NYCT & MTA Bus Company

MTA Zero-Emission Bus Transition Plan

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CONTENTS

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INTRODUCTION

The scientific evidence of our changing climate has been mounting for years and its consequences have become very real over the last decade. Ask any New Yorker about Tropical Storm Irene in 2011, Superstorm Sandy in 2012, or Tropical Storm Isaias or Hurricane Ida, which swept through New York City within a month of each other in 2021, and you'll undoubtedly hear about the tremendous damage and horrible memories these storms left in their wake.

As the planet warms, intense heat waves and heavy rainfall events will become more frequent and a more regular concern. In the longer-term, sea-level rise will increasingly threaten coastal communities and ecosystems here in the New York region and around the world.

According to both the U.S. Global Change Research Program and the Intergovernmental Panel on Climate Change, which is affiliated with the United Nations, substantial reductions in greenhouse gas (GHG) emissions will be required by mid-century to limit the global average increase in temperature to no more than 2°C, and ideally, 1.5°C.

New York is leading the way nationwide with its efforts to decarbonize its economy. In 2019, New York State passed into law the Climate Leadership and Community Protection Act, known as the CLCPA, the nation's boldest and strongest environmental legislation. It requires a 40% reduction in statewide GHG emissions from 1990 levels by 2030 and an 85% reduction by 2050. The Climate Act also establishes a goal of net zero emissions across all sectors of the economy by 2050.

To its credit, the MTA – one year before the CLCPA – committed to transition its entire bus fleet and non-revenue vehicle fleet to zero-emission vehicles by 2040. Following through and achieving this commitment will require an unprecedented level of investment and fundamental changes across all aspects of bus operations.

Full fleet transition means that zero-emissions bus purchases be rapidly scaled up. All new bus deliveries must be zero-emissions by 2029. Over the transition every bus depot will require infrastructure installation, facility modifications, and the addition of new power supply or other fueling infrastructure. Day to day processes across depot operations, fleet planning, crew scheduling, maintenance, road operations, and safety and training will be transformed.

The MTA operates the largest public bus system in North America. The MTA carries 16% of the nation's bus passengers and operates 10% of all the public transit buses in the United States. As public bus systems across the country look to transition to zero-emissions, the path set by the MTA will have impacts far beyond the boundaries of New York City.

This plan is a foundational step to ensure the MTA's transition is a success. It lays the groundwork for the transition by identifying the challenges and constraints facing the shift to zero-emissions, outlines a strategic approach to overcome them, and lays out a preliminary plan for implementation. The plan is not intended to be final or static. This document is the first step in a dynamic process, a building block to inform the ongoing effort to convert the MTA fleet to zero-emissions.

ZERO-EMISSIONS BACKGROUND

Zero-Emissions Deployment Experience

10 Bus Pilot

The MTA began its experience with zero-emissions buses through a pilot of 10 battery-electric buses starting in late 2017. The pilot included the operation of 10 buses for 3 years: 5 pilot buses from New Flyer operating in Manhattan out of MJ Quill Depot and 5 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.

To support the 5 New Flyer buses in Manhattan, two in-depot plug-in chargers were installed on the 1st floor of MJ Quill depot and on-route fast chargers were installed at both ends of the M42 route running along 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 150kWh 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 cross-town routes in Manhattan and throughout the system. The New Flyer pilot was completed in June 2021 having operated over 90,000 miles in service, avoided 172 tons of CO2 emissions, and provided valuable lessons in zero-emissions technology.

To support the 5 Proterra buses in Brooklyn and Queens, three in-depot 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 440kWh batteries designed for longer distances between charging. The buses operated on several routes out of the Williamsburg Bridge Plaza, including the B60, B39, B32, B24, and Q59. The Proterra pilot was completed in December 2021 having operated over 145,000 miles in service and avoiding 300 tons of CO2 emissions.

15 Articulated Buses

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

Buses began operation in January 2020 and are primarily 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 January 2022, the fleet has operated over 175,000 miles in service, avoiding 362 tons of CO2 emissions.

60 Standard Buses

Currently the MTA is undertaking a deployment of 60 standard battery-electric buses. A contract for the buses was signed with New Flyer in December 2021 for 525kWh battery-electric buses; deliveries are expected in 2023. Charging infrastructure to support the buses is currently being built through a partnership with the New York Power Authority (NYPA). Under the project chargers are being installed at 4 bus depots: Grand Avenue, Kingsbridge, Charleston, and East New York. In addition, new power supply is being installed at East New York depot in partnership with the power utility Con Edison to support the project.

Lessons Learned

The MTA has over four years of experience operating battery-electric buses in revenue service. This includes experience with two bus manufacturers, two bus types, and both in-depot plug-in 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-emissions 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 long periods of 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. Longer period of charging may translate to a fundamental reorganization of depot operations and a significant logistical challenge to find charging locations and sufficient charging time for every bus required for service every day. Both put significant burdens on operating staff that will require new information and management systems as well as training.

Technology teething challenges: Both buses and chargers have shown reliability issues. Battery-electric buses have much higher failure rates, lower availability, and require longer times to diagnose and fix issues compared to existing fleets. Chargers show similar challenges, including regular communications failures, long down times, and the failure to perform some advertised functions. While this is expected for new technology systems, a rapid maturation of existing technology and ensuring appropriate Service Level Agreements are included in charger deployments will be required to ensure reliability issues don’t impact the core ability of the MTA to provide transit service.

Uncertainty around rapidly developing technology: Constant change in the zero-emissions bus space carries both the benefit of improving functionality and capability and the challenge of uncertainty over what and how zero-emissions buses will operate, and depots should be modernized in the future. The range and consumption rate 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-emissions fleet.

Maintenance knowledge and staffing gaps: Currently neither the MTA nor the bus and charging equipment manufacturers have sufficient maintenance personnel with zero-emissions bus technology expertise. This causes delays in responding to and troubleshooting problems with both bus propulsion systems and bus chargers. Because few zero-emissions 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.

ZERO-EMISSIONS TRANSITION STRATEGY

Goals

The MTA's approach to the zero-emissions fleet transition will be guided by several core goals:

- **Prioritize environmental justice** – The MTA is committed to prioritizing traditionally underserved communities and those most impacted by poor air quality and climate change in the rollout of zero-emissions buses. A new Environmental Justice Scoring framework was developed by the MTA to actively incorporate these priorities in the deployment phasing process of the transition.

- **No impact on customer experience** – The transition to zero-emissions should have no negative impacts on the current level and quality of bus service provided by the MTA. The only changes customers notice should be the absence of exhaust and a quieter ride. The comfort, reliability, speed, and functionality of the fleet should be equal to or better than the current fleet.

- **Limit constraints on operations** – The transition should not significantly impact the operational functionality of the bus system. Service should be provided with roughly the same number of buses as in the current fleet. Scheduling and route planning should not have significant new constraints on bus range and service time. Charging and fueling operations should minimally restrict the operational flexibility and real-time adaptability of bus service. Changes to depot operations should not involve extensive new requirements for charging, fueling, and maintaining zero-emissions buses.

- **Reduce implementation cost and complexity** – The transition should pursue technology alternatives and implementation plans that reduce the total capital and operating burden on the MTA without limiting operational functionality or impacting the transition timeline. Pilot programs should be utilized to test new technologies and learn important lessons.

- **Empower our workforce** – Ensure that our workforce who have been safely operating and maintaining diesel, hybrid-electric and CNG propulsion types are competently trained and supported to undertake the operation and maintenance of zero-emissions propulsion technology in a seamless and safe manner.

Strategy Overview

The MTA's goals are reflected in the three sections of the MTA's transition plan: fleet, facilities, and workforce. A short summary of the major strategic elements of each section are described below (with greater detail provided in the following chapters).

The ***Fleet Transition Plan*** outlines the timeline of expected zero-emissions bus purchases and describes the schedule feasibility of MTA bus assignments under three generations of potential bus technology development. Most standard bus schedules are feasible with existing bus models, though articulated bus schedules are more problematic, and the MTA does not yet have experience with zero-emissions express buses. The MTA plans to replace existing buses with zero-emissions buses on a 1-for-1 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 planned approach to charging infrastructure operation and installation, the projected scope of charging capacity and power supply required, the types of supporting infrastructure upgrades and modifications required, and a conceptual, staged rollout plan. The MTA's approach focuses on in-depot charging, particularly in the early stages. There is an estimated need for 300 to 430MW of new power supply at depots, 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-emissions buses. The Facility Transition Plan includes a rollout prioritization framework which 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. Developing 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 where a robust training and workforce development plan is being developed.

Battery-Electric Vs. Hydrogen Fuel-Cell

The MTA's current transition plan focuses on battery-electric buses. The included analysis evaluates the possibility of achieving the transition to zero-emissions using exclusively battery-electric buses. This is largely because battery-electric buses are currently the dominant available zero-emissions technology in the US and are the only zero-emissions technology with which the MTA has direct experience.

Hydrogen fuel-cell buses offer two major potential advantages over battery-electric buses: reliable operating range of around 300 miles compared to ~100 or less with existing battery-electric models and fueling times in the minutes compared to hours for battery-electric charging. These advantages could provide significant operating benefits and cost savings. On the other hand, identifying reliable, truly zero-emissions hydrogen supply may pose challenges.

The MTA is actively pursuing opportunities to gain experience with hydrogen fuel-cell buses and fueling infrastructure. Pending greater experience, continued industry development, and validation of the costs and benefits, the MTA sees hydrogen fuel-cell technology as a promising path for zero-emissions deployments, particularly in the later phases of the transition.

Rollout Plan Summary

The MTA's transition is coordinated to align with the MTA's 5-year capital planning process. Each successive 5-year plan will coincide with a new stage of zero-emissions transition.

Stage 1 – Learning at Scale – 2015-2019 & 2020-2024 Capital Programs
This stage will see the first large scale deployments of electric buses at the MTA, with multiple depots housing fleets of 50-100 buses. The focus will be on validating charging infrastructure technology, bus range expectations, operational feasibility, and power supply construction. A total of 560 new zero-emissions buses will be deployed, comprising 60 buses funded in the 2015-2019 capital program and 500 in the 2020-2024 Capital Program. At the end of this stage zero-emissions buses will make up 9% of the total fleet. Charging infrastructure will focus on in-depot overnight charging to avoid the complexity and cost of on-route charging. Jamaica Depot, located in an environmental justice community, will be rebuilt with accommodation for 100% zero-emissions operations. The first addition of large-scale power supply at depots will be undertaken with the power utility Con Edison. Deployment locations will focus on those with environmental justice priority, existing power supply, many feasible schedules, and where existing depot conditions are easily adapted to charging infrastructure. All deployments will be battery-electric, the most tested zero-emissions propulsion alternative. Fuel-cell buses will be tested for potential future deployments (see box above). Significant emphasis will be placed on deployment-specific training and workforce development as many staff get their first hands-on experience with zero-emissions technology.

Stage 2 – Expansion Challenge – 2025-2029 Capital Program
This stage will take zero-emissions deployments to a new scale, with large deployments of over 100 buses at multiple depots and the first conversion entire depots to 100% zero-emissions operation: Jamaica Depot in Queens and East New York Depot in Brooklyn (both the highest ranked Environmental Justice locations in those boroughs). This stage will also see the last purchases of non-zero-emissions buses as all new orders starting in 2029 will be zero-emissions. A total of 1,000 new zero-emissions buses are expected to be purchased, bringing the total zero-emissions fleet share to 26%. The first zero-emissions express buses are expected to be deployed in this stage. An expected 10-15 depots will undergo major construction projects to install infrastructure and new power supply. Deployment locations will continue to be driven by environmental justice priority, schedule feasibility, and constructability. Most deployments are expected to be battery-electric, though moderate scale hydrogen fuel-cell deployments may be implemented to prove out the technology at scale. Zero-emissions training will shift from being deployment specific to become standard for all staff in operating and maintenance positions.

Stage 3 – Steady Growth – 2030-2034 Capital Program
This stage will see the conversion of roughly 1/3 of the fleet to zero-emissions. All 1,955 expected new bus purchases in this period will be zero-emissions, bringing the zero-emissions fleet share up to 60. Accommodating this major fleet expansion will require deployments at 15-20 depots, with 5 additional depots achieving 100% zero-emissions operations. By this time technology improvements are expected to eliminate most schedule feasibility issues resulting from 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 deployments.

Stage 4 – Final Push – 2035-2039 Capital Program
This stage will complete the transition to 100% zero-emissions bus service at the MTA. The last remaining approximately 2,385 buses of other propulsion types will be retired. Infrastructure construction is expected to be somewhat lighter than previous stages, following earlier projects at most locations which already completed any required major modifications and power supply additions. The focus will be on completing any particularly challenging locations that required complete rebuilds or major modifications.

MTA Zero-Emissions Transition Plan – Conceptual Rollout*

	STAGE 1	STAGE 2	STAGE 3	STAGE 4
Fleet	+560	+1,000	+1,970	+2,385
5,900 total buses	9%	26%	60%	100%
Facilities – ...with any zero-emissions buses	13	17	23	28
28 total depots	46%	61%	82%	100%
...with at least 50% zero-emissions fleet	0	4	17	28
		14%	61%	100%
...with 100% zero-emissions fleet	0	2	7	28
		7%	25%	100%
Power – ...added at depots	+138MW	+95MW	+109MW	+88MW
430MW supply needed (high estimate) – ...additions complete at	25% of depots	50% of depots	75% of depots	100% of depots
Workforce – ...at depots with a zero-emissions deployment	+7,800	+2,400	+3,500	+1,300
15,000 depot-based staff	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 operational plans, and future technology improvements

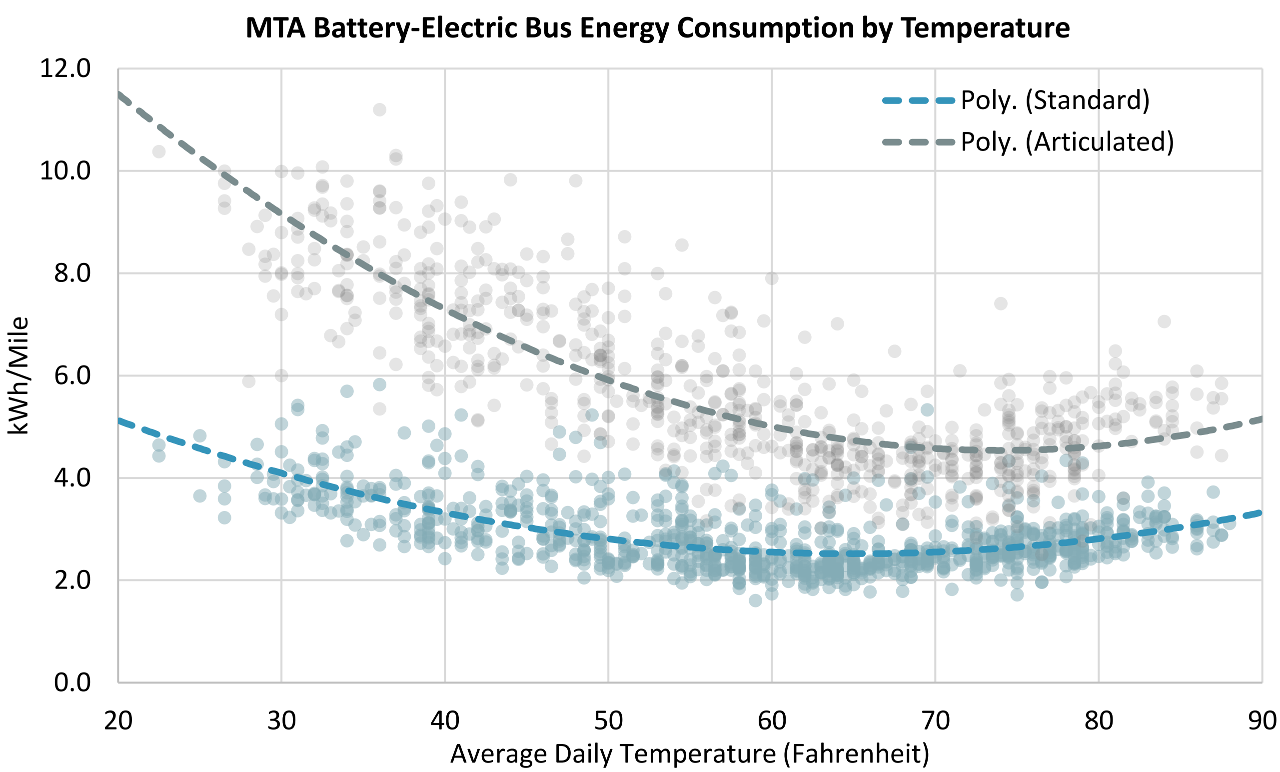
FLEET TRANSITION

Battery-Electric Bus Schedule Feasibility

Energy Consumption & 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 the current technology. MTA operating conditions pose challenges for battery-electric bus range: temperatures in winter are low; stops are frequent and long; and operating speeds are slow. The MTA has in service energy consumption data for 3 fleets: 5 New Flyer standard buses; 5 Proterra standard buses; and 15 New Flyer articulated buses. The MTA does not yet have any electric bus experience with the 3rd type of bus that the agency operates, express coach buses.

A baseline energy consumption analysis was conducted for 1-year of data, from May 2020 to June 2021, encompassing 4,845 individual driving events. In this analysis, the largest factors impacting energy consumption are temperature and operating speed. Consumption rates are approximately 50% higher in 20-30 F degree weather, compared to more moderate 40-70 F degree days. Similarly, consumption rates are around 50% higher for buses with a daily assignment that operates at speeds of 2.5-5mph compared to those operating at 7.5-10mph.



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

- Below 30-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.

- 85th 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. To ensure this variability can be accommodated within the capability of the vehicle, the 85th percentile energy consumption result is used.

MTA Experienced Energy Consumption Rate (kWh/Mile) 85th Percentile; below 30-degree days; May 2020 – June 2021		
Operating Speed (mph)	Standard Bus	Articulated Bus
2.5-5	6.7	10.5
5-7.5	4.4	9.3
7.5-10	3.6	6.7

The expected maximum bus range of is a function of energy consumption rate and battery size (the counter-intuitive relationship between speed and energy consumption rate is also a result of heat loss from urban routes and longer periods with doors open). In addition to evaluating energy consumption levels under worst case operating conditions the MTA considers the reliable share of battery available for use in service with several reductions from the manufacturer nameplate level:

- 13% battery state of charge (SOC) unusable for service – Since batteries often do not achieve full 100% SOC, 3% of battery SOC is reserved as a maximum buffer. In addition, a minimum of 10% SOC is reserved as a minimum SOC cut-off below which a bus would be taken out of service to avoid failure on route.

- 10% battery state of charge (SOC) reserved for degradation – Battery capacity degrades over time. Buses must be able to complete the same bus assignments even as batteries age. The effective range of the bus is measured at the point of end-of-life for the battery. With limited industry experience with electric bus age, the MTA is currently using 10% SOC degradation to mark battery end-of-life.

Expected Reliable Range of a 500kWh Battery-Electric Bus (Miles) 23% inaccessible SOC		
Operating Speed (mph)	Standard Bus	Articulated Bus
2.5-5	58	37
5-7.5	88	41
7.5-10	107	58

Schedule Feasibility Analysis

The MTA has evaluated all existing scheduled bus assignments for compatibility with battery-electric bus operation using fully in-depot charging. While not all schedules are currently feasible, the MTA expects that over the 18-year transition, technology improvements and minor schedule adjustments will make 100% battery-electric bus operation feasible without impacts to customer experience or total fleet size.

Process & Assumptions

Schedules were evaluated with the assumption that all charging will occur in-depot. MTA experience revealed several disadvantages to on-street charging: installation is complicated and costly, maintenance requires significant additional effort, impacts from outages can be large, and power demand occurs at peak times leading to higher demand charging costs. Given the challenges to on-street charging, the MTA evaluation focuses on fully in-depot charging.

For a bus's scheduled assignment to be feasible it must have sufficient available battery state of charge (SOC) to complete the assigned trip-level activity over the course of each service day. Infeasible assignments are the result of either the duration or mileage of an assignment being too long for the battery size and energy consumption rate of the bus, or 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. MTA analysis has considered how changes in each of these elements can affect schedule feasibility.

Impacts from changes in the technical constraints of the bus itself are evaluated by considering (for planning purposes) three generations of progressively improving battery-electric bus specifications and capabilities—note that this will need to be validated by real life improvements in battery storage capacities as the battery industry matures:

- Generation 1 – Matches existing available bus models with energy consumption rates based on past MTA experience (as described above), and existing available battery sizes

- Generation 2 – Assumes 20% decrease in energy consumption rates and minor increases in battery size over current experience

- Generation 3 – Assumes 40% decrease in energy consumption rates and moderate increases in battery size over current experience

Bus Battery Size for Schedule Feasibility Analysis (units in kWh)			
	Standard	Articulated	Express
Generation 1	525	500	500
Generation 2	550	600	500
Generation 3	600	700	600

Impacts from changes in the approach to charge management are evaluated by considering charging operations under two scenarios:

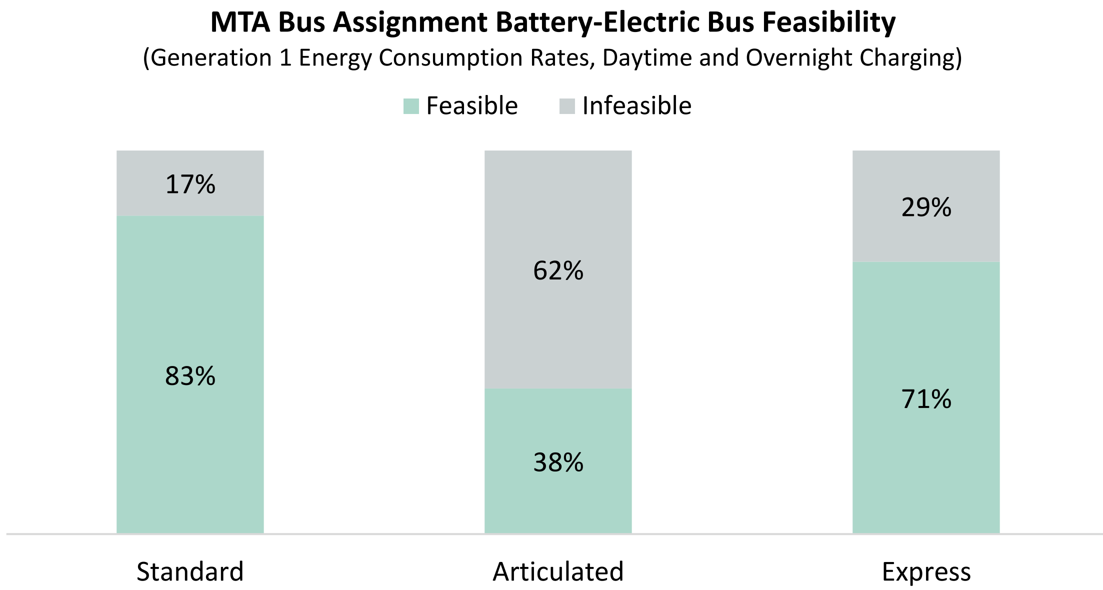
- 100% Overnight Charging – Electric utility rates for electric power are significantly lower when all demand and consumption occur between 10pm and 8am. This scenario restricts all electric bus charging to these overnight hours to evaluate the impact of achieving this operating cost benefit on schedule feasibility

- Daytime & Overnight Charging – This scenario removes restrictions on charging by time of day to allow the maximum number of bus assignments to be feasible. Only assignments that are not feasible with the overnight charging window are considered for charging during daytime hours.

All weekday bus assignments from Winter 2019 were evaluated. Over the weekend many fewer buses are operated so accommodating difficult assignments by splitting schedules is assumed to address any currently infeasible assignments on weekends without impacting fleet requirements.

Results Summary

The MTA estimates that 83% of all standard bus assignments and 38% of all articulated assignments are feasible with currently available battery-electric bus models (Generation 1). A 40% decrease in the energy consumption rate and moderate increase in battery size (Generation 3) would bring that up to 100% for standard buses and 98% for articulated buses. Any remaining infeasible schedules are expected to be addressed through minor schedule adjustments. Express bus assignments have been estimated but are considered preliminary given the lack of MTA and industry experience with this bus type.



Feasible Bus Assignments by Battery-Electric Technology Generation and Charging Approach				
Daytime & Overnight Charging				
	Standard	Articulated	Express	Total
Generation 1	83%	38%	71%	73%
Generation 2	96%	70%	91%	91%
Generation 3	100%	98%	97%	99%
Not Feasible	*0%*	*2%*	*3%*	*1%*
100% Overnight Charging				
	Standard	Articulated	Express	Total
Generation 1	53%	15%	23%	40%
Generation 2	89%	55%	46%	75%
Generation 3	100%	95%	82%	97%
Not Feasible	0%	5%	13%	3%

Baseline Fleet Replacement Needs

The MTA schedules buses for replacement based on a 12-year useful life. As part of each 5-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 quantity bus purchase requirements by type for capital programs through 2040.

MTA Expected 20-Year Bus Purchases by 5-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	1,900	760	640	**3,300**

Zero-Emissions Fleet Plan

The MTA will progressively transition its bus fleet to 100% zero-emissions (ZE) through the year 2040 over 4 stages aligned with the MTA's 5-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-emissions will increase across Stage 1 (through 2024) and 2 (2025-2029). All new bus deliveries from 2029 on will be zero-emissions.

Achieving a 100% zero-emissions 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 of buses that means the last year for non-zero-emissions bus deliveries to the MTA is 2028. A bus delivered on 12/31/2028 will complete 12 full years of service on 12/31/2040.

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 2023. The remaining 485 buses are expected to be purchased before the end of 2023 and delivered starting in 2024 or 2025. All purchases will be battery-electric.

Stage 2 – 2025-2029

Stage 2 will roughly double the number of purchases from Stage 1 with an expected total of 1,000 zero-emissions buses. This stage is expected to include the first purchase of 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 at the time. During this stage the MTA will switch to 100% zero-emissions fleet purchases. All new bus deliveries starting in 2029 will be zero-emissions.

Stage 3 – 2030-2034

Stage 3 will once again almost double the number of zero-emissions bus purchases from the prior stage, from 1,000 up to 1,970. All new buses purchased in this stage will be zero-emissions. 33% of the fleet will switch to zero-emissions during this stage, bringing the overall zero-emissions fleet share up to 60%. This stage will also see the first retirements of zero-emissions 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.

Stage 4 – 2035-2039

Stage 4 will complete the MTA transition to a 100% zero-emissions fleet. An expected total of 3,300 zero-emissions buses will be purchased. A projected 2,385 remaining buses that are non-zero-emissions will be retired and replaced. In addition, a further 965 zero-emissions 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.

Zero-Emissions Fleet Purchase & 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	3,350	3,350	0	2,385	5,900	100%

Zero-Emissions Fleet Purchase & Deployments by Bus Type & Stage				
Zero-Emissions Bus Purchases				
Stage	Standard	Articulated	Express	Total
Stage 1	455	105		560
Stage 2	750	200	50	1,000
Stage 3	1,455	190	325	1,970
Stage 4	1,900	760	640	3,300
New Zero-Emissions Conversions				
Stage	Standard	Articulated	Express	Total
Stage 1	455	105		560
Stage 2	750	200	50	1,000
Stage 3	1,455	175	325	1,955
Stage 4	1,075	670	640	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	3,735	1,150	1,015	5,900
Cumulative Zero-Emissions Fleet (Share)				
Stage	Standard	Articulated	Express	Total
Stage 1	12%	9%	0%	9%
Stage 2	32%	27%	5%	26%
Stage 3	71%	42%	37%	60%
Stage 4	100%	100%	100%	100%

Alignment with Schedule Feasibility & Technology Improvement

There are sufficient feasible bus assignments to accommodate all projected zero-emissions bus purchases and deployments in Stages 1 and 2 (through 2029) using currently available battery-electric bus range without increases to fleet size or major changes to schedules. MTA review of current bus capabilities estimates that 83% of standard bus schedules, 38% of articulated bus schedules, and 71% of express bus schedules are feasible with currently available bus models. This capability can support all planned standard and express bus deployments until Stage 4 (2034-2039) and all planned articulated deployments until Stage 3 (2030-2034).

Accommodating deployments in Stage 3 and Stage 4 will require improvements in the reliable range capability of battery-electric buses or the use of other propulsion technologies like hydrogen fuel-cell. Analysis suggests battery-electric buses need a 40% improvement in energy consumption levels and a moderate expansion of battery size for the MTA to complete the transition to zero-emissions without fleet or schedule impacts using solely battery-electric buses. The MTA plan assumes that battery-electric bus technology improvements or hydrogen fuel-cell bus capabilities will meet or exceed this level in time to accommodate all projected deployments in Stages 3 and 4 and that no increases in fleet size or major impacts to schedules will be required because of the zero-emissions transition.

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.

Zero-Emissions Fleet Purchase & Deployments by Bus Type & Stage				
Cumulative Zero-Emissions Fleet Share by Stage				
Stage	Standard	Articulated	Express	Total
Stage 1	12%	9%	0%	9%
Stage 2	32%	27%	5%	26%
Stage 3	71%	42%	37%	60%
Stage 4	100%	100%	100%	100%
Feasible Battery-Electric Bus Schedule Assignments by Technology Generation (Daytime Charging)				
	Standard	Articulated	Express	Total
Generation 1	83%	38%	71%	73%
Generation 2	96%	70%	91%	91%
Generation 3	100%	98%	97%	99%
Not Feasible	*0%*	*2%*	*3%*	*1%*

FACILITY TRANSITION

Battery-Electric Charging Infrastructure

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 re-evaluated in Stages 2-4 pending conditions at the time.

- 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 reduces the total number of pantographs compared to pantograph-up and eliminates a weight element 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.

In-Depot Vs. On-Street Charging

Based on the relatively greater disadvantages of on-street charging, in the short-term the MTA expects to focus primarily on in-depot charging for the early phases of the transition to zero-emissions buses. On-street charging may be more actively pursued during later phases, particularly to provide system resiliency at major terminals and hubs.

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 hundreds of independent 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 & 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, given the extent of existing built infrastructure throughout the city design and engineering challenges are highly likely to arise in many locations. Design approvals in depots are by comparison much simpler and less likely to encounter unexpected engineering challenges. Add that there are many fewer depots than there would be on-street locations, in-depot charging would be 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 for any reason. 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 Infrastructure Capacity Requirement

The largest variable in determining the infrastructure installation requirements of battery-electric bus charging is the total capacity of the system to be installed. While the rate of charging can vary depending on each bus's state of charge, battery size, and time to next pull out, the system must have sufficient installed and energized charging capacity to ensure all buses are charged in time to accomplish their next assignment.

Current charger installations typically use a single charging unit with capacity of 100-500kW that can be distributed to 1 or 2 dispensers. At scale, this can result in significant inefficiency (once the buses connected to the charger are finished charging, the charging unit is idle) or the need for complex yard management. It is expected that future installations will install larger centralized charging units with capacities of 1-3MW 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 and the total capacity of the system that must be purchased and installed.

Because charging technology is still developing and the consumption rates of vehicles continues to evolve as bus and battery technology changes, the MTA estimates a range of expected baseline charging capacity requirements under two scenarios:

- <u>High</u> – charging capacity of 75kW per bus. This allows for existing available charger technology installations of 150kW capacity per charger with 2 dispensers. With this equipment a 600kWh battery bus could achieve a full charge in 4 hours at full charger capacity or in 8 hours if both buses were charging simultaneously. MTA schedules show that on average buses spend 8 hours in depot overnight, meaning this equipment could reasonably support large capacity buses achieving a full charge under most existing schedules.

- <u>Low</u> – charging capacity of 50kW per bus. This assumes a high level of flexibility in distributing installed capacity among buses parked in the depot and connected to dispensers based on each vehicles' state of charge and next assignment. This per bus level corresponds to the total kWh demand of every MTA vehicle using the full accessible battery capacity of Generation 3 vehicles (as defined in the Schedule Analysis Section) spread over 8 hours of overnight charging. In other words, this system could support fleets with very large capacity batteries all using their full battery every day with only overnight charging.

In addition to this baseline capacity, the MTA expects to install two types of supplemental chargers: maintenance chargers and in-depot rapid chargers for top-ups or fast turnaround midday layovers. Charging capacity required for these functions is estimated based on:

- <u>Maintenance chargers</u> – One 50kw maintenance charger per 40 battery-electric buses

- <u>Rapid chargers</u> – One 500kw rapid charger per 60 battery-electric buses

The total charging capacity required for each depot to support 100% battery-electric bus operation is estimated based on the above assumptions. Each depot estimate includes a 5% increase to the current number of scheduled buses to allow for fleet growth, and final estimated capacity requirements are rounded up to the nearest 500kW. The table below shows the results for each depot. System-wide, a total of 328 to 458.5 megawatts (MW) of installed charger capacity is expected to support 100% battery-electric bus operation.

Projected Total Charger Capacity for 100% Battery-Electric Bus Operation (Megawatts)			
Depot	**Scheduled Buses***	**Low Required Capacity (MW)**	**High Required Capacity (MW)**
Eastchester	108	7.0	10.0
Gun Hill	236	15.5	21.5
Kingsbridge	222	14.5	20.0
West Farms	288	19.0	26.5
Yonkers	71	5.0	7.0
East New York	208	13.5	19.0
Flatbush	206	13.5	19.0
Fresh Pond	176	11.5	16.5
Grand Avenue	153	10.0	14.0
Jackie Gleason	245	16.0	22.5
Ulmer Park	206	13.5	19.0
Michael J. Quill	227	14.5	20.5
Manhattanville	195	13.0	18.0
Mother Clara Hale	95	6.5	9.0
Tuskegee Airmen	122	8.5	11.5
Baisley Park	98	6.5	9.0
College Point	274	17.5	24.5
Casey Stengel	194	12.5	18.0
Far Rockaway	93	6.5	8.5
Jamaica	196	13.0	18.0
John F. Kennedy	150	10.0	14.0
LaGuardia	206	13.5	19.0
Queens Village	231	15.5	21.5
Spring Creek	110	7.0	10.0
Castleton	187	12.5	17.5
Charleston	178	12.0	16.5
Meredith Avenue	63	4.5	6.5
Yukon	232	15.5	21.5
System Total	**4,970**	**328.0**	**458.5**
**Buses required for weekday service, does not include 15% spare*			

New Power Supply Requirement

Closely related to the capacity of chargers to be installed and energized is the power demand requirement for each depot location. Charging equipment capacity has been sized such that at peak usage under highest demand conditions, the full capacity of the system would be drawing power. Thus, the charging system capacity represents the peak required power demand at each depot. A relevant point to note here is that in later phases of the electrification of buses, it is envisaged that the electrical grid may potentially transition from summer daytime peaking to winter evening peaking (as natural gas heating in homes slowly transitions to electric based heating). It is important for the MTA to maximize evening depot charging and the rates thereof to be 'grandfathered' if the 2040s has peak demand charges at night in winter.

Some depots have existing power supply that is not used for other existing building electricity needs. System-wide there is roughly 28MW of this currently available unused supply, leaving 300 to 430MW of new power supply required to be added at depots to support 100% battery-electric bus operation. In the absence of other sources of supply this is the baseline size of the new feeder capacity required from the power utility, Con Edison.

The MTA is currently evaluating several means of reducing new power supply requirements from the grid:

- On-site storage batteries – Large-scale on-site batteries can recharge when buses are not charging and supply power to chargers when buses are charging as a means of reducing the peak demand on the power grid (behind-the-meter peak shaving). Batteries can also provide a source of continued supply in the event of power outages. The MTA is currently evaluating the costs, benefits, and construction feasibility of these systems for a potential demonstration project.

- On-site solar generation – A handful of MTA depots have open roof spaces that could be used for solar panels which in tandem with battery storage can reduce peak demand and overall power consumption from the grid. This has limited potential given the small number of depots where this might be feasible, but rooftop solar capacity is being evaluated for costs, benefits, and construction feasibility.

- Existing traction power – The MTA subway and commuter rail systems use DC 3rd rail traction power with a significant amount of installed capacity. Many bus depots are close to traction power substations and third rails. With rail operations largely pulling power during peak commute times, there is the potential of a large existing unused capacity available for bus charging overnight. The MTA in close coordination with NYSERDA (New York State Energy Research and Development Authority) is currently evaluating the technical feasibility of tapping into traction power sources for bus charging.

The table below shows the estimated total required new power supply for each depot to support 100% battery-electric bus operation, any existing available supply, and the net new power supply additions required.

New Power Supply to Support 100% Battery-Electric Bus Operation (Megawatts)					
Depot	**Existing Unused Power (MW)**	**Total Required Charger Capacity (MW)**		**Total Required New Power Supply (MW)**	
		Low	High	Low	High
Eastchester	0.2	7.0	10.0	7.0	10.0
Gun Hill	2.1	15.5	21.5	13.5	19.5
Kingsbridge	0.6	14.5	20.0	13.5	19.5
West Farms	2.0	19.0	26.5	17.0	24.5
Yonkers	0.3	5.0	7.0	5.0	6.5
East New York	0.4	13.5	19.0	13.0	18.5
Flatbush	0.5	13.5	19.0	13.0	18.5
Fresh Pond	0.7	11.5	16.5	11.0	15.5
Grand Avenue	6.0	10.0	14.0	4.0	8.0
Jackie Gleason	1.6	16.0	22.5	14.5	21.0
Ulmer Park	0.3	13.5	19.0	13.0	18.5
Michael J. Quill	1.0	14.5	20.5	13.5	19.5
Manhattanville	2.0	13.0	18.0	11.0	16.0
Mother Clara Hale	2.3	6.5	9.0	4.0	6.5
Tuskegee Airmen	1.3	8.5	11.5	7.0	10.5
Baisley Park	0.3	6.5	9.0	6.0	9.0
College Point	0.3	17.5	24.5	17.5	24.5
Casey Stengel	0.6	12.5	18.0	12.0	17.5
Far Rockaway	0.0	6.5	8.5	6.5	8.5
Jamaica	0.1	13.0	18.0	13.0	18.0
John F. Kennedy	0.4	10.0	14.0	9.5	13.5
LaGuardia	0.6	13.5	19.0	13.0	18.0
Queens Village	0.2	15.5	21.5	15.0	21.0
Spring Creek	0.5	7.0	10.0	6.5	9.5
Castleton	0.5	12.5	17.5	12.0	17.0
Charleston	2.1	12.0	16.5	10.0	14.5
Meredith Avenue	0.2	4.5	6.5	4.5	6.0
Yukon	1.1	15.5	21.5	14.0	20.5
System Total	**28.1**	**328.0**	**458.5**	**299.5**	**430.0**

Relationship with Power Utility

The MTA is actively engaged with the local power utility Con Edison to meet the 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 MTA 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. Early in the electric bus deployment process, the MTA has instituted coordination meetings with the electric utility 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 costs of energizing the fleet. In coordination with Con Edison, the MTA has begun a pilot program to deploy demand-response based charge management that will allow for automated curtailment of electric bus power demands during peak hours.

The partnership will also allow the MTA and Con Edison to jointly plan for utility disruptions and the level of curtailed service that the MTA will need to provide as a result. This includes the development of resiliency planning around planned power-shed events and unplanned scenarios that result from significant weather events, such as Super Storm Sandy. 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 Requirements, Upgrades, & Modifications

Supporting the addition of charging infrastructure and new power supply will require significant upgrades and modifications to 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. Existing building columns, walls, or roof structures may need to be reinforced to support additional weight from charging equipment, pantographs, and other new structural elements. Existing conduit, piping, and HVAC ducts may need to be moved to accommodate new equipment, conduit, and the placement of pantograph dispensers and support structures. New HVAC equipment may need to be installed to accommodate heat generation from indoor charging equipment.

Facilities must also have sufficient space to accommodate all the new equipment. Charging equipment footprints alone are expected to require space equivalent to 1 bus parking space for every 20-30 battery-electric buses, though exact space needs are highly variable depending on the condition, layout, and space utilization plans at each depot location. 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 bus parking spaces means formalizing bus parking arrangements. Currently many MTA facilities are at their capacity, and a significant share of overnight 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.

A further critical facility requirement to support the MTAs preferred approach to charging operations is the need for high enough ceilings to accommodate overhead pantograph down chargers. Some indoor parking areas at MTA depot facilities do not have sufficient ceiling height or overhead space to accommodate pantograph dispensers. Transitioning to zero-emissions in these locations may require the use of alternative charging approaches, the use of plug-in dispensers, or be candidates for 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 depot expansions, reconstruction, or the acquisition of new facilities may be required.

Existing Facility Evaluation

The MTA has begun a comprehensive evaluation of all depot facilities for the feasibility of converting operations to support a 100% zero-emissions fleet. To date the MTA has conducted a preliminary desktop review of all depot locations. A comprehensive review of all facilities for 100% battery-electric bus operation is planned in 2022.

The preliminary depot review provides a high-level evaluation of the compatibility, construction feasibility, and rough level of effort required for electrification for each of the MTA's 28 depots. The evaluation relies on asset condition assessments collected as part of the MTA's 2020-2039 20-Year Capital Needs process. These condition assessments include descriptive information for each location as well as condition ratings for the facility overall and for major subsystems. Condition ratings are on a 1 to 4 scale with 1 being the best and 4 being the poorest. This information was supplemented by a review of architectural drawings at select locations.

Each facility was evaluated for 4 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 is rated good (minimal foreseeable issues), moderate (some level of modification/accommodation expected), or constrained (significant constructability or feasibility challenge). The characteristics evaluated and rating criteria for each are:

- General Condition – identifies depots where major reconstruction or rehabilitation projects may be expected over the 20-year period of the zero-emissions transition because of the underlying age or condition of the facility. These locations are expected to have larger impacts 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. Ratings given for this characteristic:
    - *Good*: overall condition rating of 1 or 2 and facility built after 1950
    - *Moderate*: overall condition rating of 3 and facility built after 1950
    - *Constrained*: 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. Ratings given for this characteristic:
    - *Good*: electrical condition rating of 1
    - *Moderate*: electrical condition rating of 2
    - *Constrained*: 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 required for charging operations challenging. Installation of charging infrastructure is expected to reduce existing depot capacity. Those locations that are already constrained may require significant modifications or expansions. Ratings given for this characteristic:
    - *Good*: At least 15% of total parking capacity unoccupied by current fleet assignment
    - *Moderate*: >5% and <15% of total parking capacity unoccupied by current fleet assignment
    - *Constrained*: 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. 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). Ratings for this characteristic are based on review of architectural drawings in the primary indoor parking area:

- *Good*: >18 feet from floor to ceiling
- *Moderate*: 17-18 feet from floor to ceiling
- *Constrained*: <=16 feet from floor to ceiling
- *Note:* height of support structures, HVAC ducts, electrical conduit, fire suppression, and plumbing were not reviewed and may impede pantograph installation

The results of the preliminary evaluation give a rough idea of the facilities that may require the most significant upgrades and modifications to support battery-electric buses. Seven depots received a constrained rating for general condition. Ten depots received a constrained rating for electrical. Fifteen depots are rated as constrained for space. Four depots are rated constrained on ceiling height. There are 12 depots rated constrained for 2 or more characteristics.

Preliminary Existing Facility Evaluation (Good, Moderate, Constrained)					
Depot	**General Condition (G/M/C)**	**Electrical (G/M/C)**	**Space (G/M/C)**	**Ceiling Height (G/M/C)**	**2 or More Constrained Ratings**
Eastchester	M	M	G	NA	
Gun Hill	G	M	C	G	
Kingsbridge	M	M	C	M	
West Farms	G	M	C	NA	
Yonkers	M	G	M	NA	
East New York	*	C	M	G	
Flatbush	C	C	C	C	Y
Fresh Pond	G	C	M	C	Y
Grand Avenue	G	G	C	G	
Jackie Gleason	M	M	C	M	
Ulmer Park	C	C	M	C	Y
Manhattanville	G	M	C	C	Y
Michael J. Quill	G	C	C	M	Y
Mother Clara Hale	G	G	M	G	
Tuskegee Airmen	G	M	C	M	
Baisley Park	C	M	C	NA	Y
Casey Stengel	M	C	M	NA	
College Point	M	C	C	NA	Y
Far Rockaway	C	G	C	NA	Y
Jamaica	*	*	*	*	
John F. Kennedy	C	M	G	M	
LaGuardia	C	M	C	NA	Y
Queens Village	M	C	M	M	
Spring Creek	M	C	G	NA	
Castleton	C	C	G	NA	Y
Charleston	G	G	M	NA	
Meredith Avenue	G	G	C	NA	
Yukon	M	M	G	C	
*East NY is currently undergoing a significant rehabilitation; Jamaica is currently in design for a complete reconstruction					

Facility Transition & Deployment Plan

Deployment Prioritization Criteria

The MTA plans to progressively deploy zero-emissions buses as described in the Fleet Transition Plan above. New zero-emissions bus deliveries will be coordinated with infrastructure upgrade projects to install chargers (or other zero-emissions fueling infrastructure) to support rolling deployments. Timely conversion of facilities to accommodate zero-emissions technology will become an important factor as we progress into the later stages of deployment. Location selection for project phasing and the rollout of bus deployments will be driven by 5 criteria:

- Equity & Environmental Justice – Deployments will prioritize traditionally disadvantaged communities and areas with poor air quality. The MTA has developed an Environmental Justice Score that looks at both equity and air quality across the MTA bus service area. Locations with higher environmental justice scores will be prioritized for earlier and larger zero-emissions deployments. Details on the scoring methodology are included in the Equity & Environmental Justice Section.

- 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-emissions 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.

- 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 deployments will be phased to coordinate with Con Edison needs and the technical difficulty of new power installation.

- 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 4-stage transition.

- Schedule Feasibility – New zero-emissions buses will be deployed to locations where there are enough feasible bus assignments to accommodate the size of the incoming zero-emissions fleet.

Strategy & 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 2 deployments, though some depots (particularly those with early-stage projects) may see the rollout occur over 3.

Each bus deployment will include a supporting infrastructure project. Since deployments will occur over 2-3 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-emissions operation, including all required depot modifications (including EDR room upgrades, space modifications, and structural changes) 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. 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 & Deployment Plan

While detailed plans and exact deployment locations have not yet been established other than for some immediate deployments in Stage 1, to get a sense of the scale and impact of the effort required to reach 100% zero-emissions the MTA has developed a conceptual construction phasing and deployment plan.

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.

Conceptual Construction Phasing & Deployment Plan

	Depot	Stage 1	Stage 2	Stage 3	Stage 4
Brooklyn	East New York	35%	100%		
	Fresh Pond			50%	100%
	Grand Avenue	40%		100%	
	Flatbush			55%	100%
	Jackie Gleason	20%	35%	100%	
	Ulmer Park	20%			100%
Queens	Casey Stengel			70%	100%
	College Point			55%	100%
	Jamaica	20%	100%		
	LaGuardia				100%
	Queens Village	25%		100%	
	Baisley Park			80%	100%
	Far Rockaway				100%
	John F. Kennedy		30%	70%	100%
	Spring Creek				100%
Staten Island	Castleton		30%	90%	100%
	Charleston	5%	25%	55%	100%
	Meredith Avenue				100%
	Yukon	5%			100%
Bronx	Eastchester	20%		100%	
	Yonkers				100%
	Gun Hill	25%		50%	100%
	Kingsbridge	10%	45%	100%	
	West Farms		60%	85%	100%
Manhattan	Tuskegee Airmen		45%		100%
	Mother Clara Hale	25%	65%		100%
	Manhattanville			55%	100%
	Michael J. Quill	10%			100%

= New Power Supply Installation

= Depot Upgrades & Modifications

% = Charging Equipment & Bus Deployments (share of total depot fleet complete by end of stage)

WORKFORCE TRANSITION

Overview

A skilled and supported workforce is essential to achieve the MTA's goal to transition to 100% zero-emissions vehicles by 2040. Converting to zero-emissions buses will affect the duties, responsibilities, and knowledge requirements of almost every member of the MTA Department of Buses operating and maintenance staff. While many aspects of operating zero-emissions 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.

An additional aspect of the workforce transition challenge is navigating the continually changing landscape of zero-emissions 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 MTAs workforce transition must remain flexible to adapt to ongoing changes and technological innovations while ensuring that staff are fully prepared for each progressive step in the transition.

Throughout the transition the MTA is committed to continuous collaboration with its union partners, ongoing communication 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 will be:

- Ensuring the continued safe and efficient operation of bus service
- Providing robust training and support to meet all new requirements of the zero-emissions transition
- Providing opportunities for existing and new staff to continuously grow and excel
- Collaborating and communicating with staff and union partners
- Maintaining flexibility to address ongoing innovations in zero-emissions technology

Skills & Training Review

Completing the transition to zero-emissions buses will require ongoing training and support to prepare and transition the MTA workforce. The MTA has identified four major areas in which zero-emissions 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 system have provided a baseline of staff knowledge, procedures, and available training processes that has greatly smoothed 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. A clear lock-out, tag-out procedure for isolating high voltage systems for maintenance operations has been established. All bus operators at depots with electric buses have received a dedicated familiarization training that includes thorough safety information.

As zero-emissions buses continue to roll-out, safety training will continue to be a core aspect of the workforce transition. A thorough study of high-voltage safety requirements, codes, and best practices is planned in 2022 that will provide a comprehensive review of the required facilities, personal protective equipment, and procedures needed for 100% battery-electric bus operation and maintenance. Study findings will inform updated procedures and trainings and guide decision making on the dedication of resources.

Bus Maintenance

The era of combustion engines and exhaust systems will soon come to an end for our maintainers, replaced by the new age of battery and electric propulsion systems. Maintainers will need to adapt new skills to troubleshoot and fix these new 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's existing experience with hybrid buses has provided a solid background in similar battery and propulsion systems that are used on electric buses. To date the MTA has adapted and expanded on this experience to provide maintenance training and procedures for existing zero-emissions bus deployments. A collaboration with vendor equipment manufacturers has allowed for content development and skills transfer to MTA trainers. Regular experience sharing sessions have been established among bus maintainers at depots to develop and spread expertise. Standardized maintenance procedures for common zero-emissions bus repairs and diagnostics have been developed and 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.

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 Tech 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-emissions bus maintenance will leverage this existing system and staff to build and spread expertise in new zero-emissions bus equipment. This core function will be supplemented with a series of in-depth training courses on specialized systems new to zero-emissions fleets, like battery storage systems and electric propulsion systems. The MTA plans to continue to collaborate with equipment manufacturers in developing best practices and creating training materials and course offerings throughout the transition. Zero-emissions 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 will require 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 a core of knowledge, but there is still significant room for growth in expanding the staff and developing the expertise required as charging infrastructure begins to reach many more locations at much larger scale. Along with its public utility partners, the MTA is also only beginning to install large power supply equipment at bus depots. Existing MTA experience maintaining large, complicated power supply systems from the subway 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 like the already well-established bus maintenance organizational structure within the agency. This will include the establishment of a power engineering maintenance group to manage and maintain the large new 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 MTAs remaining deployments in Stage 1 of the transition 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 & 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 to facilitate daily pull-out operations. This will require significant resource development and training effort to establish best practices, create effective support tools, and integrate new procedures into operations.

For deployments to date the MTA has provided basic training on charging operations, low-battery management, and incident response as part of initial familiarization 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. Using this existing framework for expanding knowledge and skills about zero-emissions fleets will continue to be 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-emissions buses into operations continue change 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 the period when the MTA expects to develop and test best practices that can form the basis for a standard, easy to employ, and effective procedures for all aspects of zero-emissions 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.

Zero-emissions related procedures will be incorporated into all onboarding, refresher, and new equipment training with minimal expected changes to the typical time required for these trainings. More intensive specialty knowledge will be required for some positions, for example for yard shifters, yard dispatchers, and incident response staff.

Workforce Transition Framework & Stages

Based on the review of the impacts of the transition to zero-emissions operations on the MTA workforce, the expanded need for knowledge and skills identified, and the existing MTA training processes and resources available, the MTA has developed a framework to approach the workforce transition.

The early stages of the transition are expected to require a big push of training and workforce support with later stages building and expanding on the core of expertise established in earlier stages. 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-emissions 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 will reach almost every depot in the system.

The MTA plans to approach zero-emissions 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 as zero-emissions buses roll out. 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.

Familiarization Training

All operating staff working at depots where zero-emissions buses are deployed will be trained in basic high-voltage safety and general familiarization with both the bus and charging infrastructure. This will provide a common baseline of understanding shared universally by all staff. Content will include a high-level understanding of zero-emissions 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-emissions 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 2 and 8 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.

Projected Zero-Emissions Familiarization Training Content & 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 & Support Staff	• High-voltage awareness • Range and battery management • Performance monitoring and reporting	2 Hours

Specialized Skills Training

For those roles where zero-emissions buses have greater impacts on day-to-day responsibilities or require detailed understanding of new systems or skills additional specialized trainings will be provided. The need for specialized training will be greatest in the bus maintenance and facilities maintenance functions that will be responsible for troubleshooting and repair of new systems.

Several specialized training courses have already been developed, including a 10-day focused training on electric bus safety and systems for bus maintainers that will qualify bus maintainers to lockout and tagout 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. It is expected that Stage 1 of the transition will 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.

Projected Zero-Emissions Specialized Skills Training & Targets		
	Specialized Training	**Rollout Target**
Depot Bus Maintainers	Electric Bus Safety & Maintenance (10 days)	At Affected depots: • 20% of bus maintainers *Electric Bus Safety & Maintenance* qualified each year
Central Maintenance Maintainers	• Electric Bus Safety & Maintenance (10 days) • Battery-Electric Bus Overhaul Procedure (10 days)	• 50% of bus maintainers *Electric Bus Safety & Maintenance* qualified in Stage 1 • 10% of bus maintainers receive *Battery-Electric Bus Overhaul Procedure* each year
Facility Maintainers	• Charging Equipment Safety & Maintenance (5 days)	• All facility maintainers at affected depots *Charging Equipment Safety & Maintenance* qualified within 1 year of deployment • 15% of floating facilities supervisors and maintainers *Charging Equipment Safety & Maintenance* qualified each year
Dispatchers	• Depot Charge Management (2 days) • Zero-Emissions Incident Response (2 days) • Zero-Emissions Towing (5 days)	• All depot-based dispatchers at affected depots receive *Depot Charge Management* within 6 months of deployment • 20% of dispatchers receive *Zero-Emissions Incident Response* training each year • 20% of tow truck operators receive *Zero-Emissions Towing* training each year

Stage Expectations

The early stages of the transition are expected to require a big push of training and workforce support with later stages building and expanding on the core of expertise established in earlier stages.

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-emissions 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-emissions 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-emissions 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-emissions skills and knowledge will continue to be maintained and expanded. This stage will also see the winding down of all non-zero-emissions training and support infrastructure as the last remaining diesel and CNG buses retire.

Cost

Workforce development and training is expected to require up to 5% of the capital cost of the transition to zero-emissions in Stages 1 and 2, with workforce costs falling to around 2% of the capital cost in Stages 3 and 4. 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.

Estimated Workforce Transition Cost by Stage	
Stage	**Estimated Cost (Millions)**
Stage 1	$35
Stage 2	$67
Stage 3	$50
Stage 4	$76
Total	**$228**

COST & FUNDING

Capital Cost Estimate

The MTA has estimated the capital costs to purchase battery-electric buses and supporting charging infrastructure to achieve 100% zero-emissions 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 should be taken only as 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 2 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 the end of 2022 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 mid-2023. These projects serve as the primary basis for all the MTA's battery-electric bus capital cost estimates.

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 $1.1 billion. This includes roughly $686 million for the purchase of battery-electric buses and $457 million for charging infrastructure, power supply, and supporting depot modifications and upgrades.

Stage 1 Capital Cost Estimate (Millions)	
Project	Estimated Cost
15 Articulated Battery-Electric Buses and Depot Chargers	$35
60 Standard Battery-Electric Buses	$70
Phase 1 Charging Infrastructure (Supports 60 Buses)	$50
15 Bus Test Fleets (3 5-bus fleets)	$26
470 Battery-Electric Buses (380 Standard + 90 Artic)	$569
Phase 2 Charging Infrastructure (Supports 215 Buses)	$167
Phase 3 Charging Infrastructure (Supports 255 Buses)	$226
	$1,143

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 existing 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 of 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. 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. Comparing these prices to other recent diesel, hybrid, and CNG bus purchases provides a sense of the cost premium of buying battery-electric compared to traditional propulsion systems for each bus type.

The cost premium used for analysis is based on a comparison of battery-electric to diesel. Diesel is the most common propulsion type in the MTA fleet and the only propulsion type that the MTA has experience with for all three bus types operated by the agency. Since the MTA has not purchased any electric express buses, the cost is assumed to be the same as for a battery-electric standard since the diesel costs for these two fleet types are roughly similar.

Per Bus Capital Cost (2021 Dollars)		
Bus Type	Propulsion	Per Bus Cost
Standard	*Battery-Electric*	*$1,033,000*
Articulated	*Battery-Electric*	*$1,388,000*
Standard	Diesel	$635,000
Standard	Hybrid	$830,572
Standard	CNG	$679,845
Articulated	Diesel	$835,000
Articulated	CNG	$898,311
Express	Diesel	$633,695
Battery-Electric Cost Premium		
Standard BEB Premium Vs. Diesel		$398,000
Articulated BEB Premium Vs. Diesel		$553,000
Express BEB Premium Vs. Diesel		$399,305

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-emissions fleet transition plan section, standard MTA capital support costs, and inflation. Note that the transition cost estimate includes only the initial cost of transition to zero-emissions when replacing an existing carbon-emitting bus. Replacement purchases of zero-emissions buses are not included in the cost estimate. This mostly impacts the Stage 4 estimate where 965 projected bus purchases are expected to replace previously transitioned zero-emissions buses.

Bus Capital Cost Estimate (Year of Award Dollars, Millions)		
Stage	Total Estimated ZE Fleet Capital Purchase Cost	Zero-Emissions Premium Vs. Diesel
Stage 1	$686	$239
Stage 2	$1,410	$520
Stage 3	$3,043	$1,115
Stage 4	$4,827	$1,789

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. Because of the high level of uncertainty costs are estimated for a low and high scenario across 4 cost categories based on the following assumptions:

- Charging Equipment – including pantograph dispensers and gantry supports, charging cabinets, all associated electrical between the EDR room chargers and pantographs, minor relocation of ducts and conduit, and all design and project management support. Cost estimates are based on experience from the MTA's currently ongoing charger installation project which is installing pantograph chargers at 4 depots to support the recently awarded 60 bus purchase:
    - *Low*: A base of $3 million per project plus $400,000 per pantograph charging position
    - *High*: A base of $4 million per project plus $500,000 per pantograph charging position
- Depot Modifications & Upgrades –a rough per depot allowance for depot improvements required to support conversion to zero-emissions, including work such as EDR room expansion, adjustments to facility space utilization, structural reinforcement, HVAC upgrades, major duct or conduit relocations, and facility hardening to support resiliency.
    - *Low*: $10 million per depot
    - *High*: $20 million per depot
- New Power Supply –a rough per depot allowance for costs related to the provision of new power supply at each depot, including site preparation work and utility connection costs.
    - *Low*: $5 million per depot
    - *High*: $10 million per depot
- Major Rehabs and Renovations – a rough per depot allowance for major renovations required to support the conversion to zero-emissions. The number of locations requiring major renovation and the scope and cost of any work is yet to be determined. The preliminary facility condition evaluation described in the Facility Transition section above showed 12 depots with conditions rated "constrained". In advance of more accurate information the estimate assumes that 12 depots will require major renovation evenly split over stages 2, 3, and 4 of the transition.
    - *Low*: $50 million per depot
    - *High*: $100 million per depot

Facility Capital Cost Estimate (Year of Award Dollars, Millions)		
Stage	Low	High
Stage 2	$820	$1,305
Stage 3	$1,398	$2,059
Stage 4	$2,014	$2,914

Full Transition Capital Cost Estimate

The estimated total additional capital cost (beyond normal capital replacement) of the transition to 100% zero-emissions bus operations including bus purchases and all required infrastructure investments is estimated between $8.3 and $10.1 billion.

LOW Full Transition Additional Capital Cost Estimate (Year of Award Dollars, Millions)			
Stage	Zero-Emissions Premium Vs. Diesel	Facility Transition	Total
Stage 1	$239	$457	$697
Stage 2	$520	$820	$1,340
Stage 3	$1,115	$1,398	$2,513
Stage 4	$1,789	$2,014	$3,803
Total Transition	**$3,663**	**$4,635**	**$8,298**

HIGH Full Transition Additional Capital Cost Estimate (Year of Award Dollars, Millions)			
Stage	Zero-Emissions Premium Vs. Diesel	Facility Transition	Total
Stage 1	$239	$457	$697
Stage 2	$520	$1,305	$1,825
Stage 3	$1,115	$2,059	$3,174
Stage 4	$1,789	$2,914	$4,703
Total Transition	**$3,663**	**$6,735**	**$10,399**

The estimated total capital cost including the baseline cost of the bus plus the zero-emissions premium for the complete transition to 100% zero-emissions bus operation is estimated between $14.7 and $16.7 billion.

LOW Full Transition Capital Cost Estimate (Year of Award Dollars, Millions)			
Stage	Zero-Emissions Fleet Purchase	Facility Transition	Total
Stage 1	$686	$457	$1,143
Stage 2	$1,410	$820	$2,230
Stage 3	$3,043	$1,398	$4,441
Stage 4	$4,827	$2,014	$6,841
Total Transition	**$9,967**	**$4,635**	**$14,656**

HIGH Full Transition Capital Cost Estimate (Year of Award Dollars, Millions)			
Stage	Zero-Emissions Fleet Purchase	Facility Transition	Total
Stage 1	$686	$457	$1,143
Stage 2	$1,410	$1,305	$2,715
Stage 3	$3,043	$2,059	$5,102
Stage 4	$4,827	$2,914	$7,741
Total Transition	**$9,967**	**$6,735**	**$16,702**

Funding

Making the transition to 100% zero-emissions buses is a significant investment. The $8-10 billion in additional capital investment over the 20-year transition represents a significant increase over the MTA's traditional pace of funding for bus capital investments. For example, the Stage 1 additional cost of $667 million to support zero-emissions investments represents roughly 20% of total bus related investments in the 2020-2024 Capital Program. With the zero-emissions rollout pace increasing in Stage 2 and reaching a peak in Stage 3, the additional cost of zero-emissions investments will reach roughly 50% of the total cost of bus projects in the capital plan. Put another way, the additional cost of zero-emissions transition will almost double the expected amount of funding required for MTA bus capital projects over the next 20 years.

Meeting the increased investment need of zero-emissions buses will require a major expansion in historic capital funding levels for bus investments. To achieve this will likely require both major increases in funding from existing sources as well as identification of new funding sources. 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-emissions buses at the MTA.

The MTA plans to identify funding progressively, stage by stage. The zero-emissions transition stages are directly coordinated with the timeframes of the MTA's 5-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 sizeable share coming from federal formula and competitive grant funds.

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

EQUITY & ENVIRONMENTAL JUSTICE

The MTA is committed to prioritizing equity and environmental justice in the transition to a 100% zero-emissions bus fleet. NYC's buses serve a disproportionate share of low-income and minority households in NYC 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, mitigating the impacts of climate change which are expected to fall most heavily on traditionally disadvantaged communities like NYC's bus riders.

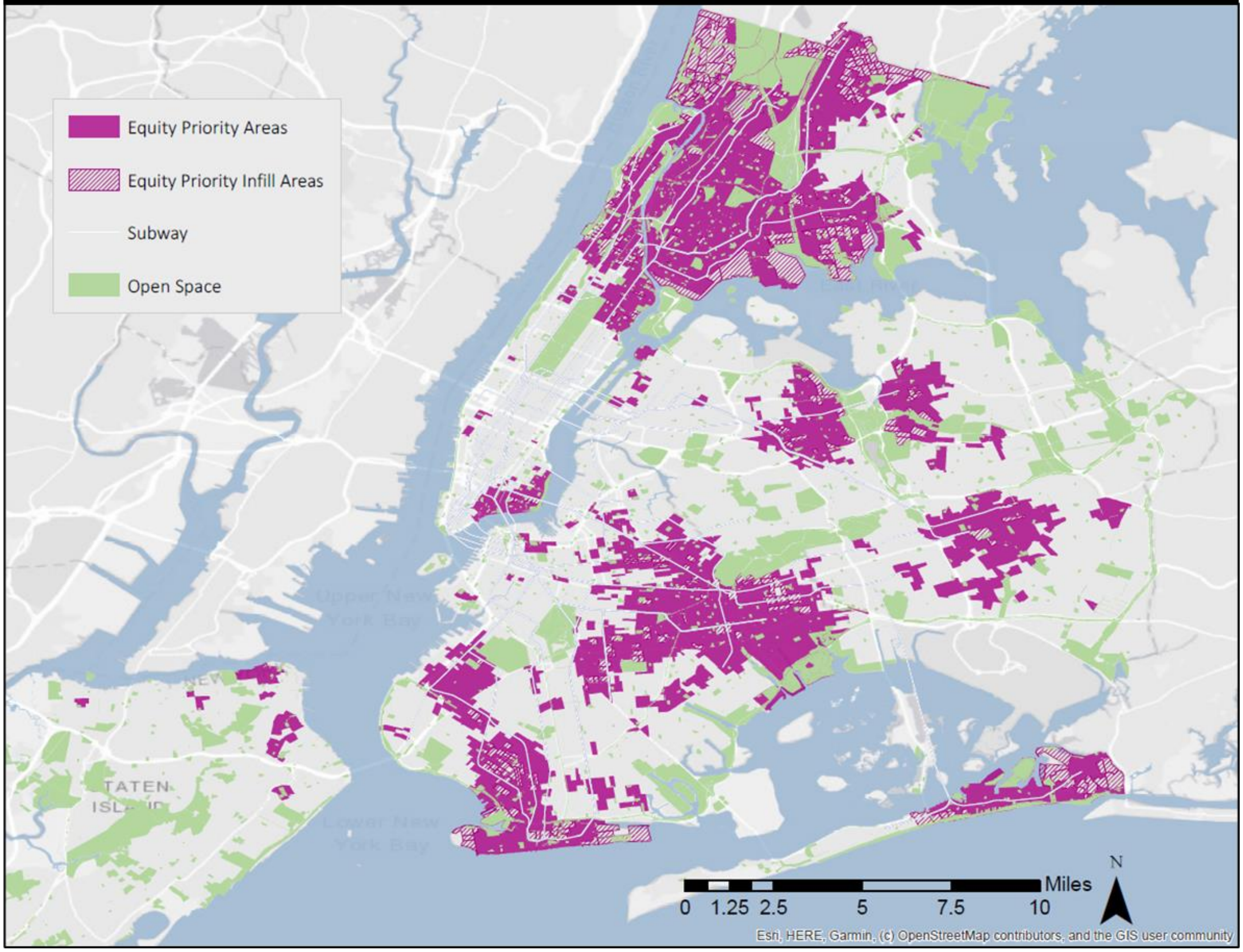
In addition to completing this transition successfully and on time, the MTA will prioritize equity and environmental justice in the rollout of zero-emissions buses. To do this the MTA has developed an Environmental Justice Score which combines considerations of equity and air quality to ensure that the benefits accrue to those communities most impacted.

Equity Priority Areas

The MTA has identified geographic Equity Priority Areas (EPA) for prioritizing equity in project planning. These areas were identified through a three-step process. First an aggregate weighted equity score was developed, using data from 13 metrics, and weighted as described in the table below. Second, a hot spot analysis was conducted to identify statistically significant geographic clusters. Third, equity priority areas were established based on a composite of the identified hot spots and the map of composite scores, including appropriate infill areas.

Equity Priority Area Metrics & Weights		
	Metric	**Weight**
High	Race	10
	Zero vehicle households	10
	Households in poverty	9
	Commute time 45 minutes or more	9
Mid	People with disabilities	6
	Limited English Proficient (LEP); English as a Second-Language (ESL) households	5
Low	Age (under 18; 75 and older)	3
	Employment status	3
	Households that spend >30% of their income on housing	3
	Public transit to work (for the majority of commute trip)	2
	Density of job location	2
	NYCHA locations (binary)	2
	Level of educational attainment	1

MTA Equity Priority Areas



Air Quality Index

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

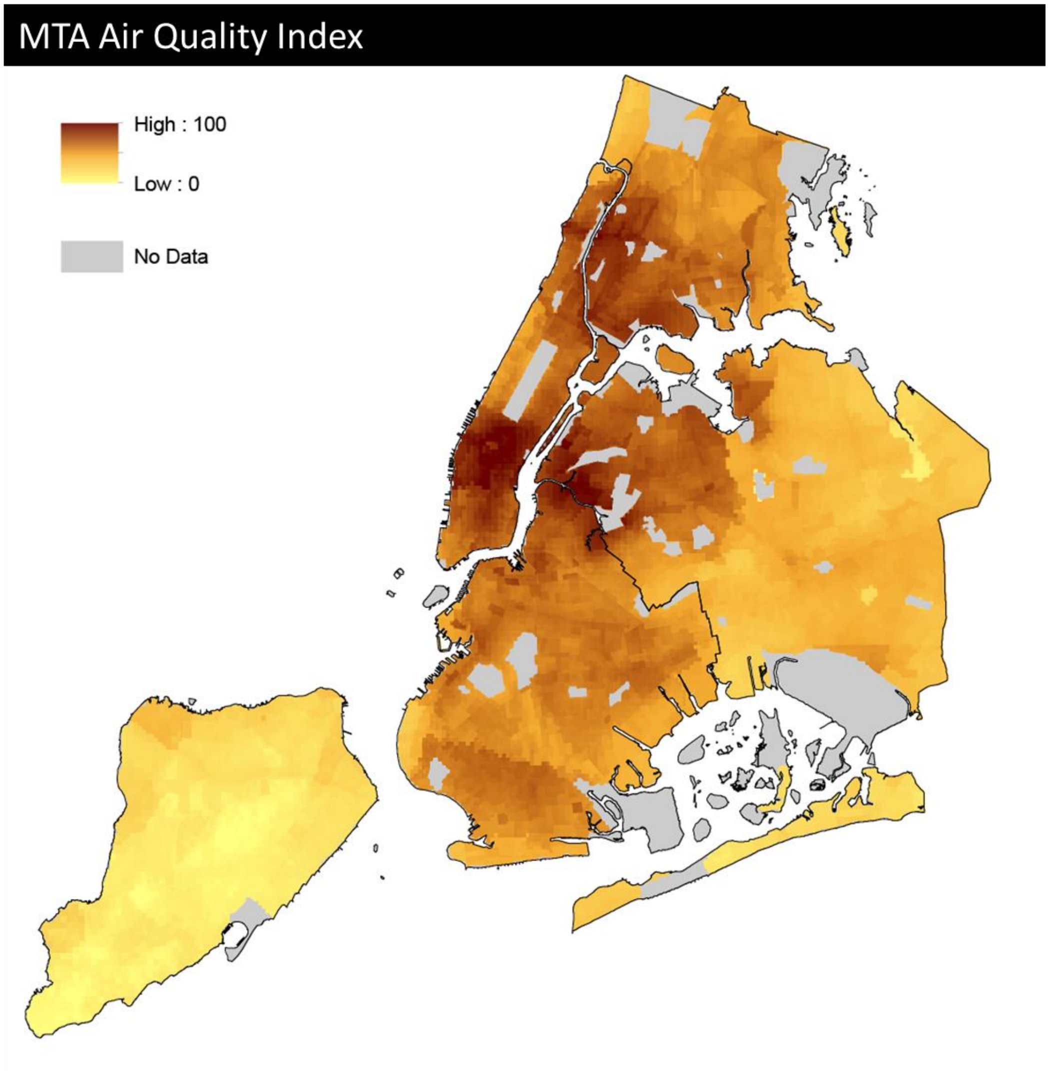
The Air Quality Index is a weighted composite of 9 air quality metrics. Included metrics include 5 of 6 EPA Clean Air Act monitored criteria pollutants as well as 4 additional metrics including several EPA risk indexes, a measure of diesel particulate matter, and asthma rates. Data is from the EPA National Air Toxics Assessment; the NYC Community Air Survey; the Center for Air, Climate, and Energy Solutions; and the Centers for Disease Control.

Weights for each metric were developed based on the risk level plus an evaluation of the existing level of exposure in NYC compared to relevant health standards and to the levels experienced in the US on average. Pollutants representing larger risk, at higher levels against 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 NYC. The table below shows the 9 metrics, their associated health impact, evaluation against health standards and the US average level, and the weights assigned to each.

MTA Air Quality Index – Pollution Measures & Weights

Category (Weight)	Metric	Health Impacts	NYC Max Vs. Health 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 by damaging foliage and decreasing growth.	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%

*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



Environmental Justice Score

For zero-emissions fleet prioritization the Equity Priority Areas (EPA) and Air Quality Index are combined to create an Environmental Justice Score. This score is developed at both the route level and the depot level to facilitate application to zero-emissions fleet rollout decisions.

Route level scores for EPAs are established based on the share of each routes' total length that passes through an EPA. Route level scores for the Air Quality Index are established based on the average air quality index of all areas within a 250-foot buffer of the route.

Depot level scores for EPAs are an average of the route level scores for all routes operating from that depot. For the Air Quality Index, depot level scores 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 air quality index within a ¼ mile radius of the depot itself.

The combined Environmental Justice Score (EJ Score), at both the route level and depot level, combines these two scores using a percentage for each: 55% EPA score, and 45% air quality score. 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 developed is below, followed by a table showing the results for all 28 MTA depots.

	Route Score	Depot Score
Equity Priority Areas *Includes 13 weighted metrics*	Share of the route operating in an equity priority area	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 ¼ mile of the depot
	=	=
Environmental Justice Score	• 55% equity priority score • 45% air quality score	• 55% equity priority score • 45% air quality score

Depot Environmental Justice Score

Division	Depot	EJ Score	Borough Rank	System Rank
Bronx	Eastchester	**44**	5	7
	Gun Hill	**57**	3	3
	Kingsbridge	**74**	1	1
	West Farms	**71**	2	2
	Yonkers	**55**	4	4
Brooklyn	East New York	**55**	1	5
	Flatbush	**38**	4	13
	Fresh Pond	**42**	3	9
	Grand Avenue	**38**	5	15
	Jackie Gleason	**37**	6	17
	Ulmer Park	**45**	2	6
Manhattan	Manhattanville	**43**	1	8
	Michael J. Quill	**29**	4	23
	Mother Clara Hale	**39**	3	12
	Tuskegee Airmen	**40**	2	10
Queens	Casey Stengel	**36**	4	18
	College Point	**33**	5	19
	Jamaica	**39**	1	11
	LaGuardia	**30**	8	22
	Queens Village	**32**	6	20
	Baisley Park	**38**	2	14
	Far Rockaway	**26**	9	24
	JFK	**38**	3	16
	Spring Creek	**31**	7	21
Staten Island	Castleton	**18**	2	26
	Charleston	**16**	4	28
	Meredith Avenue	**21**	1	25
	Yukon	**18**	3	27
System Average		**39**		

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. Transitioning the MTA bus fleet to 100% zero-emissions by 2040 is a major aspect of the MTA's agency wide effort to reduce emissions. The MTA was a founding member of the Climate Registry and has been voluntarily reporting agencywide 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 to help keep the global temperature well-below 2°C compared to pre-industrial levels as part of the Science Based Targets Initiative, a partnership that includes the United Nations Global Compact.

Throughout the transition to fully zero-emissions 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-emissions bus operation.

Carbon Impact Calculation & Savings to Date

The MTA established baseline rates of carbon emissions by vehicle and propulsion type through an analysis of fuel and energy consumption in 2019. For each fleet pounds of carbon emitted per mile as well as the metric tons of carbon (MT CO2e) emitted per year is estimated to allow comparison with zero-emissions vehicles.

Diesel & CNG Fleet Emissions

Because the MTAs 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.

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-emissions 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 MTAs existing fleet of battery-electric buses.

MTA Battery-Electric Per Bus Carbon Emissions (May 2020-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 percent renewable energy generation by 2030. As progress is made toward this state goal, emissions associated with MTA zero-emissions bus operations will progressively be reduced to zero.

Per Bus Avoided Carbon Emissions

Comparing emissions rates from traditional propulsion buses to the MTAs battery-electric buses provides an estimate of avoided carbon emissions by purchasing zero-emissions bus rather than diesel, hybrid, or CNG buses on a per bus level.

Avoided Per Bus Carbon Emissions			
Bus Type	Vs.	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

Zero-Emissions Bus Carbon Savings to Date

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-emissions fleet operation through the end of 2021.

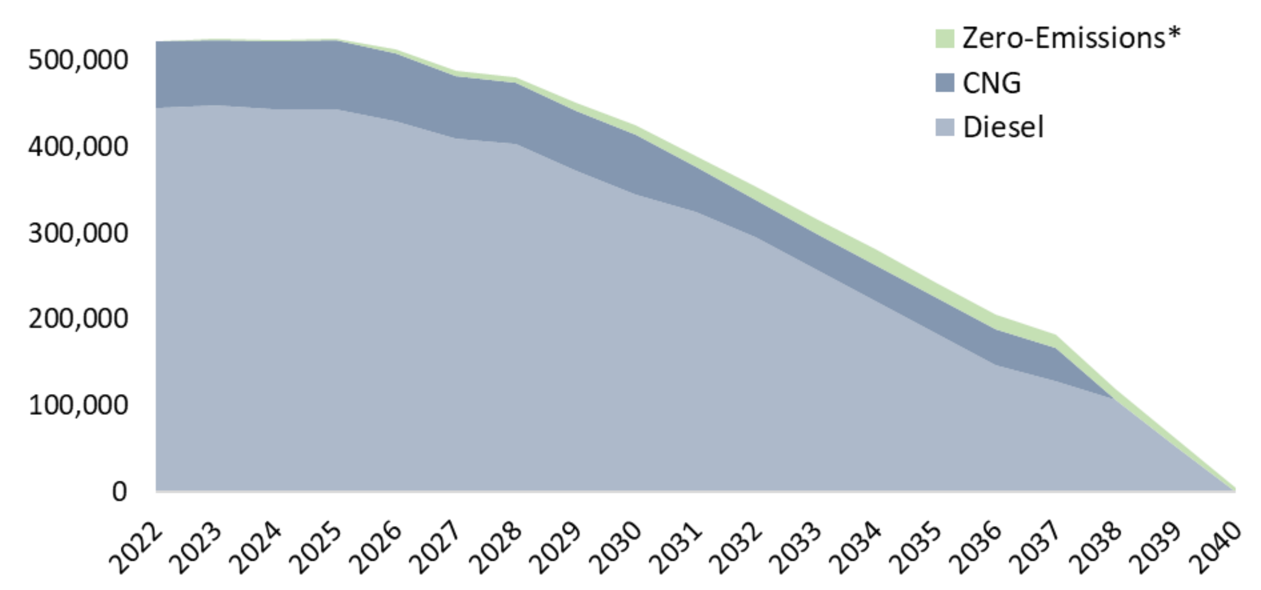
MTA Total Zero-Emissions Bus Carbon Savings Through End-of-Year 2021		
Bus Type	Total Mileage	Total Avoided MT CO2e
10 Standard Battery-Electric Bus Pilot	227,979	471
15 Articulated Buses	164,528	362
Total	**392,507**	**833**

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-emissions 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-Emissions Fleet Transition Plan section below, total annual carbon emissions from MTA bus operations are estimated for each year from 2022 through 2040.

Projected Carbon Emissions from MTA Bus Service (MT CO2e)



*As a result of electricity production, based on current NY State carbon intensity levels reduced in line with goals stipulated by the NY State Climate Act

POLICY & LEGISLATIVE IMPACTS REVIEW

Local & 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 NYS 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 goals set in EO 88 by completing ASHRAE Level 2 energy audits and recommissioning studies in approximately 50 facilities, 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 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 EV 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 carbon neutral economy, mandating at least an 85% reduction in emissions below 1990 levels with 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 MHD ZEV memorandum of understanding, with the goal of having 30% of MHD 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 EV charging of 850,000 LDVs by 2025. A point to note here is that most of Make-Ready funding is for public Level-2 charging, followed by public DC Fast Chargers. A smaller slice allocated for pilots and fleet advisory services.

The State provides nearly $6 billion in direct and State authorized support for public transportation services, more than 46 other states combined. This support is intended to maintain and enhance service levels; ensure passengers 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 municipally sponsored public transportation services in upstate New York transition to ZEVs 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. Specific to transportation, energy efficiency and end-use electrification are essential. The plan states that approximately 3 million zero-emission vehicles (predominantly battery electric) will need to be sold by 2030 and 10 million by 2050. It further states that New York will need to substantially reduce VMT while increasing access to public transportation, which should include expanding transit services structured around community needs, smart growth inclusive of equitable TOD (E-TOD), and transportation demand management.

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

New York City

New York City has long been a global leader in building emissions reductions, notably through the passage and implementation of the Climate Mobilization Act and its centerpiece, Local Law 97, which places caps on greenhouse gas 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 greenhouse gas emissions by enacting legislation phase 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 (One NYC 2050 2020) and has already purchased more than 2,000 EVs for its fleet (NYC Sustainability Office 2020).

Regional

The Regional Greenhouse Gas Initiative 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 markets. 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 DEC 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 Guidebook issued invests $91.2 billion to repair and modernize transit. The legislation supports expanded public transportation choices nationwide, including the replacement of thousands of deficient transit vehicles, including buses, with clean, 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 emissions 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)

FLEET & OPERATIONS BACKGROUND

Agency Profile

Organization

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 provides bus service in the five boroughs of New York City, serving 251 square miles and 98% of the city's population are within ¼ mile of a bus stop. The MTA operates 327 routes covering 4 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 1.1 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, 2 door, low floor buses that operate in local, limited and SBS service
- Articulated buses: 60-foot, 3 door, low floor buses that operate in local, limited, and SBS service
- Express buses: 45-foot, 1 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

MTA Active Bus Fleet (January 2022)				
Type	**Propulsion**	**NYCT**	**MTABC**	**Total**
Standard	Diesel	1,647	45	1,692
	Hybrid	948	405	1,353
	CNG	409	216	625
Articulated	Diesel	903	141	1,044
	CNG	109		109
	Electric	15		15

Express	Diesel	515	528	1,043
All Types	Diesel	3,065	714	3,779
	Hybrid	948	405	1,353
	CNG	518	216	734
	Electric	15	0	15
Total		**4,546**	**1,335**	**5,881**

Facilities Background

The MTA operates 28 depots and 3 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 (4) depots and one (1) 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-emissions fleet.

MTA Bus Depots & Bus Assignment (January 2022)		
Depot/Division	**Agency**	**Bus Assignment**
East New York	NYCT	255
Fresh Pond	NYCT	206
Grand Avenue	NYCT	172
Flatbush	NYCT	213
Jackie Gleason	NYCT	290
Ulmer Park	NYCT	245
Brooklyn		**1,381**
Casey Stengel	NYCT	227
College Point	MTABC	327
Jamaica	NYCT	199
LaGuardia	MTABC	255
Queens Village	NYCT	273
Queens North		**1,281**
Baisley Park	MTABC	111
Far Rockaway	MTABC	106
John F. Kennedy	MTABC	184
Spring Creek	MTABC	135
Queens South		**536**
Castleton	NYCT	248
Charleston	NYCT	218
Meredith Avenue	NYCT	71
Yukon	NYCT	272
Staten Island		**809**
Eastchester	MTABC	134
Gun Hill	NYCT	301
Kingsbridge	NYCT	262
West Farms	NYCT	307
Yonkers	MTABC	83
Bronx		**1,087**
Tuskegee Airmen	NYCT	143
Mother Clara Hale	NYCT	125
Manhattanville	NYCT	243
Michael J. Quill	NYCT	276
Manhattan		**787**
	NYCT Total	*4,546*
	MTABC Total	*1,335*

Capital Program Background

Capital Program Process

Investments in new buses and depot improvements are planned and funded through the MTAs Capital Program. Capital Programs are organized into 5-year investment plans. Each 5-year plan begins with a Capital Needs Assessment in which all critical assets are assessed by looking at key factors such as their age, condition, performance, location, and safety history. A prioritization process takes place to determine what investments we need to make to bring or keep our most critical assets in a state of good repair and maintain the safety and reliability of the system for our customers. Potential investments are then prioritized into five-year buckets by the major categories of work. Each 5-Year program must then 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.

MTA New York City Buses Capital Program – $3.5 billion

Category	Budget	Priority Investment Highlights
NYC Transit Buses	$1,820m	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	$722m	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

Category	Budget	Hidden Investment Highlights
NYC Transit Depots	$821m	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 lane enforcement
MTA Bus Company Depots	$149m	Modify first depot to support all-electric buses Make priority repairs at up to 5 depots, targeting structural elements, heating/ ventilation, and electrical systems Replace bus depot equipment, such as bus lifts