted for these efforts.

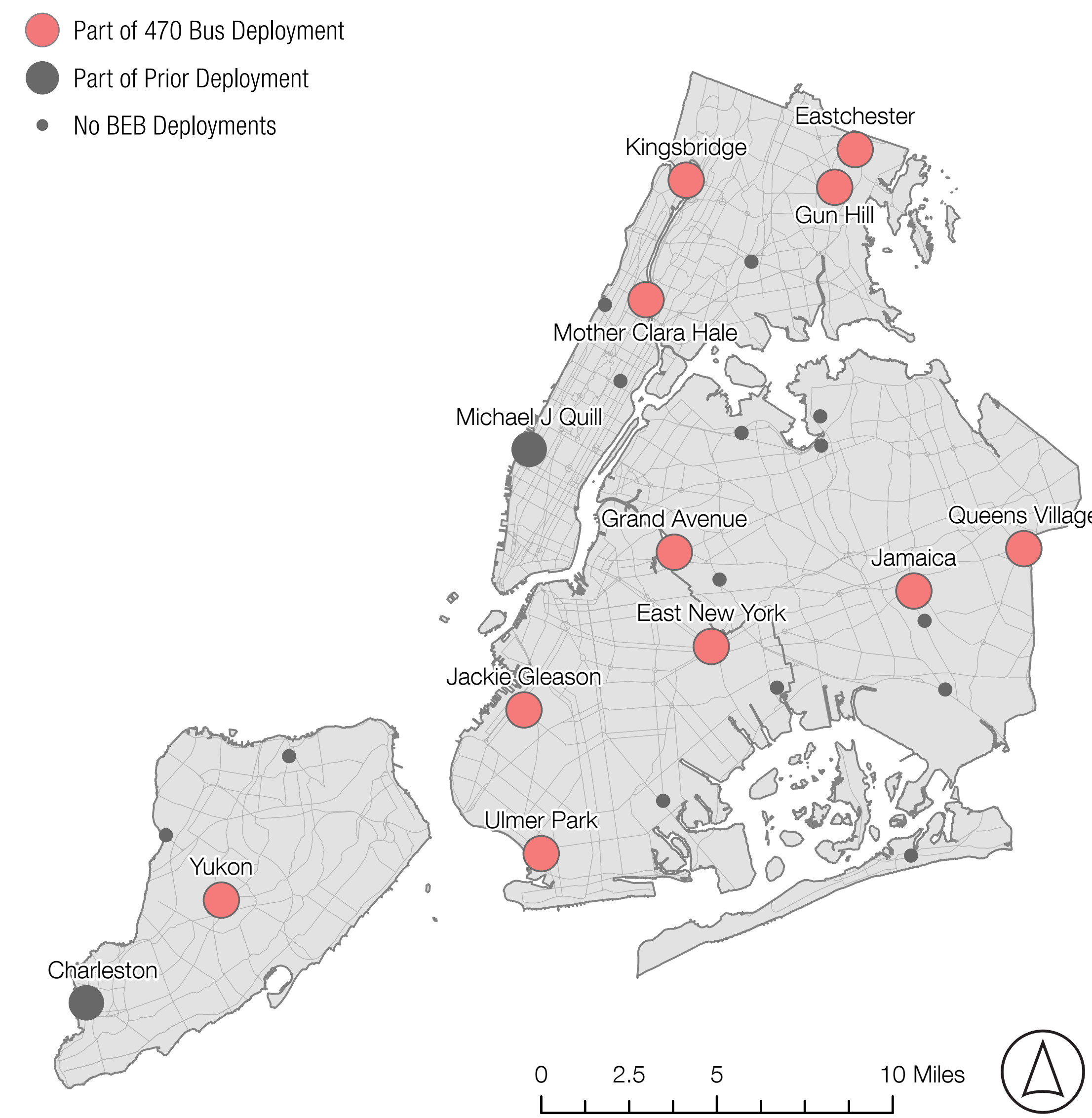
Implementation Progress Update

15 ARTICULATED BUSES

STANDARD 40-FT BUSES **60**

470 BUS DEPLOYMENT

Figure 2: Bus Deployment Locations



II.
Equity and Environmental Justice

II. Equity and Environmental Justice

The MTA is committed to prioritizing equity and environmental justice in the transition to a 100% zero-emission bus fleet. MTA's buses serve a disproportionate share of low-income and minority households compared to other modes of transportation, including subways. Transitioning the bus fleet to zero emissions will provide a direct air quality benefit to these traditionally disadvantaged communities. The transition will also reduce carbon emissions and help mitigate climate change impacts, which are expected to fall most heavily on traditionally disadvantaged communities.

The MTA developed an Environmental Justice (EJ) Score that combines considerations of equity and air quality to ensure that the benefits of the zero-emission bus rollout accrue to those communities most impacted. The following sections describe the methodology behind the Score, specifically its Areas of Concentrated Need and Air Quality Index components.

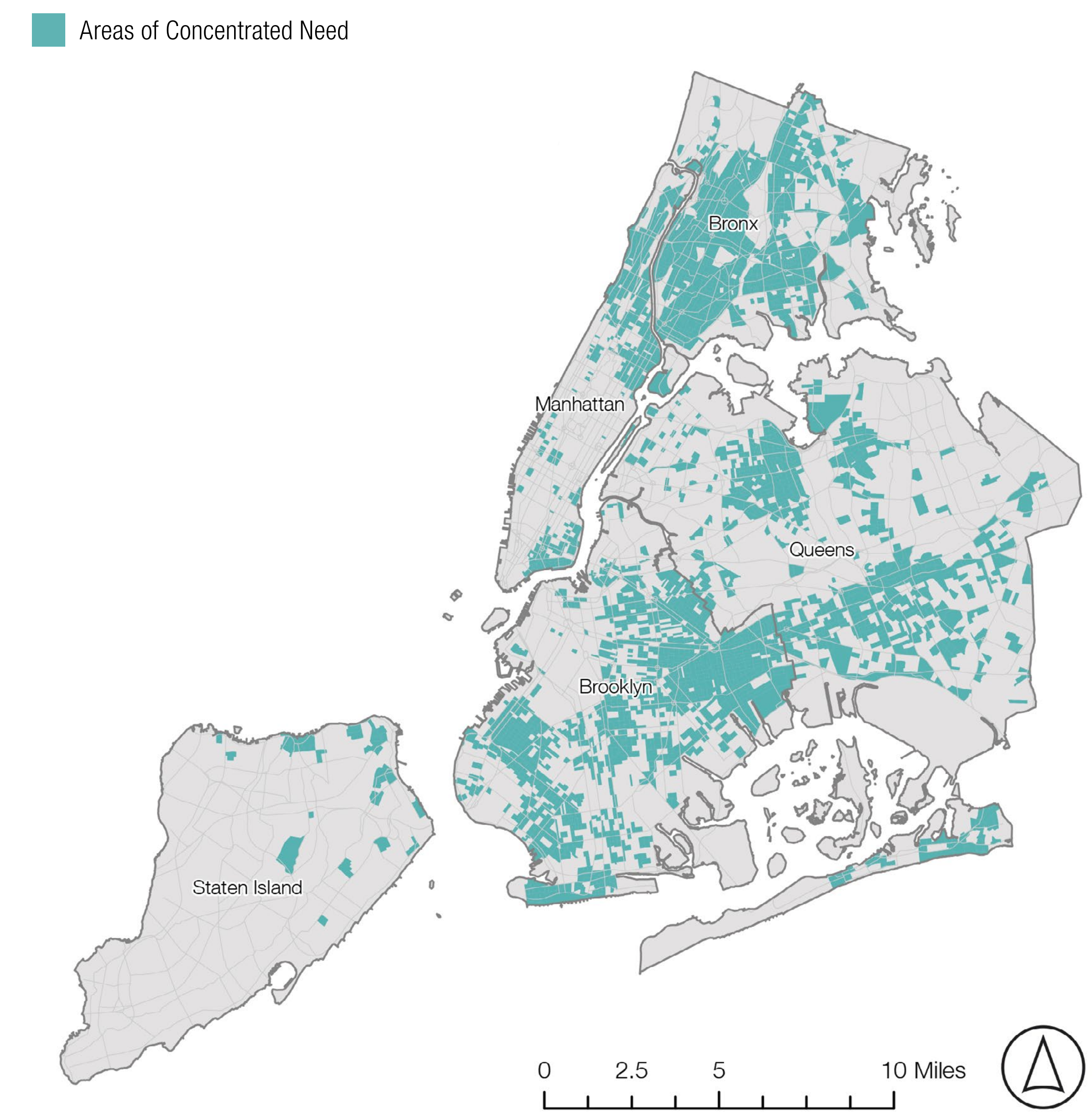
Areas of Concentrated Need

The MTA has identified geographic Areas of Concentrated Need for prioritizing equity in project planning. These areas were identified through a three-step process. First, eight metrics representing a spectrum of demographic characteristics were identified and weighted as described in the table below. Second, a combined score from 0 to 100 was established for each census block group in NYC based on the percent rank for each metric and the established weights. Third, all census blocks with a score greater than 50 were identified as areas of concentrated need (Figure 3).

Table 1: Areas of Concentrated Need Metrics and Weights

Weight Category	Theme	Metric	Weight
High	Minority	Race (minority population, all except White Alone)	10
	Transit Dependency	Zero-vehicle households	10
	Low Income	Households in poverty	9
	Access to Opportunity	Commute time 45 minutes or more in NYC; 60 minutes or more outside NYC	9
Mid	Mobility Needs	People with disabilities	6
	Minority	Limited English Proficient (LEP); English as a Second Language (ESL) households	5
Low	Transit Dependency / Mobility Needs	Age (under 18 and over 75 in NYC; over 75 outside NYC)	3
	Access to Opportunity	Level of educational attainment	1

Figure 3: MTA Areas of Concentrated Need



Air Quality Index

Combustion engines, and particularly diesel-burning engines, produce a range of emissions that have negative health impacts. One of the major benefits of zero-emission buses is the total elimination of these point source emissions. The MTA has developed an Air Quality Index to identify communities facing the greatest air quality risk and prioritize those communities to receive the benefit of zero-emission buses.

The Air Quality Index is a weighted composite of nine air quality metrics: five of six Environmental Protection Agency (EPA) Clean Air Act monitored criteria pollutants[2] as well as four additional metrics, including several EPA risk indexes, a measure of diesel particulate matter, and asthma rates.

Weights for each metric were developed based on risk, plus an evaluation of existing levels of exposure in New York City compared to relevant health standards and average levels experienced in the United States. Pollutants representing larger risk, at higher levels compared to health standards, and at higher levels compared to the US average were given higher weight in the index. The result is a score from 0 to 100 for all areas of New York City. The table below shows the nine metrics, their associated health impact, evaluation against health standards and the US average level, and the weights assigned to each.

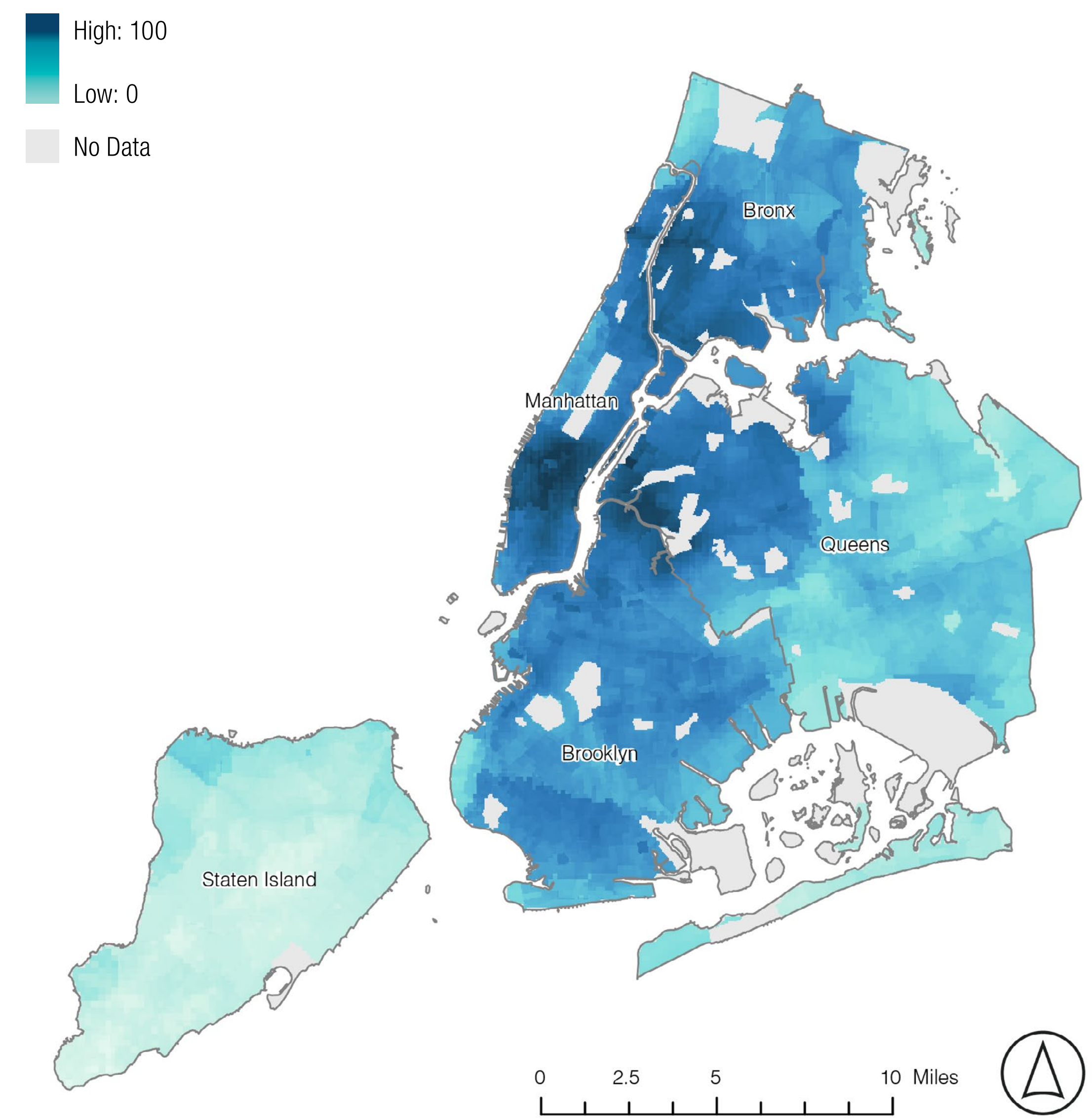
2 *No good data source could be found for the sixth pollutant, lead.*

Table 2: MTA Air Quality Index Pollution Measures and Weights

Category (Weight)	Metric	Health Impacts	NYC Max Vs. Heath Standard	NYC Avg Vs. US Avg
High (60)	Fine particulate matter (PM2.5)	Exposure can affect lung function and worsen asthma and heart disease. Long term exposure may be associated with chronic bronchitis, reduced lung function, lung cancer and heart disease.	Exceeds	93%
	EPA air toxics respiratory hazard index	Noncancer health impacts of hazardous air pollutants include effects on the respiratory system, the immune, nervous, and reproductive systems, and to organs such as the heart, liver, and kidneys	Exceeds	216%
	EPA air toxics cancer risk index	Lifetime cancer risk from inhalation of air toxics.	NA	174%
Mid (30)	Diesel particulate matter	Can cause irritation to the eyes, throat and nose, heart and lung disease, and lung cancer.	High	1409%
	Ozone	Short-term exposure can cause a variety of respiratory health effects and symptoms. Long-term exposure to ozone is linked asthma development.	High*	72%
	Asthma prevalence	Asthma causes narrowing of the airways, which makes breathing difficult and can lead to chest tightness or pain, coughing or wheezing, or shortness of breath.	NA	121%
Low (10)	Sulfur dioxide (SO2)	Short-term exposure can harm the respiratory system and make breathing difficult. High concentrations can also harm trees and plants.	Low	25%
	Nitrogen dioxide (NO2)	Nitrogen oxides can cause damage to lung tissue, breathing and respiratory problems, as well as contribute to smog and acid rain.	Low**	212%
	Carbon monoxide	Reduces the amount of oxygen that can be transported to critical organs like the heart and brain.	NA	138%

Data is from the EPA National Air Toxics Assessment, the NYC Community Air Survey, the Center for Air, Climate, and Energy Solutions, and the Centers for Disease Control.
**NYC data unit of measure is annual average; health standard is daily maximum; NYC level at ~50% of health standard suggests high risk*
***EPA NAAQS estimates that 0% of the US population is exposed to levels that exceed the health standard*

Figure 4: MTA Air Quality Index



Environmental Justice Score

Areas of Concentrated Need and the Air Quality Index are combined to create a composite EJ Score. This score is applied at both the route level and the depot level to facilitate decision making and prioritization for the zero-emission fleet rollout:

- Route-level scores for Areas of Concentrated Need are established based on the share of each routes' bus stops located in an area. Route-level scores for the Air Quality Index are established based on the average air quality index of all areas within 250 feet of the route.
- Depot-level scores for Areas of Concentrated Need are an average of the route-level scores for all routes operating from that depot. Depot-level scores for the Air Quality Index are a composite: 90% of the score is based on the average score from all the routes operating from the depot, and 10% is based on the index within a ¼ mile radius of the depot itself.

The EJ Score, at both the route level and depot level, combines these two scores using a percentage for each: 55% for Areas of Concentrated Need and 45% for Air Quality. The resulting EJ Score is on a scale from 0 to 100. A diagram explaining how route- and depot-level scores for each metric and the combined EJ Score is below, followed by a table showing the results for all 28 MTA depots.

	ROUTE SCORE	DEPOT SCORE*
Equity: Areas of Concentrated Need Includes 8 weighted metrics	Share of stops located in an area of concentrated need	Average of all routes operating out of the depot
	+	+
Air Quality Index Includes 9 weighted metrics	Average air quality index within 250-foot buffer of the route	90% average of all routes operating out of the depot* 10% air quality index within 1/4 mile of the depot
	=	=
Environmental Justice Score	55% equity priority score 45% air quality score	55% equity priority score 45% air quality score

** Differentiated by bus type depending on the analysis (e.g. only local routes, only artic, only SBS, etc.)*

Figure 5: MTA Environmental Justice Score Components

Table 3: Environmental Justice Scores by Depot

Division	Depot	EJ Score	Borough Rank	System Rank
Bronx	Eastchester	45.2	4	10
	Gun Hill	59.2	3	3
	Kingsbridge	62.9	1	1
	West Farms	61.3	2	2
	Yonkers	36.1	5	21
Brooklyn	East New York	56.4	1	4
	Flatbush	42.9	5	13
	Fresh Pond	48.0	2	5
	Grand Avenue	44.1	4	12
	Jackie Gleason	42.0	6	14
	Ulmer Park	46.3	3	8
Manhattan	Manhattanville	40.8	3	15
	Michael J. Quill	32.7	4	23
	Mother Clara Hale	47.0	1	6
	Tuskegee Airmen	44.6	2	11
Queens	Casey Stengel	36.4	6	19
	College Point	36.5	5	18
	Jamaica	37.2	4	17
	LaGuardia	38.3	3	16
	Queens Village	33.4	8	22
	Baisley Park	45.2	2	9
	Far Rockaway	30.4	9	24
	JFK	46.9	1	7
	Spring Creek	36.2	7	20
Staten Island	Castleton	21.2	1	25
	Charleston	15.9	4	28
	Meredith Avenue	20.7	2	26
	Yukon	17.8	3	27
System Average		**40.2**	**4**	

III.

Fleet Transition Plan

III. Fleet Transition Plan

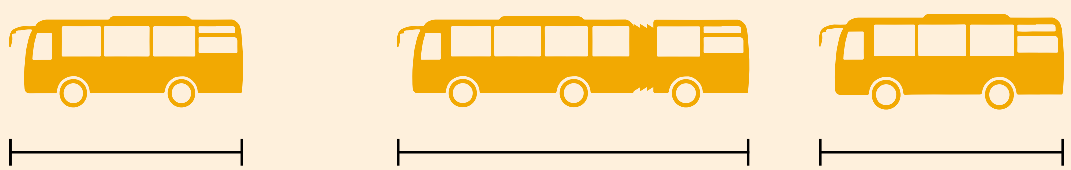
Battery-Electric Bus Technology Evaluation

Available Manufacturers and Models

Battery-electric buses must not only meet range expectations but must also stand up to the rigors of high-intensity passenger use, stop-and-go operations, cold weather, and rough roads. The MTA system is a particularly rigorous environment for these vehicles. Battery-electric buses are also a relatively new technology, and while the number of available vendors and models continues to increase, there are still relatively few that meet all the MTA's specifications and have proven reliability in difficult city environments. The MTA is committed to continuing to expand the pool of viable battery-electric bus vendors and models and proactively works with all willing vendors to encourage the continued development and improved performance of battery-electric buses.

While MTA is investigating FCEB technology, the current transition plan is focused on BEBs. This is largely because they are the dominant zero-emission technology in the US and are the only zero-emission technology with which the MTA has direct experience.

The MTA operates three bus types:



40-foot

Standard low-floor transit buses

The 40-foot standard bus category is by far the most developed with five vendors offering battery-electric models that have passed industry (Altoona) testing.

60-foot

Articulated low-floor transit buses

By contrast, there are only three vendors with 60-foot articulated battery-electric models, of which only one has previous experience with the MTA.

45-foot

High-floor express coach buses

In the express coach category, there are currently three vendors with models available. Only a very limited number of vehicles have actually been produced and operated in passenger service, and only one vendor has previous experience with the MTA.

MTA Test and Evaluate Program

The MTA is committed to working with all vendors to expand the number of battery-electric bus models capable of operating in MTA service. The MTA has unique operating conditions which have led to the establishment of rigorous technical specifications and testing standards that all bus models must pass to meet MTA procurement requirements. The MTA Test and Evaluate Program works with vendors to meet these requirements and provides an opportunity for pilot fleets of new bus models. The program creates a pathway for new vendors and bus models to become qualified, gives vendors invaluable experience with the real-world conditions of MTA operations, and provides the MTA with hands on experience of new and upcoming technologies.

Energy Consumption and Range Experience to Date

Experience operating battery-electric buses in MTA service has provided a picture of the real-world energy consumption and range realities of current technology. The MTA has in-service energy consumption data for three fleets: five New Flyer standard buses, five Proterra standard buses, and 15 New Flyer articulated buses. The MTA does not yet have any electric bus experience with express coach buses.

The MTA conducted a baseline energy consumption analysis with one year of data, from May 2020 to June 2021, encompassing 4,845 individual driving events. In this analysis, the largest factors impacting energy consumption were temperature and operating speed. Consumption rates were approximately 50% higher in 20 to 30°F weather, compared to more moderate 40-70°F days. Similarly, consumption rates were around 50% higher for buses operating at speeds of 2.5 to 5 mph compared to those operating at 7.5 to 10 mph.

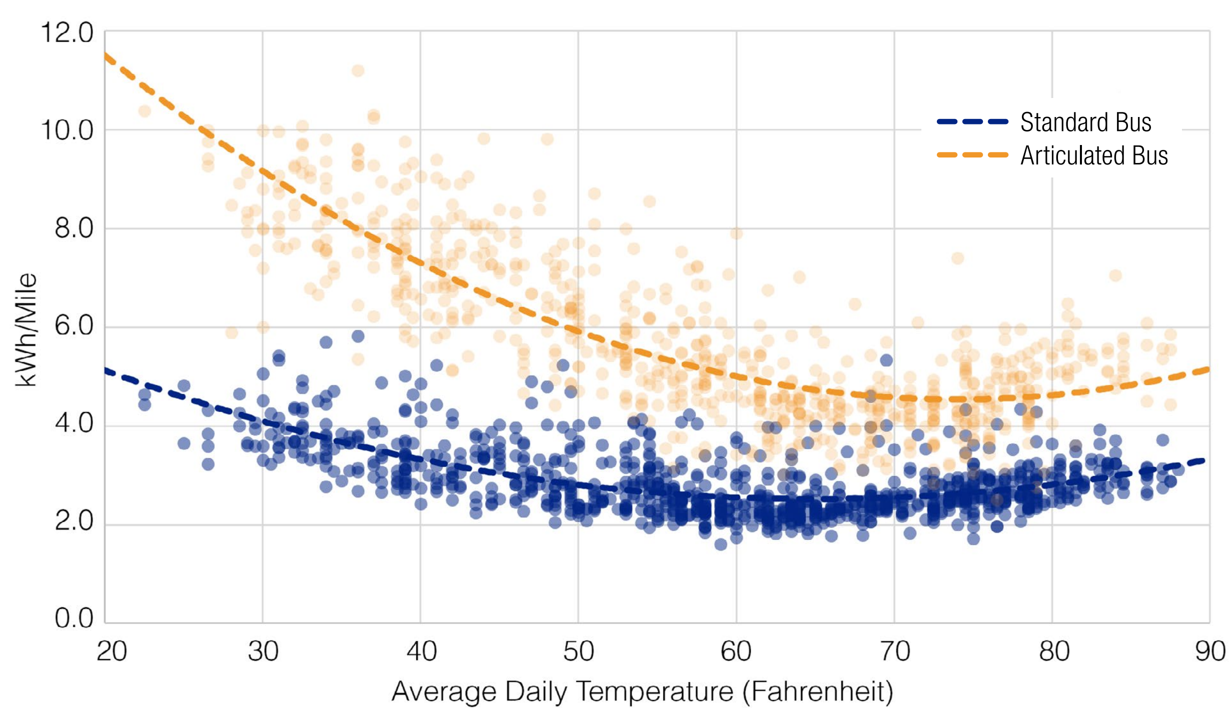


Figure 6: MTA Battery-Electric Bus Energy Consumption by Temperature

Critical Technology Drivers and Future Expectations

The battery-electric bus industry is continuing to develop and improve. As a relatively new technology, ongoing innovation and experience has the potential to drive significant improvements in performance. Under difficult operating conditions, such as low temperatures and low speeds, current battery-electric buses often have reliable ranges of less than 100 miles. The industry is keenly aware of this challenge and is focusing on improvements in energy efficiency and battery technology that will be critical drivers defining the range expectations of future vehicle models.

Energy Efficiency

The most direct way to improve vehicle range is to reduce the amount of energy consumed per mile of operation, i.e., improving energy efficiency. This is a major area of focus for technology innovation, specifically as it relates to heating, ventilation, and air conditioning (HVAC) and drivetrain systems. Without the ready availability of excess heat from internal combustion engines, battery-electric vehicles rely on electric heating systems that have proven to be the single largest element of energy consumption in cold weather. The industry is looking at all aspects of HVAC systems, and technologies such as heat pumps and carbon dioxide refrigerant are emerging as promising avenues to reduce consumption. In the drivetrain area, improved control software and updated transmissions and inverters are expected to make continued incremental improvements that can make a substantive impact on overall consumption rates.

Battery Technology

The other major driver of vehicle range is battery technology. The efficiency of the battery in charging and discharging is critical to reducing the amount of charge that is lost as heat in the process. In addition, the degradation rate of the battery over its lifetime is critical to longevity and the continued ability to hold charge over the battery's lifecycle. But perhaps most critical is energy density. Greater energy density allows for larger capacity batteries without taking up more space or adding to vehicle weight, making energy density improvements a key driver of the expected reliable range of battery-electric buses. Review of trends and emerging technologies in battery development suggest that continued improvement in performance and capacity can be expected over the course of the MTA transition period, though the rate of improvement is likely to be somewhat less rapid than in previous years.

Table 4: Key Energy Efficiency Technology Drivers and Projected Improvements

	Overall Impact Level	Technology Pathway	Near-Term Gains	Long-Term Gains
HVAC	High	Integration of heat pumps and carbon dioxide (CO2) refrigerants	+20%	+15%
Defroster	Mid	Smart shutoff timers and selectable airflow rates	+20%	+20%
Drivetrain	Mid	Improved control software, advanced transmissions, and updated inverters and power electronics	+10%	+5-10%
Air Compressor	Low	Use of improved oils and shift to electro-mechanical suspension and braking	+1%	+5%
Low Voltage Systems	Low	Automatic disconnect switches and conversion to Li-ion from lead acid	+1%	+1-5%

Bus Technology Generations

To effectively plan for the conversion to 100% zero-emission buses, the MTA has developed general expectations for battery-electric bus technology improvement. The expectations are based on a review of key technology drivers and outreach to major equipment manufacturers. They are not intended as prescriptive or predictive but only as a directional guide to allow for order of magnitude estimates of how technology improvement may impact key aspects of the MTA's transition planning such as schedule feasibility and power demand expectations.

Technology generations are anchored to future dates to align with the stages of the MTA zero-emission transition:

Generation 1
Current existing technology

Generation 2
Expectations for commercially available technology in 2028, aligned with Stage 2 of the MTA transition

Generation 3
Expectations for commercially available technology in 2038, aligned with Stage 4 of the MTA transition

Table 5: Bus Technology Generations and Technology Development Projections

	Generation 1 (Current)	Generation 2 (2028)	Generation 3 (2038)
Battery Size (kWh)	**550** Based on average of latest MTA-qualified models	**650** +100 kWh from current, based on increase from first round of models from major manufacturers vs. today's offerings	**800** +250 kWh from current, only 60 kWh above the largest current offering
Energy Efficiency Improvement	**NA** Baseline efficiency based on current experience	**+7.5%** Based on review of key technology drivers	**+15%** Based on review of key technology drivers
Battery Power to Weight Ratio	**1** Level set to current Wh/kg of the full pack assembly	**1.05** Based on historic trends of Lithium Ion battery development, and future expectations	**1.12** Based on historic trends and future expectations. 10 to 15% is the practical assumed limit

Battery Fire Safety

The MTA places the highest importance on safety and is committed to pursuing every possible means to ensure the safe operation of zero-emission vehicles. Battery fires are a new type of safety risk related to battery-electric vehicles. Because these fires do not need oxygen or any external element to continue to burn, they can be difficult to put out. Reducing the likelihood of a fire starting to begin with, providing early detection and warning systems, and being prepared for and responding quickly and effectively to an incident are all critical ways to reduce the risk and impact of battery fires. The MTA has robust existing measures in place across each of these mitigation areas and is undertaking a thorough program to continue to develop new tools, standards, and procedures to ensure battery fire risks are addressed throughout the transition to zero-emission buses.

Risk Reduction

The best way to secure against the impact of battery fires is to prevent them from starting. The MTA is working across multiple areas to reduce battery fire risk:

- Vehicle and Battery Pack Design – The MTA is working with vehicle and battery manufacturers to ensure batteries are designed to prevent the risk of fires and to reduce their severity. Elements like battery pack placement on the vehicle to avoid damage, the inclusion of proper ventilation and cooling, and the quality of materials are important safety considerations. Just as critically, good design must be supported by quality assurance checks and manufacturing process reviews.
- Maintenance and Training – Regular inspections and maintenance of critical on-bus electrical systems and battery housings and wiring connections is essential. The MTA has set rigorous standards for maintenance and inspections and has a thorough training program to ensure staff are knowledgeable and capable to identify and address any potential issues.

Monitoring, Detection, and Warning

Situational awareness can provide invaluable time and information to mitigate the risk and impact of battery fires. The MTA is working in several areas to establish comprehensive monitoring, detection, and warning systems:

- Battery Health Monitoring – The MTA is working with vehicle and battery manufacturers to develop robust battery monitoring systems that can provide ongoing real-time information on key aspects of battery performance. Monitoring can allow for condition-based maintenance to address potential risk factors before they become a problem and may be able to identify early warning signs and provide advance notice to operators and incident response staff.

- Early Gas Detection – Detection systems that monitor battery pack gas levels are an emerging area of technology. The MTA is evaluating the potential of these systems to provide early warnings of battery fires and automatically power off the vehicle or charging system.

Incident Preparedness and Response

Having the appropriate tools and procedures in place and acting quickly and purposefully in the event of an incident can reduce the severity and impacts of a battery fire. The MTA is working across a broad range of preparedness and response areas:

- Onboard Fire Suppression – Preventing the spread of a battery fire once it has started is critical to reduce its impact. Fire suppression systems installed in the battery compartment are a first line of defense. The MTA is working to develop minimum standards for onboard suppression systems.
- Facility Fire Suppression and Ventilation – While putting out a battery fire is very difficult, robust fire suppression systems in vehicle parking and charging locations can help mitigate impacts and prevent fires from spreading between vehicles. In addition, smoke from battery fires is highly toxic. Proper ventilation, particularly in indoor locations, can reduce the risk of smoke inhalation. The MTA is committed to installing appropriate fire suppression and ventilation systems for all bus parking and charging areas.
- Response Protocols and Training – Responding quickly and effectively is key to reducing the scope and severity of a battery fire. Clear procedures combined with regular training and drills lay the groundwork for an effective response. The MTA has battery fire response procedures and training already in place and will continue to update and improve according to emerging best practices.
- Isolation and Containment Areas – One of the best ways to reduce the spread and impact of a battery fire is to isolate the vehicle or equipment. This can be done via designated areas that are hardened against the spread of fire and equipped with fire suppression and ventilation. The MTA is committed to identifying and equipping isolation areas for all facilities operating battery-electric buses.
- FDNY Partnership – Battery fires cannot easily be put out and require specialized training and equipment. Fire department participation will be critical to all preparation and incident response at the MTA. The MTA has a long-running productive relationship with the FDNY and is deepening that engagement through a joint working group on battery fire safety that will develop standards for fire suppression mitigation equipment and incident response protocols.

Bus Structural Qualification

New York City streets are a grueling operating environment that impose uniquely challenging conditions for buses. Difficult road conditions, continual construction, high passenger loads, and frequent stop-and-go travel mean buses are put under high levels of physical strain on a daily basis. To withstand continued stress throughout their 12-year service life, buses must have very durable and well-engineered structural framing. In light of this, the MTA requires all buses, including new zero-emission models, to pass a structural qualification test to be eligible for long-term operation in MTA service. This can be a significant hurdle for new bus vendors and manufacturers that do not have previous experience working in environments like NYC. To date only one battery-electric bus manufacturer has passed the MTA's structural qualification test. The MTA is actively working with additional vendors to qualify their zero-emission bus models.

Battery-Electric Bus Schedule Feasibility

The MTA has evaluated all existing scheduled bus assignments for compatibility with battery-electric bus operation. For a scheduled assignment to be feasible, it must have sufficient available battery state of charge (SOC) to complete all assigned passenger trips over the course of each service day.[3] Infeasible assignments are the result of either 1) the duration or mileage of an assignment being too long for the battery size and energy consumption rate of the bus or 2) the available charge time between assignments being insufficient to restore enough SOC to complete the next assignment. Thus, feasibility is a function of both the technical constraints of the bus itself, as well as of the charging equipment and charge management approach.

Energy Consumption Modeling Methodology and Assumptions

MTA schedule feasibility was modeled using specialized software. The modeling tool takes all existing bus schedules, estimates the energy required for each one, and determines whether a battery-electric bus can successfully complete the assignment. The model estimates energy consumption based on multiple factors that impact vehicle performance: speed, temperature, elevation change, and passenger load. Energy consumption in the model was calibrated to align with real-world experience from the MTA's 15 articulated bus fleet.

Worst Case Conditions

The MTA must plan to reliably provide service under worst case conditions. For planning purposes, the MTA models energy consumption rates with conservative assumptions:

- 23-degree temperature – New York City has an average of more than 115 days each year with low temperatures below 30 degrees Fahrenheit, and more than 50 days with lows below 20 degrees. Energy consumption rates are evaluated in cold weather to ensure bus assignments can be successfully fulfilled by electric vehicles year-round.
- 90th percentile results – Even under similar temperatures and service assignments, energy consumption rates vary due to differences in operator behavior, traffic conditions, passenger loads, and dwell durations. While some of the variation in operator behavior may be reduced through training, most of the conditions leading to variability in energy consumption cannot be controlled. Thus the 90th percentile energy consumption result is used.

Available Battery Capacity

The MTA also assumes that available battery capacity will be less than manufacturer specifications:

- 25% battery SOC unusable for service – Since batteries often do not achieve a 100% SOC, 10% of battery SOC is reserved as a buffer. In addition, 15% is reserved as a minimum cut-off below which a bus would be taken out of service to avoid failure on route.
- 20% battery SOC reserved for degradation – Battery capacity degrades over time, and buses must be able to complete the same assignments even as batteries age. The reliable range of the bus is measured at the end-of-life for the battery. With limited industry experience regarding battery ageing and degradation rates, the MTA uses 20% SOC degradation to mark battery end-of-life.

3 In some cases, this analysis may propose to split an assignment into shorter pieces that are considered "feasible" if doing so does not increase the fleet size.

Schedule Feasibility Analysis Results

The modeling tool was applied to the MTA's Fall 2022 weekday schedule. Schedule feasibility was modeled for each of the three technology generations described above to estimate the impacts of technology change over the course of the MTA's zero-emission transition. The MTA estimates that 98% of all standard bus assignments and 81% of all articulated assignments are feasible with currently available battery-electric bus models (Generation 1). By the target date for the completion of the transition (Generation 3), technology improvement is projected to increase schedule feasibility to 100% for standard buses and 92% for articulated buses. Express bus assignments have been estimated but are considered preliminary given the lack of MTA and industry experience with this bus type.

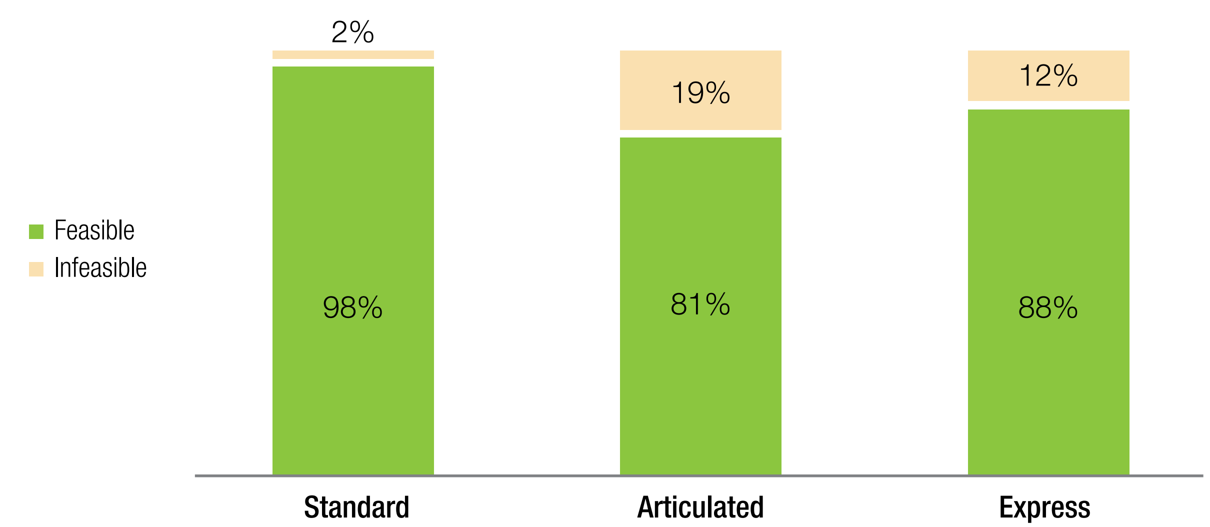


Figure 7: MTA Battery-Electric Bus Schedule Feasibility (Generation 1)

Table 6: Feasible Bus Assignments by Battery-Electric Technology Generation

	Standard	Articulated	Express	Total
Generation 1	98%	81%	88%	94%
Generation 2	99%	87%	90%	97%
Generation 3	100%	92%	91%	98%
Not Feasible	*0%*	*8%*	*9%*	*2%*

Baseline Fleet Replacement Needs

The MTA schedules buses for replacement based on a 12-year useful life. As part of each five-year capital program, the age and condition of the bus fleet is reviewed along with expected changes in bus fleet requirements to accommodate growth, conversions from standard to articulated bus types, and any other service adjustments. The resulting estimate of needs informs the quantity of new bus purchases included in the immediate capital program and provides a guide of expectations for subsequent capital programs. The table below shows estimated bus purchase requirements by type through 2040.

Table 7: MTA Expected 20-Year Bus Purchases by Five-Year Capital Program

Capital Program	Standard	Articulated	Express	Total
2020-2024	1,735	335	365	**2,435**
2025-2029	1,250	625	350	**2,225**
2030-2034	1,455	190	325	**1,970**
2035-2039	1,750	865	685	**3,300**

Zero-Emissions Fleet Plan

The MTA will progressively transition its bus fleet to 100% zero-emission through the year 2040 over four stages aligned with the MTA's five-year capital programs. New zero-emission bus purchases and deployments are coordinated with fleet replacement and retirement needs. The share of new bus purchases that are zero emission will increase across Stage 1 (through 2024) and 2 (2025-2029). All new bus deliveries from 2029 on will be zero-emission.

Achieving a 100% zero-emission fleet by 2040 requires that the last remaining diesel and CNG powered buses in the MTA fleet be retired and replaced before the end of the year in 2040. With a 12-year useful life, that means the last year for non-zero-emission bus deliveries to the MTA is 2028. A bus delivered on December 31, 2028, will complete 12 full years of service on December 31, 2040.

1 Stage 1

Through 2024

Stage 1 includes both the 2015-2019 Capital Program and the current 2020-2024 Capital Program. During this stage, 560 battery-electric buses will be purchased and deployed. At this time, 15 buses have been deployed and another 60 have been purchased with delivery expected in 2024. The remaining 485 buses are expected to be purchased before the end of 2023 and delivered 2025 through 2026. All purchases will be battery-electric.

2 Stage 2

2025-2029

Stage 2 will roughly double the number of purchases from Stage 1 with an expected total of 1,000 zero-emission buses. This stage is expected to include the first purchase of zero-emission express buses. Most purchases are expected to be battery-electric, though some hydrogen fuel cell purchases will be considered pending the state of the technology and results of any MTA pilot experience. During this stage the MTA will switch to 100% zero-emission fleet purchases. All new bus deliveries starting in 2029 will be zero-emission.

3 Stage 3

2030-2034

Stage 3 will once again almost double the number of zero-emission bus purchases from the prior stage, from 1,000 up to 1,970. All new buses purchased in this stage will be zero-emission. One-third of the fleet will switch to zero emissions, bringing the overall zero-emission fleet share up to 60%. This stage will also see the first retirements of zero-emission buses, as the 15 articulated buses delivered in 2020 will reach the end of their useful life and be replaced. The type of propulsion purchased in this stage will depend on experience to date with battery-electric and hydrogen fuel cell deployments.

4 Stage 4

2035-2039

Stage 4 will complete the MTA transition to a 100% zero-emission fleet. An expected total of 3,300 zero-emission buses will be purchased. A projected 2,385 remaining buses that are non-zero-emission will be retired and replaced. In addition, a further 965 zero-emission buses from previous stages will be retired as they reach the end of their useful lives. The propulsion type of purchases in this stage will depend on experience to date with battery-electric and hydrogen fuel cell deployments.

Table 8: Zero-Emission Fleet Purchase and Deployment Stages

Stage	Capital Program	Total Bus Purchases	Total ZE Purchases	Total Non-ZE Purchases	New ZE Conversions	Cum. ZE Fleet	ZE Fleet Share
Stage 1	2015-2019	1,776	60	1,716	60	60	1%
Stage 1	2020-2024	2,435	500	1,935	500	560	9%
Stage 2	2025-2029	2,225	1,000	1,225	1,000	1,560	26%
Stage 3	2030-2034	1,970	1,970	0	1,955	3,515	60%
Stage 4	2035-2039	3,300	3,300	0	2,385	5,900	100%

Table 9: Zero-Emission Fleet Purchase and Deployments by Bus Type and Stage

Zero-Emissions Bus Purchases				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Stage 1	455	105	0	**560**
Stage 2	750	200	50	**1,000**
Stage 3	1,455	190	325	**1,970**
Stage 4	1,750	865	685	**3,300**
New Zero-Emissions Conversions*				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Stage 1	455	105	0	**560**
Stage 2	750	200	50	**1,000**
Stage 3	1,455	175	325	**1,955**
Stage 4	925	775	685	**2,385**
Cumulative Zero-Emissions Fleet (Count)				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Stage 1	455	105	0	**560**
Stage 2	1,205	305	50	**1,560**
Stage 3	2,660	480	375	**3,515**
Stage 4	3,585	1,255	1,060	**5,900**
Cumulative Zero-Emissions Fleet (Share)				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Stage 1	13%	8%	0	**9%**
Stage 2	34%	24%	5%	**26%**
Stage 3	74%	38%	35%	**60%**
Stage 4	100%	100%	100%	**100%**

** Conversions are defined as zero-emission buses replacing fossil fuel buses (but not other zero-emission buses.)*

Alignment with Schedule Feasibility and Technology Improvement

The table below shows expected fleet share by bus type and stage alongside scenarios of battery-electric bus technology improvement generations as discussed in the Schedule Feasibility Analysis section above. The MTA can accommodate all projected zero-emission bus purchases and deployments in Stages 1 and 2 (through 2029) without increasing the fleet size or making major changes to schedules. As an estimated 98% of standard bus schedules, 81% of articulated bus schedules, and 88% of express bus schedules are feasible with currently available battery-electric bus models, this capability can support all planned standard, articulated, and express bus deployments until Stage 4 (2034-2039).

Accommodating deployments in Stage 4 will require improvements in the reliable range capability of battery-electric buses or the use of other propulsion technologies like hydrogen fuel cells. Currently expected technology improvements appear sufficient to meet schedule requirements for standard buses but not for all articulated and express buses. With 8% of existing articulated bus schedules and 9% of existing express bus schedules infeasible even with Generation 3 technology, providing service will require either onboard heaters, on-route charging, or an increase in fleet size to complete the transition. Articulated and express buses might also be prime candidates for hydrogen fuel cell technology. Because increases in fleet size require not only the purchase of additional vehicles but also expansions to facility space and additional operating staff effort, the MTA will only consider fleet size increases as a last resort. Current plans assume that infeasible schedules converted in Stage 4 will be met either through improved battery-electric bus technology, the use of onboard heaters, targeted on-route charging, or use of hydrogen fuel cell buses.

Table 10: Zero-Emission Fleet Deployment and Feasibility by Bus Type and Time Period

Cumulative Zero-Emissions Fleet Share by Stage				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Stage 1	13%	9%	0%	**9%**
Stage 2	34%	24%	5%	**26%**
Stage 3	74%	38%	35%	**60%**
Stage 4	100%	100%	100%	**100%**
Feasible Battery-Electric Bus Schedule Assignments by Technology Generation (Daytime Charging)				
Stage	**Standard**	**Articulated**	**Express**	**Total**
Generation 1	98%	81%	88%	**94%**
Generation 2	99%	87%	90%	**97%**
Generation 3	100%	92%	91%	**98%**
Not Feasible	*0%*	*8%*	*9%*	***2%***

IV.
Facility Transition Plan

IV. Facility Transition Plan

The MTA's facility transition plan assumes in-depot charging with high-capacity chargers and pantograph dispensers. By modeling the number of simultaneously active chargers required to support all bus schedules at each depot throughout the day, the MTA was able to estimate peak power demands and the minimum charger capacity required. The agency evaluated its 28 depots against these power demand and charging projections, allowing for an understanding of which facilities will likely require the most significant upgrades and modifications to support battery-electric buses. (To the extent that fuel cell electric buses are utilized, the necessary facility upgrades and transition steps may change). The facility upgrade projects and vehicle deployments will be phased based on five criteria: equity and environmental justice, borough distribution, power supply, construction feasibility, and schedule feasibility.

Power and Charging Infrastructure Requirement

Charging Infrastructure Approach

MTA charging infrastructure planning is guided by the following approach:

In-depot charging

Given the disadvantages of on-street charging (see inset), the MTA expects to provide most charging infrastructure in existing depots, at least through the end of Stage 1. On-street charging will be reevaluated in Stages 2-4.

Pantograph-down dispensers

Pantographs allow for automated connection between chargers and buses, avoiding safety hazards and staff time to plug and unplug buses. Pantograph-down dispensers reduce the total number of pantographs (compared to pantograph-up dispensers) and eliminate weight from the bus itself.

Dedicated dispenser positions for each in-service bus

Providing a dedicated parking and charging position for each in service bus simplifies yard operations and allows for sophisticated charge management control at scale, which can reduce power costs and ensure buses are sufficiently charged and ready for service.

High-capacity chargers with multiple dispensers

Current charger installations typically use a single charging unit with capacity of 100-500 kW that can be distributed to one or two dispensers. At scale, this can result in significant inefficiency or the need for complex yard management. The MTA expects that most future installations will use larger centralized charging units with capacities of 1-3 MW connected to 10 or 20 dispensers, allowing installed capacity to be more precisely targeted to vehicles based on need, greatly improving the efficiency of the system.

On-Street Charging Challenges

Space Acquisition

Most MTA bus routes do not start and end in formal terminals with large available space for charging equipment. With over 300 routes and more than 600 terminal locations, finding space for charging infrastructure at even a fraction of those terminals would require extensive real-estate transactions. Relying on this for the bulk of charging infrastructure would be a significant risk factor to achieving the MTAs 2040 goal.

Design and Approval

Even once space is identified, the complexity of public approvals and overlapping jurisdictions that are common in New York City would add time and cost to many on-street charger installations. In addition, design and engineering challenges are highly likely to arise in many locations. Design approvals in depots are much simpler and less likely to encounter unexpected engineering challenges. Overall, in-depot charging will have a much less costly and risky design and approval process.

Reliability Risk

In a system based around on-street chargers there is a risk of significant operational impacts if chargers are out of service. Either a large amount of redundant capacity needs to be installed at each charging location, adding cost and complexity, or the MTA must accept impacts to service if chargers go out of service. It is also more likely that an unexpected event leads to an outage for on-street chargers that are in a largely uncontrolled environment compared to the controlled environment in depots.

Maintenance Complexity

Servicing a distributed network of potentially hundreds of on-street locations would require a large, mobile workforce. The added complexity of having to get to and from each location, and to access charging equipment at those locations in the middle of the active life of the city is a significantly greater challenge than maintaining even a larger number of chargers in depots.

Charging and Power Demand Projection

Alongside schedule feasibility analysis, the MTA has projected charging infrastructure and power demand needs to support battery-electric bus operations. The MTA projection identifies the number of simultaneously active chargers required to support all bus schedules at each depot for every minute of the day, while optimizing operations to reduce total power demand.

To project the amount of power demand required from the power utility, an additional 5% buffer is added to the peak demand used by the chargers directly, and a power factor of 90% is applied to account for transmission and reactive power losses.

Table 11: Projected Charger and Power Demand Requirements for 100% Battery-Electric Bus Operations

Depot	Simultaneous Active 150 kW Chargers	Peak Power Demand (MW)	Required Utility Capacity (MVA)
Eastchester	42	6.3	7.4
Gun Hill	80	12.0	14.0
Kingsbridge	62	9.3	10.9
West Farms	78	11.7	13.7
Yonkers	26	3.9	4.6
East New York	60	9.0	10.5
Flatbush	53	8.0	9.4
Fresh Pond	44	6.6	7.7
Grand Avenue	42	6.3	7.4
Jackie Gleason	64	9.6	11.2
Ulmer Park	56	8.4	9.8
Michael J. Quill	52	7.8	9.1
Manhattanville	44	6.6	7.7
Mother Clara Hale	26	3.9	4.6
Tuskegee	44	6.6	7.7
Baisley Park	35	5.1	6.0
College Point	100	15.0	17.5
Casey Stengel	60	9.0	10.5
Far Rockaway	35	5.2	6.1
Jamaica	48	7.2	8.4
John F. Kennedy	47	7.0	8.2
LaGuardia	58	8.7	10.2
Queens Village	63	9.5	11.1
Spring Creek	36	5.4	6.3
Castleton	62	9.3	10.9
Charleston	76	11.4	13.3
Meredith Avenue	24	3.6	4.2
Yukon	76	11.4	13.3
System Total	**1,493**	**223.8**	**261.7**

Solar Power and Battery Storage

Meeting the large demand for energy required to power battery-electric buses is one of the biggest challenges facing the MTAs transition to zero-emissions. While most of the required power is expected to come through traditional utility connections in partnership with ConEdison, on-site solar generation and battery storage systems offer several potential benefits:

Reduce Grid Demand

Storing solar energy in batteries and using it when bus charging demand is highest reduces the magnitude of the power service required from the utility. This has several benefits. It reduces the amount of power infrastructure both the utility and the MTA must install, and it creates a more predictable, even demand profile which is easier for the utility to meet.

Cost Savings

Solar and battery systems can reduce costs for the MTA in several ways. Most directly, all the power generated by solar panels can offset power that would otherwise be purchased from the utility. In addition, the MTA gets cost savings through reduced upfront capital costs to install power infrastructure and from lower monthly bills from reduced demand charges.

Resiliency

From supporting continued mobility following weather events to providing evacuation services for hospitals and at-risk populations, buses are an essential part of NYC's response to unexpected events. Solar and battery systems are a source of independent and ongoing power that can provide critical operational continuity in the event of power disruptions or outages.

The MTA is actively pursuing opportunities to pilot a solar and battery storage system to evaluate these potential benefits in practice and assess the real-world ability of the system to integrate with bus charging infrastructure.

Utility Rates

With the potential for over two million kWh of electricity to power a full fleet of battery-electric buses each day, the cost of electricity is expected to be a significant ongoing cost for the MTA. Current rate structures are designed to encourage electricity use during off-peak times by charging higher rates at peak times of consumption from 8am-10pm, and particularly from 6pm-10pm. While the MTA has some opportunity to control when buses charge, avoiding peak rate times is not possible for a large share of the fleet because buses are heavily utilized and closely scheduled. The MTA supports efforts to review utility rate structures for opportunities to bring down the effective cost per kWh for electric vehicle charging, particularly for essential public service fleets like transit buses.

Relationship with Power Utility

The MTA is actively engaged with Con Edison to meet power supply needs for battery-electric bus operations. Together, the MTA and Con Edison are working on ongoing projects to bring new power supply to depots in support of Stage 1 of the transition, as well as planning for the following stages.

The focus of the MTA-Con Edison partnership is to ensure that a jointly coordinated charge management strategy balances MTA's power needs with those of the utility. The MTA has already instituted coordination meetings with Con Edison to clarify infrastructure needs and rate schedules. In addition to load and project planning, the coordination sessions allow for discussions about beneficial programs that reduce total electrification costs. For example, the MTA has begun a charge management pilot program that automatically curtails power demands during peak hours.

The partnership will also allow the MTA and Con Edison to jointly plan for utility disruptions. This includes the development of resiliency plans for significant weather events. The MTA and Con Edison will jointly plan for any additional infrastructure necessary to satisfy minimum service needs, including options for emergency power backup systems and corresponding levels of resilience.

Facility Upgrades and Modifications

Expected Facility Impacts

The transition to zero-emission buses requires significant upgrades and modifications to the MTA's depots. Electric Distribution Room (EDR) equipment, including switchgear, breakers, and panels, will need to be significantly expanded in almost every depot. Large quantities of conduit will be required to connect all charging equipment to all dispensers and to the EDR rooms and power sources. Steel gantries or other structures will need to be installed in yards and in depots to support overhead pantograph dispensers.

Some of MTA's depots may need other modifications. The additional weight of charging equipment, pantographs, and other new structural elements may require reinforcement of building columns, walls, or roof structures. There may also be a need to move existing conduit, piping, and HVAC ducts to accommodate new equipment, conduit, and the placement of pantograph dispensers and support structures. In some cases, depots may also require new HVAC equipment to accommodate heat generation from indoor charging equipment, or upgraded fire suppression systems to provide increased flow and coverage to address battery fire safety risks.

Facilities must also have sufficient space to accommodate all the new equipment. Charging equipment footprints alone are expected to require the equivalent of one bus parking space for every 20 to 30 battery-electric buses, though exact space needs are highly variable depending on the condition, layout, and space utilization plans at each depot. Expansion of EDRs and space for new power supply equipment will further eat into already constrained depot space. Accommodating this equipment is likely to reduce available bus parking space, require significant expansions and upgrades to EDRs, and necessitate modifications to other depot support facilities.

In addition, the goal of providing dedicated charging dispensers to most (if not all) bus parking spaces means formalizing bus parking arrangements. Currently, many MTA facilities are at capacity, and a significant share of overnight bus parking occurs in ad hoc spaces. Ensuring parking spaces are clearly delineated and supplied with charging dispensers will require thorough reevaluation of space utilization plans and is likely to result in the need for depot modifications or expansions.

Adequate ceiling height is another critical facility requirement to support the MTA's preferred approach to charging operations. Some indoor parking areas at MTA depots do not have sufficient ceiling height or overhead space to accommodate pantograph dispensers. Transitioning to zero-emission buses in these locations may require the use of alternative charging approaches, plug-in dispensers, or hydrogen fuel cell operations.

Taken together, the need for improved electrical infrastructure, adjustments to existing equipment and structures, and new demands on space and ceiling heights will require significant upgrades and modifications in many depots. In some cases, existing depot space may not be sufficient to accommodate all new equipment, and the MTA may need to expand, reconstruct, or acquire new facilities.

Facility Evaluation and Needs

The MTA has begun evaluating its 28 depot facilities and has completed a preliminary review of all locations. The preliminary depot review provided a high-level evaluation of the compatibility, construction feasibility, and rough level of effort required for electrification.

The evaluation relied on asset condition assessments collected as part of the MTA's 2020-2039 20-Year Capital Needs process. These condition assessments included descriptive information for each location as well as condition ratings for major subsystems and the facility overall. Condition ratings were on a 1 to 4 scale with 1 being the best and 4 being the worst. The MTA supplemented this information with a review of architectural drawings at select locations.

Each facility was evaluated for four characteristics related to the feasibility and level of effort required to install battery-electric charging infrastructure and supporting new power supply. Construction feasibility and effort for each characteristic was rated as good (minimal foreseeable issues), moderate (some level of modification expected), or constrained (significant constructability or feasibility challenge).

Facility Evaluation Criteria

General Condition

Identifies depots where major reconstruction or rehabilitation projects may be expected over the 20-year period of the zero-emission transition because of the underlying age or condition of the facility. These locations are expected to require more significant modifications when trying to accommodate charging infrastructure. They may also represent opportunities to incorporate electrification modifications and equipment as part of other state-of-good-repair projects.

GOOD	MODERATE	CONSTRAINED
Overall condition rating of 1 or 2 and facility built after 1950	Overall condition rating of 3 and facility built after 1950	Overall condition rating of 4 or facility built in 1950 or before

Electrical

Identifies depots where major expansion or upgrades to the EDR room and other electrical infrastructure are expected to support charging infrastructure installation.

GOOD	MODERATE	CONSTRAINED
Electrical condition rating of 1	Electrical condition rating of 2	Electrical condition rating of 3 or 4

Space

Identifies depots where parking capacity or existing space utilization may make the addition of new infrastructure and the formalization of parking assignments challenging.

GOOD	MODERATE	CONSTRAINED
At least 15% of total parking capacity unoccupied by current fleet assignment	>5% and <15% of total parking capacity unoccupied by current fleet assignment	5% or less of total parking capacity unoccupied by current fleet assignment

Ceiling Height*

Identifies depots where installing overhead pantograph chargers may pose significant challenges.

GOOD	MODERATE	CONSTRAINED
>18 feet from floor to ceiling	17 to 18 feet from floor to ceiling	<=16 feet from floor to ceiling

Note: the height of support structures, HVAC ducts, electrical conduit, fire suppression, and plumbing were not reviewed and may impede pantograph installation.
**Applied only to depots where >15% of parking is indoors (15% is the MTA's standard spare factor; buses not in regular daily service would not need to be parked in a pantograph-equipped parking space).*

The results of the preliminary evaluation give a rough idea of which facilities may require the most significant upgrades and modifications to support battery-electric buses. Seven depots are rated as constrained for general condition. Ten depots are rated as constrained for electrical. Fifteen depots are rated as constrained for space. Four depots are rated constrained for ceiling height. Twelve depots are rated as constrained for two or more characteristics.

Table 12: Preliminary Existing Facility Evaluation

Depot	General Condition	Electrical	Space	Ceiling Height	Two or more Constrained Ratings
Eastchester	Moderate	Moderate	Good	NA	
Gun Hill	Good	Moderate	Constrained	Good	
Kingsbridge	Moderate	Moderate	Constrained	Moderate	
West Farms	Good	Moderate	Constrained	Constrained	
Yonkers	Moderate	Good	Moderate	NA	
East New York	*	Constrained	Moderate	Good	
Flatbush	Constrained	Constrained	Constrained	Constrained	Yes
Fresh Pond	Good	Constrained	Moderate	Constrained	Yes
Grand Avenue	Good	Good	Constrained	Good	
Jackie Gleason	Moderate	Moderate	Constrained	Moderate	
Ulmer Park	Constrained	Constrained	Moderate	Constrained	Yes
Michael J. Quill	Good	Moderate	Constrained	Constrained	Yes
Manhattanville	Good	Constrained	Constrained	Moderate	Yes
Mother Clara Hale	Good	Good	Moderate	Good	
Tuskegee Airmen	Good	Moderate	Constrained	Moderate	
Baisley Park	Constrained	Moderate	Constrained	NA	Yes
College Point	Moderate	Constrained	Moderate	NA	
Casey Stengel	Moderate	Constrained	Constrained	NA	Yes
Far Rockaway	Constrained	Good	Constrained	NA	Yes
Jamaica	*	*	*	*	
John F. Kennedy	Constrained	Moderate	Good	Moderate	
LaGuardia	Constrained	Moderate	Constrained	NA	Yes
Queens Village	Moderate	Constrained	Moderate	Moderate	
Spring Creek	Moderate	Constrained	Good	NA	
Castleton	Constrained	Constrained	Good	NA	Yes
Charleston	Good	Good	Moderate	NA	
Meredith Avenue	Good	Good	Constrained	NA	
Yukon	Moderate	Moderate	Good	Constrained	

**East NY is currently undergoing a significant rehabilitation; Jamaica is currently in design for a complete reconstruction.*

Good Moderate Constrained

Infrastructure Phasing and Deployment Plan

Deployment Prioritization Criteria

The MTA plans to progressively deploy zero-emission buses as described in the Fleet Transition Plan above. New zero-emission bus deliveries will be coordinated with infrastructure upgrade projects to install chargers (or other zero-emission fueling infrastructure) to support rolling deployments. The timely conversion of facilities will become an important factor as the MTA progresses into the later stages of deployment. Location selection for project phasing and the rollout of bus deployments will be driven by five criteria:

1 Equity and Environmental Justice

Deployments will prioritize historically disadvantaged communities and areas with poor air quality. Locations with higher EJ Scores will be prioritized for earlier and larger zero-emission deployments. Details on the scoring methodology are included in the ***Equity and Environmental Justice*** section.

2 Borough Distribution

Deployments will be spread across the geographic area served by the MTA to meet public expectations of fairness, share the benefits of zero-emission buses to as many communities as possible, gain feedback from as broad an array of riders as possible, and expand operating staff experience and familiarity.

3 Power Supply

In the short term, deployments will emphasize locations with existing available supply to limit the number of locations where large power projects are required. In the long term, the MTA will coordinate with Con Edison to phase deployments based on needs and the technical difficulty of new power installation.

4 Construction Feasibility

In the short term, deployments will focus on depots where facility space as well as architectural, electrical, and operational conditions are suitable to support the installation of charging infrastructure with minimal disruption and cost. In the long term, deployments will be phased to balance the volume of required work, cost, and operational impact over the four-stage transition.

5 Schedule Feasibility

MTA will deploy new zero-emission buses to locations where there are enough feasible bus assignments to accommodate the size of the incoming zero-emission fleet.

Strategy and Phasing Approach

Most depot facilities are expected to see bus deployments spread over multiple stages. Particularly in the early stages, deployments will consist of partial fleets, to avoid the risk of service disruptions from potential reliability issues and to ensure bus counts are well within the number of feasible schedule assignments at each location.

Later stage deployments will bring zero-emission fleets up to 100% at each depot. For most depots the transition is expected to occur over two deployments, though some depots (particularly those with early-stage projects) may see the rollout occur over three.

Each bus deployment will include a supporting infrastructure project. Since deployments will occur over two to three stages at each depot, depots will experience multiple infrastructure installation projects. To reduce the operational impact and complexity of repeated projects, the first infrastructure project at each depot is expected to provide all the supporting upgrades required to pave the way for full zero-emission operation, including all required depot modifications (including EDR room upgrades, space modifications, and structural changes) and sufficient new power supply to support full electrification. The MTA anticipates displacement of some bus parking during the construction of these upgrades, so construction plans will address bus staging to avoid any operational disruptions.

With support infrastructure in place, subsequent installation projects will focus on providing charging equipment and dispensers. In most cases, the provision of charging equipment and dispensers will coincide with fleet purchases and deployments at each location. In some cases, however, charging infrastructure quantities may exceed immediately planned bus deployments where there are cost or operational efficiencies.

Conceptual Construction Phasing and Deployment Plan

While detailed plans and exact deployment locations have not yet been established other than for deployments in Stage 1, the MTA has developed a conceptual construction phasing and deployment plan to gauge the scale and impact of the effort.

The plan represents one possible scenario of infrastructure projects and bus deployments that is consistent with the agency's transition goals, prioritization approach, and fleet replacement schedule. This plan should be considered an example of one possible path. The actual rollout will likely include significant adjustments as further analysis, technology development, and operational experience are incorporated.

Table 13: Conceptual Construction Phasing and Deployment Plan

	Depot	Bus and Charging Equipment Deployments (share of total)				Timing of New Power Supply Installation	Timing of Depot Upgrades and Modifications
		Stage 1	Stage 2	Stage 3	Stage 4		
BROOKLYN	East New York	32%	73%	73%	100%	Stages 1 and 2	Stage 2
	Fresh Pond	0	0	100%	100%	Stage 3	Stage 3
	Grand Avenue	36%	36%	36%	100%	Stage 4	Stage 1
	Flatbush	0%	0%	100%	100%	Stage 3	Stage 3
	Jackie Gleason	20%	59%	100%	100%	Stage 1	Stage 1
	Ulmer Park	16%	16%	16%	100%	Stage 1	Stage 1
QUEENS	Casey Stengel	0%	69%	100%	100%	Stage 2	Stage 2
	College Point	0%	0%	51%	100%	Stage 3	Stage 3
	Jamaica	23%	77%	77%	100%	Stage 1	Stage 1
	LaGuardia	0%	0%	0%	100%	Stage 4	Stage 4
	Queens Village	24%	24%	86%	100%	Stage 1	Stage 1
	Baisley Park	0%	40%	40%	100%	Stage 2	Stage 2
	Far Rockaway	0%	0%	0%	100%	Stage 4	Stage 4
	John F. Kennedy	0%	0%	100%	100%	Stage 3	Stage 3
	Spring Creek	0%	0%	0%	100%	Stage 4	Stage 4
STATEN ISLAND	Castleton	0%	0%	78%	100%	Stage 3	Stage 3
	Charleston	9%	9%	9%	100%	Stage 4	Stage 4
	Meredith Avenue	0%	0%	0%	100%	Stage 4	Stage 4
	Yukon	4%	51%	93%	100%	Stage 2	Stage 2
BRONX	Eastchester	19%	19%	100%	100%	Stage 1	Stage 1
	Gun Hill	19%	19%	53%	100%	Stage 1	Stage 1
	Kingsbridge	10%	10%	54%	100%	Stage 1	Stage 1
	West Farms	0%	0%	57%	100%	Stage 2	Stage 2
	Yonkers	0%	0%	0%	100%	Stage 4	Stage 4
MANHATTAN	Tuskegee Airmen	0%	0%	14%	100%	Stage 2	Stage 2
	Mother Clara Hale	30%	30%	30%	100%	Stage 2	Stage 2
	Manhattanville	0%	0%	100%	100%	Stage 3	Stage 3
	Michael J. Quill	9%	53%	53%	100%	Stage 4	Stage 4

V.
Workforce Transition Plan

V. Workforce Transition Plan

Overview

A skilled and supported workforce is essential to achieve the MTA's goal of 100% zero-emission vehicles by 2040. The transition will affect the duties, responsibilities, and knowledge requirements of almost every member of the MTA operating and maintenance staff. While many aspects of operating zero-emission buses resemble existing practices, adapting to new battery-electric or hydrogen fuel cell propulsion systems will require adjustments to safety procedures, charging and fueling operations, and maintenance practices, as well as aspects of service management and depot operations.

The MTA's workforce transition must navigate the continually changing landscape of zero-emission technology. As technology changes, the way it needs to be operated and maintained will also change, and with it required staff skills and training. The MTA's workforce transition must remain flexible, adapting to technological innovations while ensuring that staff are fully prepared for each progressive step in the transition.

The MTA is committed to continuously collaborating with its union partners, communicating with staff on their experience and needs, and providing robust training and support such that existing and new employees alike are capable and confident in their jobs.

Preparing for this workforce transition requires establishing new operating practices and policies and updating and expanding the skill set and training resources provided to MTA staff.

The goals of the workforce transition are:

Safety:
Ensuring the continued safe and efficient operation of bus service

Training:
Providing robust training and support to meet all new requirements of the zero-emissions transition

Advancement:
Providing opportunities for existing and new staff to continuously grow and excel

Collaboration:
Collaborating and communicating with staff and union partners

Innovation:
Maintaining flexibility to address ongoing innovations in zero-emissions technology

Skills and Training Review

The MTA has identified four major areas in which zero-emission buses will change workforce knowledge and skill requirements: safety, bus maintenance, facilities maintenance, and operations. The extent of the impact and the number of staff affected varies significantly among these categories and between specific staff members and roles. This section reviews each area of expected change, the staff that will be affected, how the MTA has approached training and workforce transition in that area to date, future expected workforce and training needs, and existing resources and processes that can be leveraged to support the transition.

Safety

Batteries on buses and charging equipment in depots and on streets are high voltage electrical systems that bring new safety requirements affecting maintenance, operations, and incident management. All staff need a baseline awareness and safety skill set. Maintainers and incident response staff need more robust training appropriate to working closely with high voltage systems.

The MTA's existing experience with high voltage systems from hybrid buses and the subway provides a baseline of staff knowledge, procedures, and available training processes that greatly smooths the incorporation of this expanded safety requirement into bus operations. The MTA has already made progress by developing and incorporating high voltage safety training and certification programs for bus maintainers and supervisors working with currently deployed battery-electric buses. All bus operators at depots with electric buses have received a dedicated familiarization training that includes thorough safety information.

Safety training will continue to be a core aspect of the workforce transition. The MTA is undertaking a thorough study of high-voltage safety requirements, codes, and best practices that will provide a comprehensive review of the required facilities, personal protective equipment, and procedures needed for 100% battery-electric bus operations and maintenance. Study findings will inform updated procedures and trainings and guide decision making on the dedication of resources. Also note that, to the extent that MTA utilizes fuel cell electric buses, additional training will be necessary to address hydrogen fuel safety practices.

Bus Maintenance

The era of combustion engines and exhaust systems will soon come to an end for MTA's maintainers, replaced by the new age of battery and electric propulsion systems. Maintainers will need to adapt new skills to troubleshoot and fix these components. Bus operators and service management staff will need awareness of these types of components, how they might fail, and how to respond.

The MTA has a robust and well-established process for incorporating new bus types and bus systems into maintenance operations. All new bus models and new onboard bus systems are thoroughly reviewed by the MTA Technology Services group in conjunction with equipment manufacturers. Maintenance procedures are established, and a system of policy directives and trainings ensure knowledge, skills, and support materials continually flow to depot maintenance staff. The transition to zero-emission bus maintenance will leverage this existing system and staff to build and spread expertise in new zero-emission bus equipment.

The MTA's existing experience with hybrid buses has provided a solid background in battery and propulsion systems that are similar to those used on electric buses. To date, the MTA has adapted and expanded on this experience to provide maintenance training and procedures for existing zero-emission bus deployments. A collaboration with vendor equipment manufacturers has allowed for content development and skills transfer to MTA trainers. Maintainers have established regular experience-sharing sessions to develop and spread expertise at depots. Standardized maintenance procedures for common zero-emission bus repairs and diagnostics are now incorporated into day-to-day operations. In addition, a series of specialized trainings on battery-electric propulsion and energy storage system troubleshooting and maintenance is in development. Zero-emission skills training will be a core aspect of the MTA's new and existing workforce development programs, including in mentorship and recognition programs.

Facilities Maintenance

The installation of charging equipment and new power supply and distribution equipment is a significant expansion in the scale and complexity of facilities maintenance. New expertise will be required in troubleshooting and fixing charging equipment and pantograph dispensers. This represents a significant expansion of existing facilities maintenance responsibilities and expertise. Power supply and distribution systems will also require expanded facilities maintenance staff attention.

The MTA has developed a baseline of technical expertise in charging equipment operations and maintenance through experience with battery-electric bus deployments to date. Close coordination with equipment manufacturers and hands-on troubleshooting have provided staff with core knowledge, but there is still significant room for growth as charging infrastructure reaches many more locations at a much larger scale. Along with its public utility partners, the MTA is only beginning to install large power supply equipment at bus depots. Existing MTA experience maintaining the subway's large, complicated power supply systems will serve as a resource as this function expands into bus operations and maintenance.

Moving forward, the MTA will develop a robust, facilities-centric charging infrastructure monitoring and maintenance structure similar to its already well-established bus maintenance organizational structure. This will include a new power engineering maintenance group to manage and maintain the power supply and distribution infrastructure required to support battery-electric charging.

Charging equipment is rapidly changing, and the MTA expects the design and components of future systems to be significantly different from those installed to date. For example, the MTA does not yet have direct, hands-on experience with in-depot pantograph charging systems but expects them to be the primary approach to charging for the bulk of the transition. Lessons learned from the MTA's remaining Stage 1 deployments will be critical to understanding the maintenance needs, processes, and skill requirements for the future. Continued and strengthened partnerships with the New York Power Authority, New York State Energy Research and Development Authority, Con Edison, and equipment manufacturers to refine products and establish best practice maintenance procedures will be a key input to the MTA's development of a robust facilities maintenance program.

Operations

Charging requirements and range limitations mean new operational practices in various aspects of operations. Bus operators and service managers will need to know how to deal with low-battery situations and incidents that may occur on the road, as well as how to interface with charging infrastructure. Yard dispatchers and managers will need to understand how to coordinate charging operations to ensure buses are charged and available for the next day's service, as well as which bus assignments are feasible for battery-electric buses. This will require significant resource development and training effort to establish best practices, adopt effective support tools, and integrate new procedures into operations.

For deployments to date, the MTA has provided basic instruction on charging operations, low-battery management, and incident response as part of initial trainings for all bus operators and dispatchers at affected depots. Appropriate procedures and training materials have been developed in coordination with equipment manufacturers and MTA staff. Basic support tools in the form of updated yard management and pull-out sheets have been developed to help manage charging coordination and schedule assignments.

The MTA has a robust existing training program for bus operators and dispatchers, beginning with extensive onboarding training over several weeks for new staff, followed by regular refresher trainings. Whenever a new bus model or change to service or operations is introduced, all staff affected are trained. This existing framework is a valuable tool to support the transition.

At the current scale of deployments, the complexity and intensity of operational impacts remains relatively small. In addition, operational practices are still evolving as technology capabilities and means of integrating zero-emission buses into operations continue changing with ongoing experience. As the scale and complexity of deployments expands rapidly, the extent of impact on operations and the need for updated training and support tools will also increase. The MTA expects this learning process to continue over the course of Stage 1 deployments. This will be a critical time for knowledge acquisition as well as developing and testing best practices. The best practices should support standard, easy to employ, and effective procedures governing all aspects of zero-emission bus operations. The MTA expects a significant amount of effort to go into the development and testing of operating practices, support tools, and training approaches during this period.

Workforce Transition Framework and Stages

Based on the MTA's review of workforce impacts, the expanded need for knowledge and skills related to zero-emission operations, and the availability of existing training processes and resources, the MTA has developed a framework to approach the workforce transition.

The early stages of the transition are expected to require substantial training and workforce support, with later stages building and expanding on this core of expertise. Stage 1 will emphasize testing and development of procedures, operational approaches, and training practices, as well as maintaining a robust support and training regime for all staff at locations receiving zero-emission vehicle deployments. This stage will establish and refine workforce and training practices based on hands-on experience. Stage 2 will see most of the workforce receiving training as deployments reach almost every depot in the system.

The MTA plans to approach zero-emission skill and knowledge expansion through a combination of familiarization training and specialized skills training. Training capabilities will be developed through a train-the-trainer process to ensure MTA training staff are prepared to meet the demand for classes. Vendor staff are expected to support train-the-trainer activities as well as provide some direct training to depot and operations staff, particularly alongside initial bus purchases and charging equipment installations.

Stage Expectations

The early stages of the transition will require substantial training and workforce support, with later stages building and expanding on this core of expertise.

- Stage 1 will emphasize testing and development of procedures, operational approaches, and training practices as well as maintaining a robust support and training regime for all staff at locations receiving zero-emission deployments. This stage will establish and refine workforce and training practices based on hands-on experience. The first staff will receive specialized trainings.
- Stage 2 will see most of the workforce receiving training as deployments reach almost every depot in the system. Specialized trainings will grow in maturity and be available to almost every employee. Zero-emission knowledge will be incorporated into new staff trainings for most positions and become incorporated into standard practices in all aspects of operations, maintenance, and management.
- By Stage 3, zero-emission knowledge will be firmly established as an integral part of every staff member's role, skill set, and knowledge base. Workforce support and training will continue to evolve to meet the latest technology changes. Specialized skills will be deeply engrained in the workforce. Training will focus on maintaining and expanding an existing skill base and recruiting and training new staff.
- In Stage 4, established zero-emission skills and knowledge will continue to be maintained and expanded. This stage will also see the winding down of all non-zero-emission training and support infrastructure as the last remaining diesel and CNG buses retire.

Familiarization Training

All operating staff working at depots where zero-emission buses are deployed will receive basic high-voltage safety training and general familiarization with both the bus and charging infrastructure. This will provide a common baseline of understanding shared by all staff. Content will include a high-level understanding of zero-emission buses and charging infrastructure and thorough grounding in safety issues and how to respond in the case of both expected and unexpected events.

Initial familiarization trainings will be adapted to include relevant additional information related to the specific job duties of staff members. For example, bus operators will receive training on how to position battery-electric buses under overhead chargers, how to interpret dashboard notifications, and how to respond to common issues and incidents. Bus maintainers will receive deeper training in how to disengage and isolate high-voltage components and background in the major systems and components of the bus. This will be the primary avenue for providing training on new operational practices and incorporating the unique features of zero-emission buses into existing procedures. The depth and intensity of these trainings will depend on the specific role and level of contact with new systems and procedures. Familiarization trainings are expected to take between two and eight hours depending on the role. Because new equipment familiarization is already an aspect of existing training plans, only a portion of these hours will represent additional staff training time.

Table 14: Projected Zero-Emission Familiarization Training Content and Hours

	Content	Projected Time
Bus Operator	• High-voltage awareness • Range and battery management • Dashboard controls • Condition reporting and road calls	4 Hours
Dispatcher	• High-voltage awareness • Range and battery management • Incident scenarios and response	4 Hours
Facility Maintenance	• High-voltage awareness • Charger equipment components • Common failure modes • Failure response and reporting	8 Hours
Bus Maintenance	• High-voltage awareness • Battery and propulsion system components • Common failure modes • Failure response and reporting	8 Hours
Management and Support Staff	• High-voltage awareness • Range and battery management • Performance monitoring and reporting	2 Hours

Specialized Skills Training

For those roles where zero-emission buses have greater impacts on day-to-day responsibilities or require detailed understanding of new systems or skills, the MTA will provide additional specialized trainings. The need for specialized training will be greatest for staff responsible for the troubleshooting and repair of new systems.

Several specialized training courses have already been developed, including a ten-day focused training on electric bus safety and systems for bus maintainers that will qualify bus maintainers to maintain electric buses, perform electrical diagnostics and testing, and work inside battery units.

Additional specialized trainings will be developed for facilities maintenance staff and for dispatchers in specialized roles. Stage 1 of the transition will likely see significant investment in developing the background knowledge and procedures as well as the detailed course materials for a broadening slate of specialized training programs.

Table 15: Projected Zero-Emission Specialized Skills Training and Targets

	Specialized Training	Rollout Target
Depot Bus Maintainers	• Electric Bus Safety and Maintenance (ten days)	• At affected depots: 20% of bus maintainers Electric Bus Safety and Maintenance qualified each year
Central Maintenance Maintainers	• Electric Bus Safety and Maintenance (ten days) • Battery-Electric Bus Overhaul Procedure (ten days)	• 50% of bus maintainers Electric Bus Safety and Maintenance qualified in Stage 1 • 10% of bus maintainers receive Battery-Electric Bus Overhaul Procedure each year
Facility Maintainers	• Charging Equipment Safety and Maintenance (five days)	• All facility maintainers at affected depots Charging Equipment Safety and Maintenance qualified within one year of deployment • 15% of floating facilities supervisors and maintainers Charging Equipment Safety and Maintenance qualified each year
Dispatchers	• Depot Charge Management (two days) • Zero-Emission Incident Response (two days) • Zero-Emission Towing (five days)	• All depot-based dispatchers at affected depots receive Depot Charge Management within six months of deployment • 20% of dispatchers receive Zero-Emission Incident Response training each year • 20% of tow truck operators receive Zero-Emission Towing training each year

Cost

Workforce development and training is expected to require $277 million over the full transition. This cost includes dedicated internal training department staff to establish training requirements, develop materials, and manage training and skills dissemination. It also includes staff time to attend trainings, vendor resources to provide trainings, resources to develop training materials and updated procedures, and funding for training equipment and support tools. Detailed costs will be developed on a rolling basis alongside specific deployments.

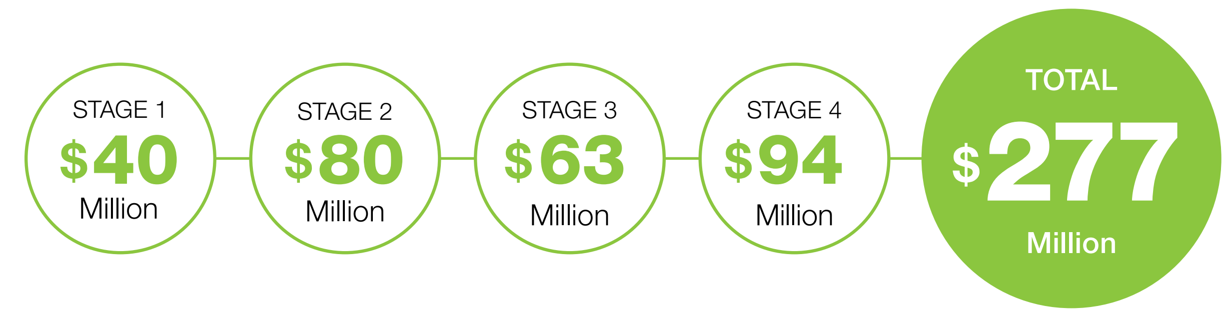


Figure 8: Projected Zero-Emission Specialized Skills Training and Targets

VI.
Cost and Funding

VI. Cost and Funding

Capital Cost Estimate

The MTA has estimated the capital costs to purchase battery-electric buses and supporting charging infrastructure to achieve 100% zero-emission bus operations by 2040. Capital costs for projects in Stage 1 are funded in approved MTA Capital Programs (the 2015-2019 and 2020-2024 Capital Programs) and have either already been implemented or are based on a higher level of scope development. Cost estimates for Stages 2, 3, and 4 are based on projected rollout phasing and generalized scope assumptions, both of which are uncertain, variable, and highly likely to change. As a result, estimates of the total capital cost of the transition represent order of magnitude estimates.

Stage 1 Capital Cost Estimate

Stage 1 includes 560 battery-electric buses and supporting charging infrastructure. This stage is funded across two MTA Capital Programs: the 2015-2019 Program, which included funding for 60 battery-electric buses, and the current 2020-2024 Program, which includes funding for 500 battery-electric buses.

Through mid-2023, the MTA has completed procurements for 75 buses in this stage: 15 articulated buses and supporting charging infrastructure that began operation in early 2020, and 60 standard buses and supporting charging infrastructure that is currently in construction and expected to start revenue service in 2024.

To complete the 560 buses included in Stage 1, the MTA plans to undertake several additional projects:

- A purchase of 470 battery-electric buses, including 90 articulated buses and 380 standard buses
- Two charging infrastructure projects, installing equipment at 10 depots in support of the 470-bus purchase
- The purchase of three 5 bus test fleets to gain experience with new manufacturers and bus models, a total of 15 test buses

The total projected capital cost of all completed, ongoing, and planned battery-electric bus projects in Stage 1 is $1.7 billion. This includes roughly $868 million for the purchase of battery-electric buses and $851 million for charging infrastructure, power supply, and supporting depot modifications and upgrades. The Stage 1 capital costs are estimated as 7% of the total transition costs.

Stage 2-4 Capital Cost Estimate

Capital costs for later stages are based on several uncertain and unknown elements. First, rollout phasing is projected and highly likely to change. Second, charging infrastructure scope assumptions are generalized and likely miss significant variation and specific conditions of individual locations. Third, costs for both buses and charging infrastructure are based on a limited sample of projects and do not consider future changes in available products, the impact of technology maturation on product design, demand pressures and production capacity, or other outside economic factors. Understanding the limits of future projections, the MTA has attempted to estimate the capital cost of future stages using the best currently available information.

Battery-Electric Bus Capital Cost Estimate

Bus purchase costs are estimated based on past MTA experience and analysis of market conditions. The MTA purchased 15 articulated battery-electric buses in 2019 for $1.38 million per bus, and 60 standard battery-electric buses in 2021 for $1.03 million per bus. Accounting for inflation, supply chain challenges, and other market conditions, the MTA estimates the current cost of articulated battery-electric buses at $1.83 million and battery-electric standard buses at $1.4 million. With limited existing market experience, express buses are estimated at the same cost as a standard bus.

Table 16: Per Bus Capital Cost (2023 Dollars)

Bus Type	Propulsion	Per Bus Cost
Standard and Express	Battery-Electric	$1,400,000
Articulated	Battery-Electric	$1,830,000

Bus capital cost estimates for each future stage are developed using the above per bus costs along with the projected bus purchase schedule laid out in the zero-emission ***Fleet Transition Plan*** section, standard MTA capital support costs, and inflation. The cost estimate includes only the initial cost of replacing an existing carbon-emitting bus; replacement purchases of zero-emission buses are not included. This mostly impacts the Stage 4 estimate, where 965 projected bus purchases are expected to replace previously transitioned zero-emission buses.

Facility Transition Capital Cost Estimate

While exact scope and deployment locations are not yet determined, the MTA has developed an estimate for facility transition costs for Stages 2, 3, and 4 based on the conceptual phasing and deployment plan described in the ***Facility Transition*** section above. Costs are estimated across four cost categories:

1. Charging Equipment – including indoor and outdoor structures, chargers, pantograph assembly, and AC/DC distribution.
2. Depot Modifications and Upgrades – including work such as environmental, architecture, structural, plumbing, communications, excavation, civil work, utility relocation, and commissioning/certification.
3. HVAC and Fire Suppression – including ventilation and cooling systems and upgrades to pumps and fire suppression.
4. EDR and Power Supply – including costs related to EDR upgrades, Con Edison services, and substations.

Full Transition Capital Cost Estimate

The estimated total capital cost for the complete transition to 100% zero-emission bus operation is estimated at $23.7 billion, including $11.9 billion for vehicles and $11.7 billion for facilities.

Table 17: Full Transition Capital Cost Estimate, (Year of Award Dollars, Millions)

Bus Type	Zero-Emission Fleet	Facility Transition	Total
Stage 1	$868	$851	$1,720
Stage 2	$1,685	$1,652	$3,337
Stage 3	$3,763	$3,689	$7,452
Stage 4	$6,628	$5,517	$11,145
Total Transition	**$11,944**	**$11,709**	**$23,653**

Funding

Making the transition to 100% zero-emission buses is a significant investment. The $23.7 billion capital investment over the 20-year transition represents a significant increase over the MTA's traditional pace of funding for bus capital investments. Meeting the increased investment need of zero-emission buses will require a major expansion in historic capital funding levels for bus investments. Major increases in funding from existing sources as well as identification of new funding sources will be required. At the federal level, the major increase in funding for the Low and No Emissions Grant made through the Infrastructure Investment and Jobs Act and the significant new revenue stream for MTA capital projects from New York City's forthcoming Central Business District Tolling program are examples of the types of new and expanded funding sources that will be required to fully fund the transition to zero-emission buses at the MTA.

The MTA plans to identify funding progressively, stage by stage. The zero-emission transition stages are directly coordinated with the time frames of the MTA's five-year capital program cycles. Funding needs and sources for each stage will be established as part of the standard MTA capital program process. Funding needs for Phase 1 are included in the MTA's 2015-2019 and 2020-2024 Capital Programs to be funded through a combination of sources, with a sizable share coming from federal formula and competitive grant funds.

Table 18: Capital Program Funding Sources

Level	Source
Agency	Dedicated Taxes
	Bonds and PAYGO
	Central Business District Tolling
Local and State	City of New York Budgetary
	State of New York Budgetary
	NYPA EV Make Ready Progra
Federal	FTA Formula
	FTA Low and No Emissions Competitive Grant
	FTA Bus and Bus Facilities Competitive Grant

VII.
Carbon Impacts

VII. Carbon Impacts

The MTA is committed to reducing carbon emissions from all aspects of its operations and is a signatory to the Paris Climate Agreement. The MTA was a founding member of the Climate Registry and has been voluntarily reporting agency wide carbon emissions since 2008, including emissions from diesel and CNG powered buses. In addition, in November 2019 the MTA committed to setting a science-based carbon emission target as part of the Science Based Targets Initiative, a partnership that includes the United Nations Global Compact.

Transitioning the MTA bus fleet to 100% zero-emission by 2040 is a major aspect of the MTA's agency wide effort to reduce emissions. Throughout the transition to fully zero-emission bus operations, the MTA will continue to closely monitor and track carbon emissions and carbon savings. In addition to tracking actual carbon emissions levels, the MTA has estimated carbon savings (avoided emissions) from the transition to 100% zero-emission bus operations.

Carbon Impact Calculation and Savings to Date

The MTA established baseline rates of carbon emissions by vehicle and propulsion type through an analysis of fuel and energy consumption. For each fleet, pounds of carbon emitted per mile as well as the metric tons of carbon (MT CO2e) emitted per year are estimated to allow comparison with zero-emission vehicles.

Diesel and CNG Fleet Emissions

Because the MTA's fleet is constantly being replaced and each new bus model has slightly different fuel consumption rates, the performance of newer bus models was selected to establish the baseline for diesel and CNG burning fleets. Actual miles per gallon (mpg) in 2019 was used to establish consumption rates. Carbon emissions per mile was established using EPA published factors of carbon intensity by fuel type (22.4 pounds or carbon per diesel gallon, and 11.7 pounds of carbon per therm of CNG). Finally, an estimate of annual metric tons of carbon emitted per bus was developed using average per vehicle mileage by bus type from 2019.

Table 19: Diesel, Hybrid, and CNG per Bus Carbon Emissions (2014-2019 Model Years)

Bus Type	Propulsion	MPG/Miles Per Therm 2019	Pounds Carbon Per Mile	Annual MT CO2e
Standard	Diesel	3.7	6.0	70
	Hybrid	4.5	5.0	58
	CNG	1.8	6.5	75
Articulated	Diesel	3.0	7.6	84
	CNG	1.5	7.9	88
Express	Diesel	4.3	5.2	70

Note: Since 2020 the MTA uses 100% renewable natural gas to power CNG buses. Renewable natural gas is captured from dairies, landfills, and other sources that would otherwise release natural gas directly into the atmosphere.

Battery-Electric Bus Emissions

While there are zero point-source emissions from battery-electric and other zero-emission buses, depending on the source of energy used to power the vehicles, there may still be carbon emissions associated with operating these vehicles. The MTA powers its battery-electric buses from the New York power grid. The New York State energy supply includes power produced by carbon emitting power plants. States report the carbon intensity of energy production to the US Energy Information Administration. In 2020, New York emitted 0.46 pounds of carbon for each kilowatt-hour of power generated. The per bus carbon intensity of operating battery-electric buses in MTA service can be estimated using this number and actual energy consumption rates from the MTA's existing fleet of battery-electric buses.

Comparing emissions rates from traditional propulsion buses to the MTA's battery-electric buses provides an estimate of avoided carbon emissions on a per-bus level.

Using the actual mileage MTA's existing fleet of battery-electric buses have operated in service in combination with the carbon savings rates per mile described above gives a picture of the total actual carbon emissions avoided through the MTA's zero-emission fleet operation through June 2023.

Table 20: MTA Battery-Electric per Bus Carbon Emissions (May 2020 to June 2021)

Bus Type	Avg. kWh/mile	Pounds Carbon Per Mile	Annual MT CO2e
Standard	3.22	1.48	17
Articulated	5.93	2.73	30

Note: The State of New York passed the Climate Leadership and Community Protection Act (Climate Act), which mandates a goal of a zero-emission electricity sector by 2040, including 70% renewable energy generation by 2030. As progress is made toward this state goal, emissions associated with MTA zero-emission bus operations will progressively be reduced to zero.

Table 21: Avoided per Bus Carbon Emissions

Bus Type	Compared to	Avoided Pounds Carbon Per Mile	Avoided Annual MT CO2e
Standard BEB	Diesel	4.6	53
	Hybrid	3.5	40
	CNG	5.0	58
Articulated BEB	Diesel	4.8	54
	CNG	5.1	57

Table 22: MTA Total Zero-Emission Bus Carbon Savings Through June 2023

Bus Type	Total Mileage	Total Avoided MT CO2e
10 Standard Battery-Electric Bus Pilot	227,979	471
15 Articulated Buses	348,837	767
Total	**576,816**	**1,238**

Full Fleet Transition Carbon Savings

In 2017, the latest year for which data is complete, MTA buses emitted 522,315 metric tons of carbon dioxide equivalent (MT CO2e). This includes both emissions from burning diesel fuel (445,671 MT CO2e) and from CNG combustion (76,644 MT CO2e). As the MTA fleet of zero-emission buses continues to grow, total carbon emissions from MTA buses will continually decline and reach zero by 2040.

An estimate of MTA buses declining contribution to carbon emissions through 2040 has been developed to project this trend. Using baseline carbon emissions from 2017, the carbon emissions rates by fleet and propulsion type described above, actual mileage by fleet and propulsion type from 2019, and the projected fleet share by propulsion type through 2040 as described in the Zero-Emission ***Fleet Transition Plan*** section below, total annual carbon emissions from MTA bus operations are estimated for each year from 2022 through 2040.

A critical aspect of making the MTA's bus operations truly zero-emissions is New York State's commitment to transition to zero-emission electricity generation. In 2019 the State passed the Climate Leadership and Community Protection Act (Climate Act), which mandates a goal of a zero-emission electricity sector by 2040, including 70% renewable energy generation by 2030. As progress is made toward this State goal, emissions associated with MTA zero-emission bus operations will progressively be reduced to zero and have been incorporated into the MTA's carbon estimates.

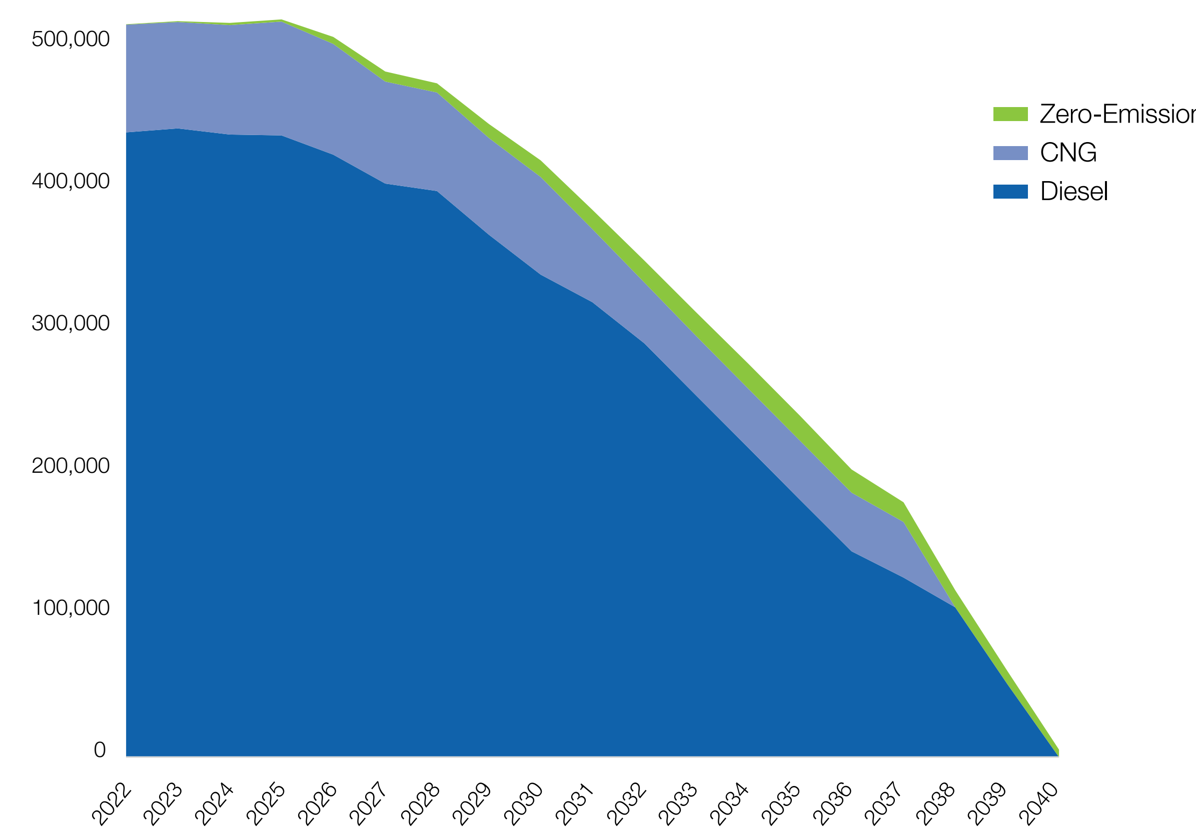


Figure 9: Projected Carbon Emissions from MTA Bus Service (MT CO2e)

VIII.

Policy and Legislative Impacts Review

VIII. Policy and Legislative Impacts Review

Local and Regional

New York State

In 1990, the NYS Department of Environmental Conservation adopted California's Low Emission Vehicle Program, requiring all new vehicles sold in the state to meet California emissions standards, which were more stringent than federal standards. This action established more stringent emissions standards for MTA's fleet of light-duty vehicles, leading to reductions in smog-forming pollutants such as hydrocarbons, carbon monoxide, and oxides of nitrogen.

NYS Executive Order 88 was signed in 2012, requiring state agencies and authorities to reduce energy consumption in facilities with greater than 20,000 square feet by 20% per square foot. It also included requirements on facility submetering for gas and electric, improved operations and maintenance procedures, and energy audits or recommissioning studies. MTA achieved the goals set in EO 88 by completing ASHRAE Level 2 energy audits and recommissioning studies in approximately 50 facilities and installing LED lighting, high-efficiency HVAC equipment, and advanced metering infrastructure (AMI) for electricity and natural gas.

In 2013, the State initiated two major actions in transportation decarbonization programs. First, the State signed the light-duty zero-emission vehicle (ZEV) memorandum of understanding, which formed the Multi-state ZEV Taskforce, a coalition of states working together to advance the deployment of ZEVs through policy research and marketing campaigns. Second, the State launched Charge NY, a series of initiatives that, over time, grew to include the Drive Clean Rebate program, offering up to $2,000 for electric vehicle purchases or leases; the New York State Truck Voucher Incentive program, offering incentives of up to $385,000 for the purchase or lease of electric trucks and buses; the Charge Ready NY program, offering $4,000 per Level 2 charging port; and awareness and educational campaigns.

In 2019, New York State enacted the Climate Leadership and Community Protection Act, or CLCPA, arguably the most aggressive clean energy and climate agenda in the country. The CLCPA calls for a carbon neutral economy, mandating at least an 85% reduction in emissions below 1990 levels with a 40% reduction in emissions by 2030, 70% renewable electricity by 2030, and 100% zero-carbon electricity by 2040.

In July 2020, New York announced two new sweeping programs. First, New York was one of 15 states to sign a medium- and heavy-duty ZEV memorandum of understanding, with the goal of having 30% of these vehicle sales be ZEVs by 2030 and 100% by 2050. Second, New York announced a $701 million Make-Ready program, through which investor-owned utilities pay up to 100% of the costs of electric facilities necessary to make sites ready for electric vehicle charging of 850,000 light-duty vehicles by 2025. Most of Make-Ready funding is for public Level-2 charging, followed by public DC Fast Chargers. A smaller slice is allocated for pilots and fleet advisory services.

The State provides nearly $6 billion in direct and State authorized support for public transit services, more than 46 other states combined. This support is intended to maintain and enhance service levels; ensure passenger fares are reasonable and equitable; and support environmental/climate and economic goals. Due in large part to downstate transit use, the State's per capita motor fuel consumption is the lowest in the nation.

State government is also supporting the transition of municipally sponsored public transit services in upstate New York through a multi-year funding commitment to provide the incremental cost of procuring all-electric buses.

In addition, the CLCPA also included the formation of the New York State Climate Action Council (CAC), a 22-member committee that has prepared a Scoping Plan to achieve the emissions reductions called for by the CLCPA. Achieving the emission limits requires action in all sectors, the report states, requires critical investments in New York's economy. Investments specific to transportation, energy efficiency, and end-use electrification are essential. The plan states that approximately three million zero-emission vehicles (predominantly battery-electric) will need to be sold by 2030 and ten million by 2050. It further states that New York will need to substantially reduce vehicle miles traveled while increasing access to public transit, which should include expanding transit services structured around community needs, smart growth inclusive of equitable transit-oriented development, and transportation demand management.

The CAC's Scoping Plan calls upon the State of New York to work with municipally sponsored public transit systems on a plan to transition to all-electric/zero-emission vehicles at defined replacement schedules appropriate for the transit provider.

New York City

New York City has long been a global leader in emissions reductions from buildings, notably through the passage and implementation of the Climate Mobilization Act and its centerpiece, Local Law 97, which places caps on GHG emissions from existing large buildings.

In December 2021, New York City accelerated efforts to construct next-generation electric buildings, improve air quality and public health, and reduce GHG emissions by enacting legislation phasing out the use of fossil fuel combustion in all new construction projects, becoming the largest city in the nation and the first large cold-weather city to do so. The new law sets restrictions on fossil fuel usage in newly constructed residential and commercial buildings by phasing in strict emissions limits beginning in 2023. All buildings of all sizes must be made fully electric by 2027.

The law is expected to prevent 2.1 million tons of carbon emissions by 2040. The new law will help accelerate a green transition and help achieve the City's goal of carbon neutrality by 2050, consistent with limiting global warming to 1.5 degrees Celsius to prevent the most devastating impacts of the climate crisis.

In addition to State-level initiatives, many local jurisdictions and organizations, including counties, cities, utilities, and ports, are aggressively pursuing climate action and transportation GHG emissions reduction. For example, New York City is a member of the C40 Cities Climate Leadership Group that implemented a 2050 carbon neutrality goal and has already purchased more than 2,000 electric vehicles for its fleet.

Regional

The Regional Greenhouse Gas Initiative (RGGI) is a multi-state carbon dioxide emissions cap-and-trade initiative requiring affected fossil fuel generators to procure carbon dioxide emissions allowances. The costs for these allowances are factored into the costs of operating fossil fuel-fired generators. Suppliers seek to recover these costs through competitive offers in the wholesale electricity market. Through this initiative, each participating state determines a set number of allowances, the majority of which are collectively auctioned. The level of available allowances is established in advance and lowered over time to encourage generators to invest in strategies to reduce carbon dioxide emissions.

In December 2020, the NYS Department of Environmental Conservation finalized new RGGI regulations that cap New York's carbon dioxide emissions at approximately 21 million tons by 2030, representing a 5.2-million-ton reduction in carbon dioxide emissions from 2020 levels. The updated rule expanded applicability to generators of 15 MW or greater in New York. New Jersey re-joined RGGI in 2020, and Virginia joined in 2021. Other states, such as Pennsylvania and North Carolina, are considering joining RGGI in the future. The expansion of the RGGI region and anticipated changes to program design features affect the dynamics of allowance cost and availability going forward.

The regional emissions cap, the cost containment reserve, and the three-year compliance periods are designed to minimize reliability concerns. RGGI allowance prices are influenced by the availability and prices of natural gas, the in-region production of emissions-free energy from nuclear facilities and renewable and other clean energy resources, and the overall demand for electricity. The member states will initiate a comprehensive program review in 2021-22.

Federal

The Bipartisan Infrastructure Law invests $91.2 billion to repair and modernize transit. The legislation supports expanded public transit choices nationwide, including the replacement of thousands of buses with zero-emission vehicles.

In addition to making the best use of federal funds received via formulas, the MTA plans to pursue discretionary funding in cooperation with state and local partners from the following discretionary programs to accelerate its transition to zero-emission fleets, both on road and on rail:

- Charging and Fueling Infrastructure Grants ($1.25 billion over 4 years)
- Rail Vehicle Replacement Grants ($1.5 billion over 4 years)
- National Electric Vehicle Infrastructure Discretionary Grant program ($2.5 billion over 4 years)
- Low or No Emission (Bus) Grants ($5.6 billion over 4 years)
- Bus and Bus Facilities Competitive Grants ($1.97 billion over 4 years)
- Strengthening Mobility and Revolutionizing Transportation (SMART) Grants ($500 million available)

A.

Appendix

A. Appendix: Fleet And Operations Background

Agency Profile

Organization

The MTA operates bus service in the five boroughs of New York City through two of its constituent agencies: New York City Transit (NYCT), which also operates the city's subway service, and the MTA Bus Company (MTABC). While separate legal entities, the two agencies are managed and operated together with a single, seamless customer experience.

Service Profile

The MTA has a service area of 251 square miles; 98% of the city's population are within ¼ mile of a bus stop. The MTA operates 327 routes covering four types of service:

- Local: providing core service, serving neighborhoods and local connections
- Limited: providing inter-neighborhood connectivity with greater stop spacing
- Select Bus Service (SBS): priority service on highest ridership lines with off-board fare payment, bus lanes, transit signal priority, and long stop spacing (like Bus Rapid Transit)
- Express: providing commuter service from outer borough neighborhoods into Manhattan business districts

Ridership

In 2021, MTA buses carried 1.2 million average weekday riders, down from a pre-pandemic level of 2.1 million in 2019. The COVID-19 pandemic significantly depressed ridership for 2020 and 2021. Emerging from the pandemic, the MTA expects ridership to return to close to pre-pandemic levels by 2024.

Fleet Background

The MTA operates a fleet of over 5,800 buses including three bus types:

- Standard buses: 40-foot, two door, low floor buses that operate in local, limited and SBS service
- Articulated buses: 60-foot, three door, low floor buses that operate in local, limited, and SBS service
- Express buses: 45-foot, one door, high floor coach buses that operate in express commuter service

The MTA currently operates buses with several propulsion types:

- Diesel: powered by a diesel gasoline internal combustion engine, employed for express, articulated, and standard buses
- Hybrid Diesel-Electric: carrying both a diesel engine and electric batteries and traction motors, employed on standard buses
- Compressed Natural Gas (CNG): powered by the combustion of natural gas stored in high-pressure tanks, employed for standard and articulated buses
- Battery-Electric: powered by electric batteries and an electric traction motor system, currently employed for standard and articulated buses

Table 23: MTA Active Bus Fleet (June 2023)

Bus Type	Propulsion	NYCT	MTABC	Total
Standard	Diesel	1,972	39	2,011
	Hybrid	569	398	967
	CNG	403	220	623
Articulated	Diesel	892	141	141
	CNG	109		109
	Electric	15		15
Express	Diesel	517	517	1,034
All Types	Diesel	3,381	697	4,078
	Hybrid	569	398	967
	CNG	512	220	732
	Electric	15	0	15
Total		**4,477**	**1,315**	**5,792**

Facilities Background

The MTA operates 28 depots and three Central Maintenance Facilities (CMF) dispersed across the five boroughs in New York City area and Yonkers (Westchester). Depots are typically used for parking, fueling, and routine maintenance. CMFs are used for heavy maintenance and repair of buses. CMFs also include several employee workshops for surface transportation training and institutional instructions. While all depots and CMFs are capable of diesel fuel dispensing, four depots and one CMF location are capable of CNG dispensing as well. All depots and CMFs will need to be upgraded with the infrastructure to support the zero-emission fleet.

Table 24: MTA Bus Depots and Bus Assignment (June 2023)

Depot Division	Agency	Bus Assignment
East New York	NYCT	239
Fresh Pond	NYCT	212
Grand Avenue	NYCT	168
Flatbush	NYCT	216
Jackie Gleason	NYCT	289
Ulmer Park	NYCT	239
Brooklyn		**1,363**
Casey Stengel	NYCT	239
College Point	MTABC	327
Jamaica	NYCT	201
LaGuardia	MTABC	248
Queens Village	NYCT	274
Queens North		**1,289**
Baisley Park	MTABC	109
Far Rockaway	MTABC	103
John F. Kennedy	MTABC	178
Spring Creek	MTABC	136
Queens South		**526**
Castleton	NYCT	232
Charleston	NYCT	219
Meredith Avenue	NYCT	73
Yukon	NYCT	274
Staten Island		**798**
Eastchester	MTABC	132
Gun Hill	NYCT	299
Kingsbridge	NYCT	236
West Farms	NYCT	294
Yonkers	MTABC	82
Bronx		**1,043**
Tuskegee Airmen	NYCT	156
Mother Clara Hale	NYCT	143
Manhattanville	NYCT	250
Michael J. Quill	NYCT	224
Manhattan		**774**
	NYCT Total	**4,477**
	MTABC Total	**1,315**

Capital Program Background

Capital Program Process

Investments in new buses and depot improvements are planned and funded through the MTA's Capital Program. Capital Programs are organized into five-year investment plans. Each five-year plan begins with a Capital Needs Assessment in which all critical assets are assessed by looking at key factors such as age, condition, performance, location, and safety history. A prioritization process takes place to determine what investments the agency needs to make to bring or keep critical assets in a state of good repair and maintain the safety and reliability of the system. Potential investments are then prioritized into five-year buckets by the major categories of work. Each five-year program must be approved by the MTA Board and approved by a committee of the New York State Legislature.

2020-2024 Capital Program

The MTA is currently undertaking capital investments, including bus purchases and depot improvement projects, under the 2020-2024 Capital Program. The program is the largest in MTA history, encompassing over $51 billion in investments. Buses account for $3.5 billion of the 2020-2024 MTA Capital Program, including $1.1 billion for the purchase of 500 electric buses and associated charging infrastructure and depot modifications.

Table 25: MTA 2020-2024 Capital Program

Category	Budget	Priority Investment Highlights
NYC Transit Buses	$1,809 million	• Purchase a total of 1,548 new buses for local and express services throughout the network. • New bus purchases include 475 standard and articulated all-electric buses, accelerating NYCT's transition to a zero-emission fleet. • The fleet is being expanded to provide better connectivity and more direct service
MTA Bus Company Buses	$722 million	• Purchase a total of 874 new buses for local and express services throughout the network. • New bus purchases include 25 standard all-electric buses, commencing MTA Bus's transition to a zero-emission fleet. • The fleet is being expanded to provide better connectivity and more direct service
NYC Transit Depots	$821 million	• Reconstruct the Jamaica Depot • Modify up to 7 depots to support all-electric buses • Make priority repairs and improvements at bus depots and maintenance shops throughout the system • Replace bus depot equipment, such as bus washers, lifts, and paint booths • Purchase equipment to support automated bus late enforcement
MTA Bus Company Buses	$149 million	• Modify first depot to support all-electric buses • Make priority repairs at up to five depots, targeting structural elements, heating/ventilation, and electrical systems • Replace bus depot equipment, such as bus lifts


CHARGING
4953
ELECTRICBUS
+selectbusservice


clean-energy bus

2023