



Washington Metropolitan Area
Transit Authority

Metrobus

Fleet Management Plan



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Executive Summary

The Metrobus Fleet Management Plan details how Metro will modernize and maintain its bus fleet and supporting facilities to meet service demands between 2021 and 2038.

Metrobus Overview

Metrobus service operates on 245 routes and 159 lines, reaching over 10,600 stops and covering over 2,396 street miles in the Washington metropolitan area. As of FY2022, a fleet of nearly 1,600 vehicles is stored and maintained at 10 bus divisions throughout the region. Service is provided on a combination of local, limited-stop (MetroExtra), and express routes connecting the region to Metrorail, employers, medical centers, schools, colleges, universities, airports, military installations, and other commuter rail facilities.

Key Conclusions

The Metrobus Fleet Management Plan provides a forward-looking plan for Metrobus operations. This plan covers current and projected bus fleet service levels, ridership projections, bus fleet requirements including fleet replacement and retirement plans, vehicle types, and bus facility plans.

In accordance with the conclusions summarized within this document, Metro plans to:

- Operate a steady state Metrobus fleet size of approximately 1,593 total vehicles.
- Increase use of higher capacity articulated buses, growing from 4% to 12% of the active Metrobus fleet, enabling expanded Metrobus service capacity on high ridership corridors.
- Begin migration toward a 100% zero-emission bus fleet by 2045 through initial focus on electric buses, along with an expanded use of compressed natural gas (CNG) or other lower-emission buses as a transitional strategy while electric bus technologies mature.
- Convert at least one additional garage to support electric bus operations by the end of the decade and begin development of projects for additional conversions to be completed by the early 2030s.
- Adopt a spare ratio of 19.5% to support the anticipated increased maintenance requirements of the expanded articulated bus fleet as well as the adoption of new propulsion technologies and other special projects.

Ridership and Service

Metrobus and Metrorail experienced significant ridership decline in 2020 as a result of the coronavirus pandemic. By fall 2021, Metrobus ridership had recovered to approximately two-thirds of pre-pandemic levels. While the long-term effects of the pandemic remain uncertain, Metro is preparing for continued ridership recovery over the next several years. As this is a planning document forecasting demand through 2038, preparations regarding the Metrobus fleet and facilities are intended to respond to forecasted long-term ridership demand.

The Metrobus long-term ridership forecast predicts that Metrobus ridership will recover to pre-pandemic levels and then increase by an average of 0.23% annually through 2038. Overall, this will result in an increase of about 19,000 daily trips, from about 425,000 weekday boardings in 2019 to 444,00 by 2038. Because this growth is expected to be distributed unevenly along Metrobus routes and lines, service patterns will be adjusted over time to respond. While ridership is anticipated to grow in the long run, Metro expects to accommodate this modest increase in ridership with the existing fleet size and an expanded articulated bus fleet.

Metro is committed to providing equitable transportation to the region, as communities are stronger when everyone has access to reliable and affordable transportation. Public transportation connects people to jobs, housing, health care, schools, grocery stores, and more, and ensuring broad access and eliminating barriers to using transit is important to the agency's success. Metro is advancing recommendations from the Bus Transformation Project, including restructuring the bus network to improve access to destinations, increase ridership, and make efficient and equitable use of resources, and transitioning to cleaner buses and upgrading its facilities to improve the region's air quality and reduce greenhouse gas emissions.

Some initiatives that align with the priorities in the Bus Transformation Project Strategy are already underway. In September 2021, Metro implemented more frequent, all day service at 12- to 20-minute headways or better on 36 of the most-used bus lines. Fare changes included free transfers between rail and bus and a cheaper weekly bus pass. Metro and local jurisdictions are also partnering to speed up buses and improve reliability by implementing dedicated bus lanes, transit signal priority, queue jumps, and violation detection and enforcement policies.

Electric Bus Transition

Metro is beginning its transition to electric buses producing zero tailpipe emissions, which will support a clean and sustainable region, reduce greenhouse gas and on-the-road vehicle emissions, decrease vehicle noise, and improve the overall customer experience. Throughout the United States, many major metropolitan areas, including the Metro service area, have set zero-emission goals and made investments in electric buses. In June of 2021, Metro's Board of Directors approved a bus procurement strategy and fleet composition targets which would create a 100% zero-emission fleet by 2045 and fully transition new bus purchases to electric or other zero-emission technologies by 2030.

In the near-term, Metro will focus on the procurement of electric buses while continuing to evaluate the development of other zero-emission technologies, including hydrogen fuel cell buses. Hydrogen fuel cell vehicles are an emerging technology with limited demonstrations to date, but may represent an important component of Metro's long-term zero-emission implementation. This document will generally refer to buses by their specific propulsion type.

Metro is initiating a 12-bus test and evaluation program at its Shepherd Parkway Operating Division, with two articulated and ten standard length electric vehicles joining the Metrobus fleet by the end of

FY2023. Through this evaluation program, Metro will gather additional data and operational experience to inform plans to move forward with an electric bus program. Transitioning beyond this test and evaluation to a larger overall electric bus fleet will require close coordination with local, regional, and federal partners. Areas of coordination will include energy infrastructure investments and increases in funding for capital investments associated with electric bus technology.

Current challenges towards a full conversion of the Metrobus fleet to electric vehicles include higher capital costs when compared to traditional buses, unique infrastructure requirements, operating limitations (including range and battery life), and reliability. As electric bus technology matures, some initial hurdles are expected to subside, especially with regards to these vehicles’ reliability, availability, and battery storage capacity.

Fleet Procurement

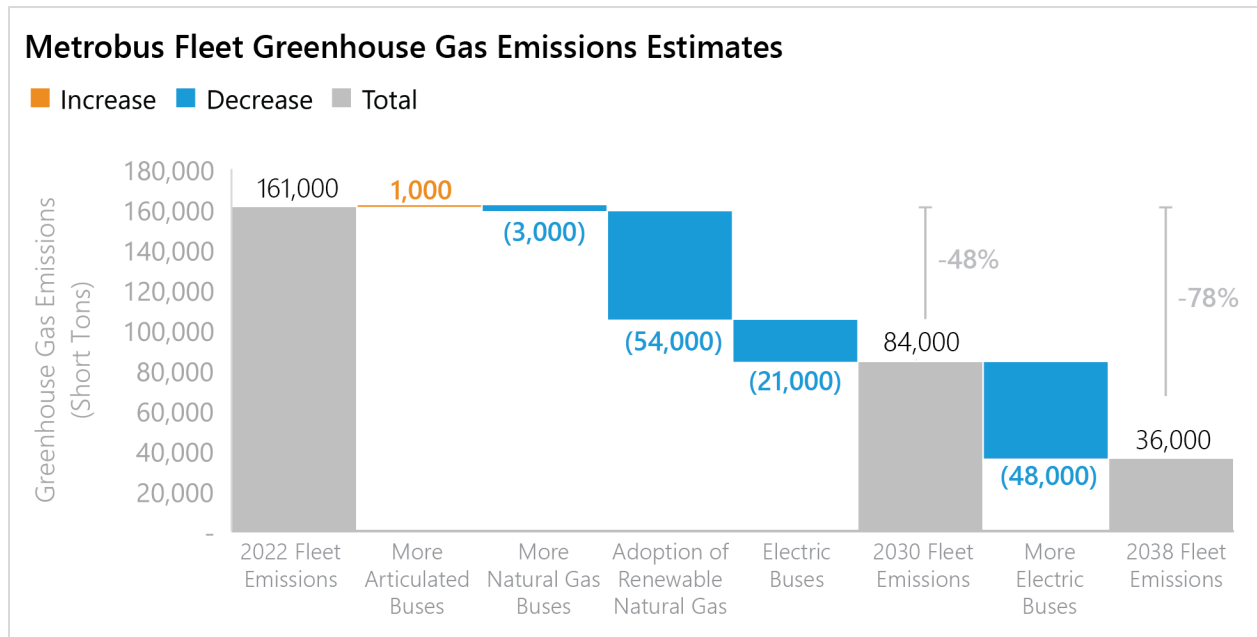
Metrobus currently operates a mixed fleet of compressed natural gas (CNG), diesel, and hybrid buses with one electric bus. Metro plans to shift its new procurements to electric and CNG buses with a transition to purchasing all electric buses by FY2030. Table E-1 outlines the projected procurement approach, by fuel type, outlined in this fleet plan. Metro plans to remain flexible in its procurement plans as facility support capacity and technology performance continue to evolve in the coming years.

Table E-1: Total Projected Bus Procurement by Fuel Type, FY2024-FY2038

Fuel Type	FY24–FY28	FY29	FY30–FY38
Compressed Natural Gas Buses Procured	75 per year	50 per year	0 per year
Electric Buses Procured	25 per year	50 per year	100 per year
Total Buses Procured	100 per year	100 per year	100 per year

This schedule will require facility conversion to support electric buses, which includes dedicated charging, systems, and electric utility support. CNG buses emit fewer local air pollutants and greenhouse gases than traditional diesel buses and additional improvements in emissions may be realized through the use of renewable natural gas sources. The estimated greenhouse gas emission impacts of this strategy are shown in Figure E-1.

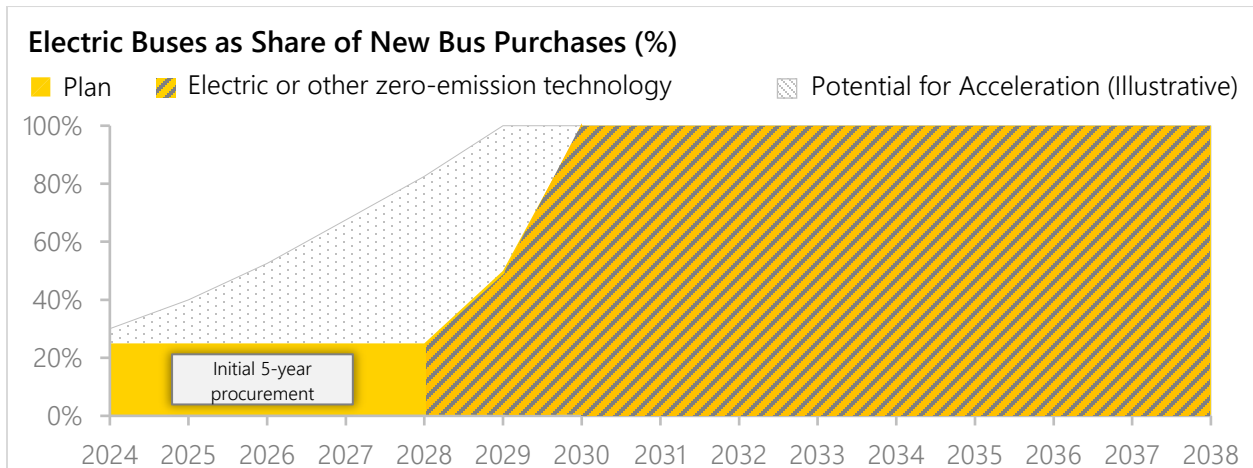
Figure E-1: Estimated Annual Metrobus Fleet Greenhouse Gas Emissions, Selected Years



Metro plans to adapt the pace of its conversion to electric buses in response to the progression and maturity of vehicle technology as well as the availability of the funding sources required to meet anticipated capital costs. If electric or other zero-emission buses demonstrate performance on par with conventional vehicles in terms of annual hours or miles of service, reliability, availability, and range, it may enable a more rapid transition.

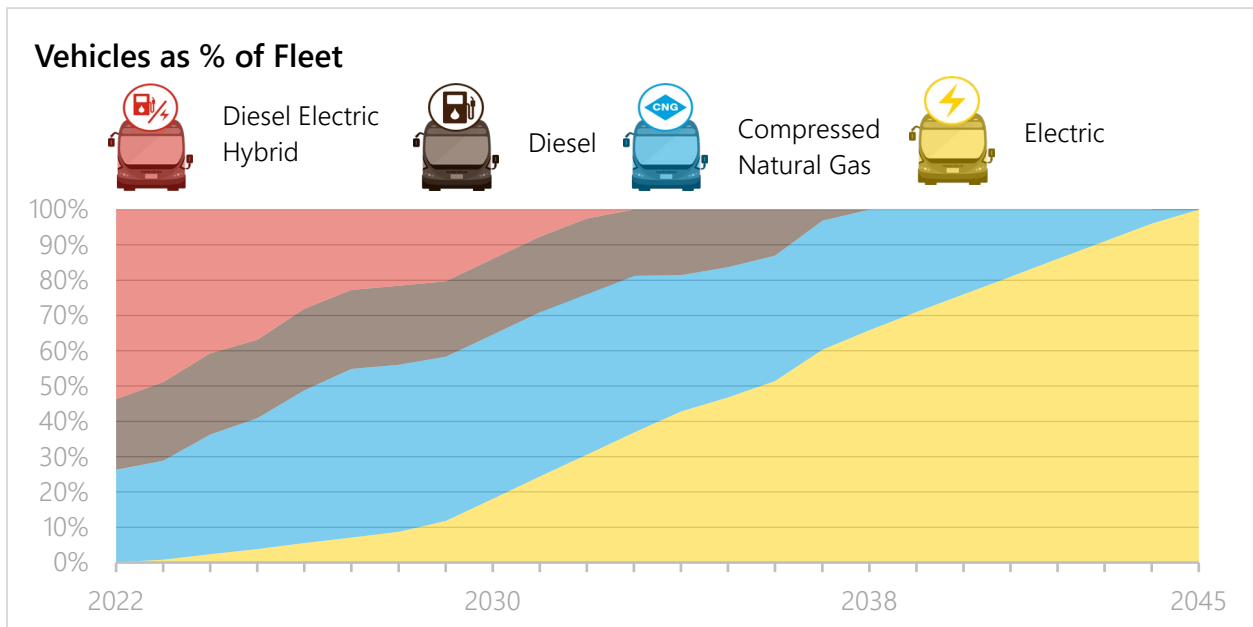
Figure E-2 demonstrates Metro’s planned procurement levels as well as an illustrative path for a potential expedited transition to electric or other zero-emission bus technologies.

Figure E-2: Electric Bus Procurement Paths, FY2024–FY2038



The projected long-term composition of the Metrobus fleet is shown in Figure E-3. With fleet procurement transitioning to the purchase of only electric buses by FY2030, the share of electric buses in the Metrobus fleet would increase steadily throughout multiple procurement cycles as other vehicles are retired.

Figure E-3: Projected Share of Vehicles in Metrobus Fleet by Propulsion Technology



Facility Capacity

Metro’s existing and programmed facilities will offer sufficient capacity to accommodate the planned increase in the size of the Metrobus articulated fleet—Metro will be able to house 324 articulated buses beginning in FY2027, upon the completion of reconstruction activities at Northern and Bladensburg Divisions. However, current Metrobus facilities and infrastructure are not sufficient to support the anticipated growth of the electric bus fleet. As a result, this plan has identified the facilities gaps expected through FY2038, and estimates the total number of facilities which will require conversion to accommodate these new vehicles. Table E-2 summarizes these capacity needs.

Table E-2: Division Needs, Existing and Planned Vehicle Capacity, Selected Years

	FY25	FY30	FY35	FY38
Electric Bus Storage Capacity	13	163	163	163
Electric Bus Fleet Size	63	288	785	1,048
Electric Bus Capacity Gap	50	125	622	885

In September 2021, Metro announced plans to reopen Northern Bus Garage with the infrastructure and equipment needed to operate 100% electric vehicles.¹ This facility’s 150-bus capacity will support the conversion of the Metrobus fleet to fully zero-emission technologies by 2045.

The average Metrobus operating division has a capacity of approximately 165 buses, with the smallest division having a capacity of 83 and the largest a capacity of 263. Starting in FY24 and continuing in FY25, Metro will require at least one additional partial facility conversion to accommodate the storage and fueling of its projected FY25 electric bus fleet size of 63 vehicles. The electric bus fleet will continue to grow over time, requiring the equivalent of five or more facility conversions by FY38.

¹ <https://www.wmata.com/about/news/First-all-electric-bus-garage-to-be-built-at-Northern-bus-facility.cfm>

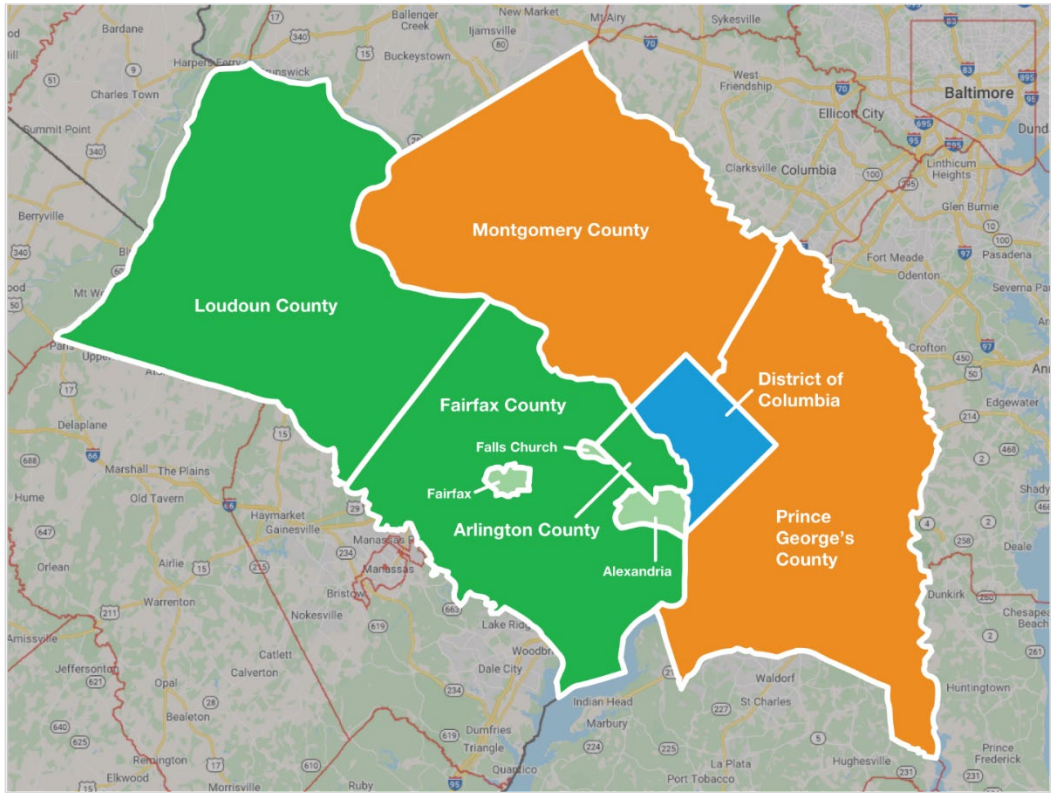
Section 1. Introduction

The Metrobus Fleet Management Plan documents the process and practices by which Metro establishes its current and projected Metrobus revenue vehicle fleet and facilities requirements. This planning document provides a system-wide analysis of Metro’s bus fleet size from FY2021 through FY2038, taking into consideration current and future ridership demand, policy goals, fleet supply, and capacities of the Metrobus maintenance programs and facilities.

1.1 System Overview

Metrobus is an essential fixture of the Washington metropolitan region’s transportation network. Created in 1973 through the consolidation of four private bus companies, the system now connects 2,417 street miles and a population of 3.9 million residents, carrying large volume ridership through major urban corridors as well as delivering riders to more remote destinations within a service area of 1,500 square miles.

Figure 1-1: WMATA Compact Area



The Metrobus service area encompasses the District of Columbia, Maryland's Montgomery and Prince George's counties, and Northern Virginia's Arlington and Fairfax counties and cities of Alexandria, Fairfax and Falls Church. Figure 1-1 shows the jurisdictions in which Metrobus operates.²

Operating 245 routes on 159 lines³, Metrobus reaches 10,687 bus stops.⁴ Many routes connect to Metrorail stations, facilitating transfers between modes. In FY2019⁵, Metrorail and Metrobus combined carried 284 million passenger trips, 104 million of which were on Metrobus⁶. As a result of the coronavirus pandemic, Metrorail weekday ridership declined by approximately 85% from December 2019 and December 2020; Metrobus ridership declined by about 50% during that same period, owing to the transit-dependent populations and essential workers that depend on Metrobus service. Within the Metro service area, more than 5% of residents either ride a Metrobus or use another local bus service to commute to work during the morning peak period. More than half the region's jobs are located within a half mile of a Metrorail station or Metrobus stop. Metrobus's reasonably priced, flexible service is accessible to people with disabilities, and all vehicles provide bike racks.

Metro is responsible for 11 operating and maintenance divisions and one maintenance-only division that service the fleet. The four divisions located in the District of Columbia accommodate 38% of all vehicles, while the four in Maryland service 38%, and the three in Virginia service 24%.

Two new operating divisions were recently constructed and opened for Metrobus service. Cinder Bed Road Bus Garage in Northern Virginia was opened to revenue service in 2018, followed by Andrews Federal Center Bus Garage in Prince George's County in 2019. A new Compressed Natural Gas (CNG) fueling facility is also under construction and will open at Shepherd Parkway Division in approximately FY2023.

Northern Division was closed to all operations and maintenance activity in 2019 for a full reconstruction and retrofit. Upon its reopening in approximately FY2026, Northern will have the infrastructure and equipment needed to run 100% electric vehicles. This facility will also have the capacity to support up to 75 articulated buses.

² Although Loudoun County has joined the WMATA regional compact in anticipation of the opening of the Silver Line Phase 2 extension to Ashburn, the only Metrobus route to serve the county at this time is Route 5A within Dulles International Airport. Before the B30 route was permanently discontinued in 2020, Metrobus also previously served Arundel Mills and the Baltimore-Washington International Airport in Anne Arundel County, Maryland.

³ Prior to the coronavirus pandemic.

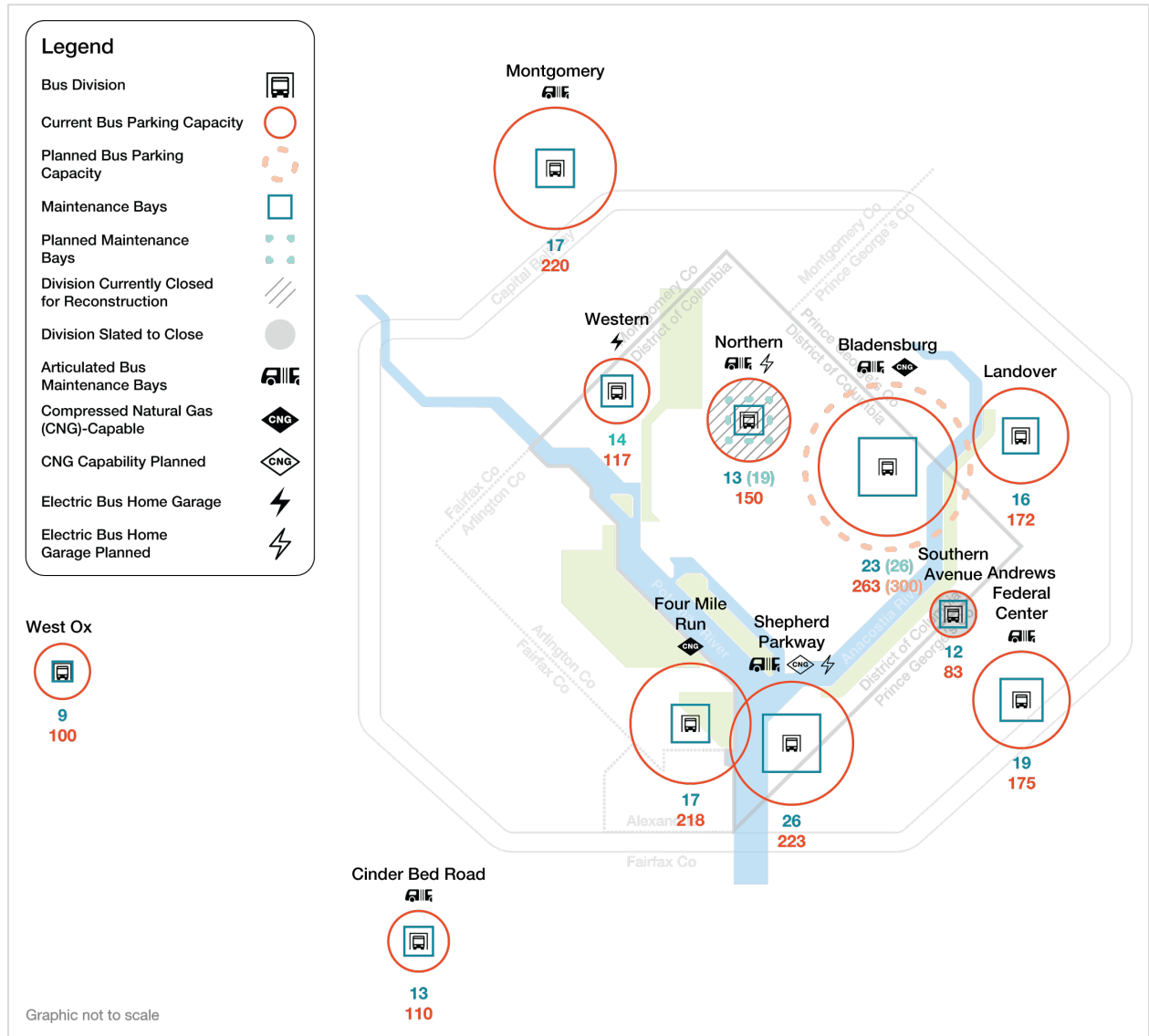
⁴ Source: Metro FY2021 Budget https://www.wmata.com/about/records/public_docs/upload/FY2021-Approved-Budget_Final-2.pdf

⁵ Metro's fiscal years begin on July 1 and conclude on June 30 of the following calendar year.

⁶ Farebox ridership estimates provided from Metrobus Ridership Date Portal on December 15, 2020. <https://www.wmata.com/initiatives/ridership-portal/>

Bladensburg Division is also undergoing major reconstruction to expand its capacity by approximately FY2027. Unlike Northern, the division has not closed and has maintained operating and maintenance capability during construction. When the reconstruction efforts at Northern are complete, Southern Division is expected to close in approximately FY2026, though these plans have not been finalized. Metro's operating divisions and their respective functions are shown in Figure 1-2.

Figure 1-2: Metrobus Operating Divisions



1.2 Overview of Metrobus Fleet

As of the end of FY2021, the Metrobus fleet consists of 1,557⁷ vehicles, as shown in Table 1-1. The total fleet number includes 1,270 buses scheduled for the provision of peak service, with remaining vehicles utilized for maintenance, reserve service and other contingency purposes. The exact size of the Metrobus fleet contracts and grows slightly over time as vehicles undergo maintenance, new vehicles are procured, and older vehicles are retired.

Table 1-1: Metrobus Fleet Count by Facility⁸

Division	Fleet Count
Bladensburg	272
Shepherd Parkway	221
Western	127
Andrews Federal Center	169
Landover	176
Montgomery	215
Southern Avenue	88
Cinder Bed Road	54
Four Mile Run	218
West Ox ⁹	-
Carmen Turner Facility ¹⁰	17
Total	1,557

1.3 Bus Transformation Project

The Bus Transformation Project was initiated to prioritize and improve bus service. In September 2018, a task force of strategic planning leaders from Metro and other organizations in the public, private, and nonprofit sectors gathered input from the public and developed a ten-year Action Plan for improving the speed, frequency, reliability, accessibility, and affordability of bus service.

⁷ Metro's active fleet size, which includes active buses required for peak service and scheduled headway management, spare buses for operating continuity, maintenance, and special projects.

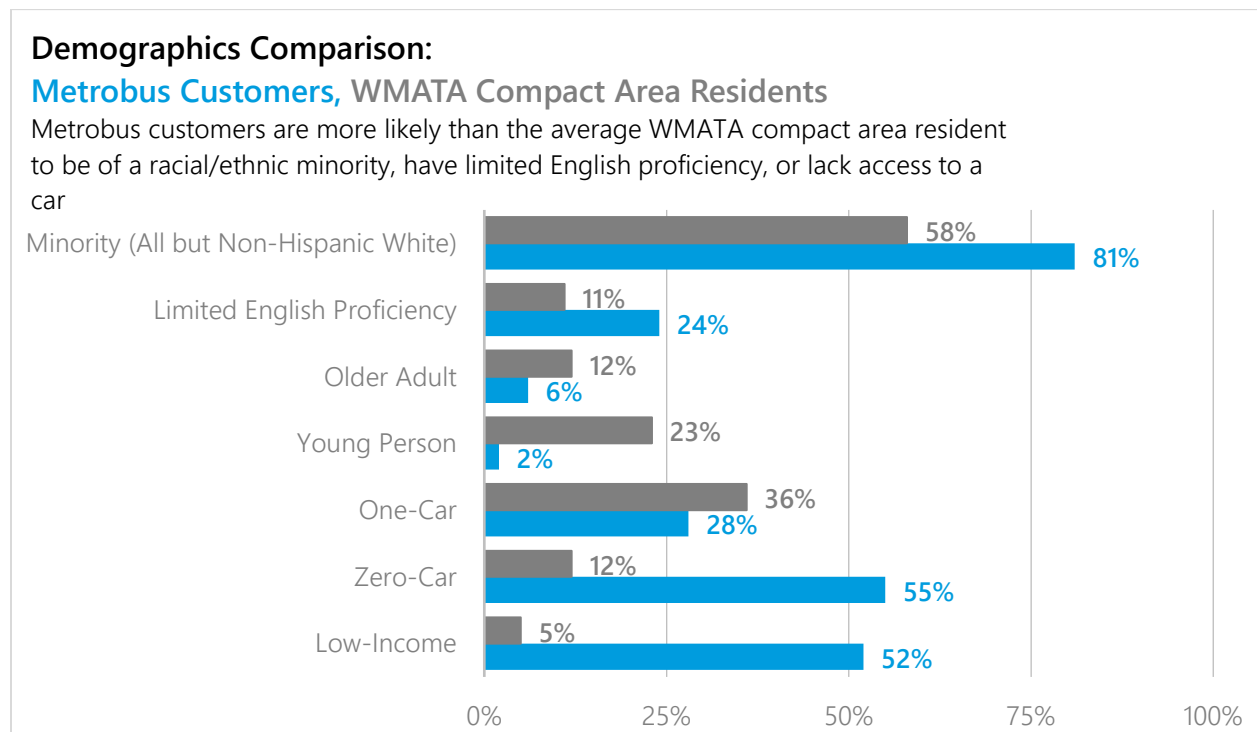
⁸ As of July 1, 2021. Due to operational requirements, divisions may exceed listed capacity in some cases.

⁹ In March 2021, Metro announced the temporary closure of its West Ox facility to allow for streamlined operations, reduced costs, and improved efficiency. <https://www.wmata.com/about/news/Metrobus-service-changes-March-14-21.cfm>

¹⁰ Training vehicles and vehicles undergoing specific maintenance or overhaul activities may be assigned to the Carmen Turner Facility.

Bus ridership has declined and travel speeds have slowed¹¹ as the region’s buses have continued to compete with personal cars and ride-hailing vehicles for road space and curb access. Declining bus speeds have disproportionately impacted low-income and non-white area residents, who comprise the majority of Metrobus customers. Particularly affected by these impacts on bus service are the 55% of Metrobus riders who do not own a car and, therefore, rely on bus service as a primary mode of transportation.

Figure 1-3: Demographic Comparison of Metrobus Customers and WMATA Compact Area Residents¹²



The Bus Transformation Project’s Strategy establishes five goals to guide the improvement of bus service: regional connectivity, rider experience, financial stewardship, sustainability, and equity. It recommends 26 tangible actions be taken to achieve these goals. The Action Plan specifies which regional stakeholders will be involved in executing each of the Strategy’s actions and plans each initiative’s completion over the course of a 2020–2030 timeline.

¹¹ Source: Washington Area Bus Transformation Project. <https://bustransformationproject.com/wp-content/uploads/2018/11/Bus-Transformation-Project-White-Paper-1.pdf>

¹² Source: Washington Area Bus Transformation Project. <https://bustransformationproject.com/resources/the-bus-system-and-its-riders-today/>

Metro's Board officially endorsed the vision of the Bus Transformation Project and resolved to pursue actions, including:

- Directing the incorporation of Bus Transformation Strategy recommendations in Metro's budgeting and planning;
- Directing Metro staff to coordinate bus service with other regional operators to implement these strategic recommendations and improve the unification of regional bus service;
- Recognizing the importance of implementing bus priority interventions such as Bus Rapid Transit (BRT) and bus-only lanes;
- Utilizing project recommendations as guidance for establishing Metrobus service standards, defining cost allocation, and shaping the customer experience.

Some initiatives that align with the priorities articulated in the Bus Transformation Project Strategy are already underway. Metro and the jurisdictions are partnering to improve bus service for riders and the region. In September 2021, Metro implemented more frequent, all day service at 12- to 20-minute headways or better on 36 of the most-used bus lines. Fare changes included free transfers between rail and bus and a cheaper weekly bus pass.

Regional jurisdictions have also partnered with Metro to coordinate implementation of Bus Priority that will improve the speed and reliability for buses. Virginia, the District, and Maryland are all implementing dedicated bus lanes, and working with Metro to implement transit signal priority, queue jumps, and violation detection and enforcement policies.

Mobile fare payments using a virtualized SmarTrip card on Apple (iOS) and Android devices were made available to customers riding Metro and regional transit partner services in 2020 and 2021. The mobile initiative contributes to the Bus Transformation Project's goal of enhancing fare interoperability among regional transit providers, as well as its broader mission of making riding Metrobus easier and more appealing.

1.3.1 Bus Network Redesign

One of the recommendations of the Bus Transformation Project was to redesign the bus network. A growing number of transit agencies around the country have conducted network redesign processes to adapt their service to local land use, economic, and population changes. Many of these agencies have emphasized a high-frequency route network in their redesigns, as well as improved service for suburb-to-suburb trips. Metro has engaged in conversations with a variety of stakeholders on the scope and goals of a redesign of the Metrobus network and expects to initiate an effort in 2022. Any potential impact on fleet requirements is unknown at this time.

1.4 Organization of Report

This report is structured as follows:

Section 1: Introduction – This section briefly summarizes Metrobus operations and describes additional areas of fleet plan context.

Section 2: Ridership Demand – This section summarizes current ridership characteristics and projects ridership growth through 2038.

Section 3: Fleet Requirements – This section provides an analysis of the demand for revenue vehicles and projects the fleet size based on demand. The demand analysis assesses the actual number of buses needed to meet service demand on the current set of bus routes. This section also provides an overview of the performance and design measures Metro applies for network service evaluation and the current system performance and fleet requirements.

Section 4: Fleet Supply – This section addresses the supply of Metrobus revenue vehicles based on planned fleet procurements for the period FY20–FY28. It accounts for total buses to be owned by fiscal year, anticipated procurement, and vehicles available for service. It also outlines the current fleet composition by size, age and fueling technology and summarizes the Metrobus replacement and expansion program.

Section 5: Fleet Maintenance – This section identifies maintenance requirements to support the projected fleet size based on previous sections. It provides an overview of the fleet maintenance program and assesses the performance of the current Metrobus fleet.

Section 6: Facilities Capacity – This section summarizes existing and planned Metrobus facilities and their role in supporting Metrobus service operations. Section 6 also identifies anticipated gaps between existing capacity and future needs.

Appendices – These sections present additional data tables and information to supplement the sections of this document.

Section 2. Ridership Demand

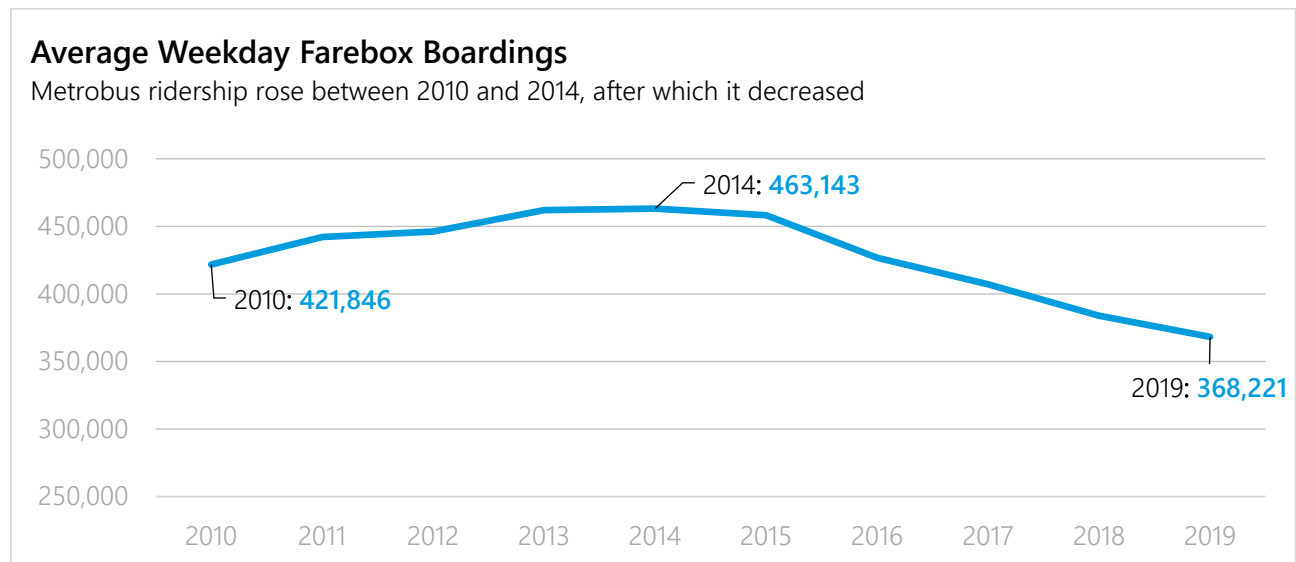
This section documents recent Metrobus ridership trends and Metro’s approach to determining future ridership on the Metrobus system. Section 3 will apply this forecast to the calculation of the number of vehicles that will be required to meet the demand.

2.1 Ridership Trends

In the early 2010s, bus ridership at Metro grew steadily, reaching a high point in 2014. After 2014, however, bus ridership began to decline. This trend mirrors others seen across the transit industry in the United States. Falling bus speeds, the growth of ride-hailing companies such as Uber and Lyft, demographic changes, low unemployment, low gas prices, and a rise in wages that has led to growing auto ownership among lower-income people are all factors which may influence these trends. Additional socioeconomic and demographic ridership data is included in the appendix of this document.

Figure 2-1 shows average weekday ridership from 2010 to 2019, including the increases in the first part of the 2010s and the declines in the latter half of the decade.¹³

Figure 2-1: Metrobus Average Weekday Farebox Boardings, May 2010–May 2019



The region—as defined by the Census Bureau—saw its population grow by nearly 12% between 2010 and 2019, during which time employment grew by an even greater rate of 15%. Since 2014, median incomes have increased by 16%, nearly twice the rate of inflation. While the number of households in

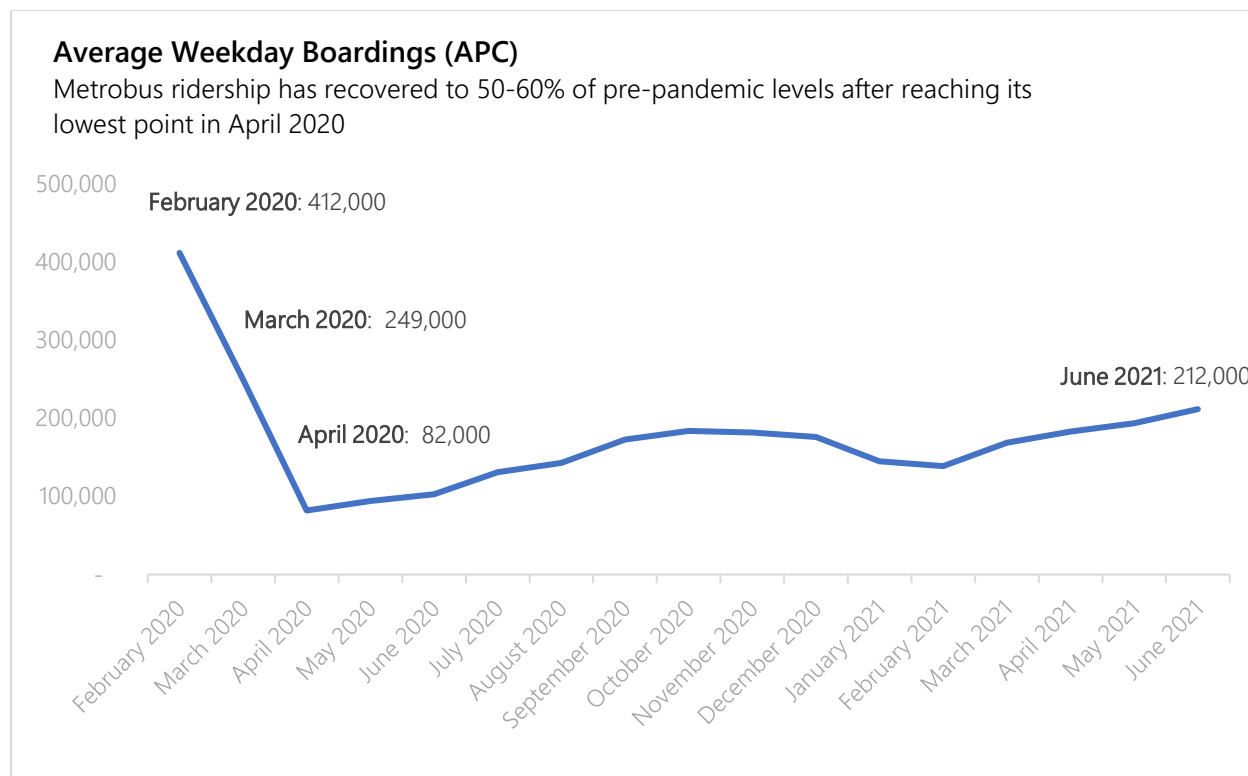
¹³ The figure shows farebox-based ridership trends that may not align with other ridership figures in this document as Metro did not obtain automatic passenger counters (APC) systems for the bus fleet until midway through this timeframe.

the region grew by 10%, the number of households with annual incomes of less than \$25,000—whose members make up a large portion of Metrobus ridership—fell by more than 14% over that same time period. The number of households with access to at least one vehicle grew faster than the total number of households between 2010 and 2019, and, while the number of “zero-car households” within the region remained around 210,000 throughout the decade, the percentage of households with access to a vehicle grew from 88.9% to 90.1%. These changes in economic conditions may have reduced the number of transit dependent people in the region.

The coronavirus pandemic caused Metrobus ridership to fall significantly in the spring of 2020. Ridership began to grow later in 2020 as businesses around the region re-opened. By December 2020, Metrobus ridership had recovered to about 50% of normal levels, with about 75% of normal service operating.

Figure 2-2 shows the impact of the pandemic on bus ridership. Metrobus ridership levels in January and February 2020 were higher than the same months in 2019, indicating a potential ridership recovery. However, ridership began to decline rapidly in March, with average weekday boardings dropping from 344,000 in February to 111,000 in April. Ridership climbed to 127,000 in May before ridership fell to its lowest level in June. Metrobus service was reduced to 50% or less of regular levels from mid-March through mid-August 2020. Average weekday boardings grew steadily through the summer and early fall, and restoration of bus services to about 75% of pre-pandemic levels in September 2020 supported a noticeable increase in ridership in late August. By fall 2021, Metrobus ridership had recovered to approximately two-thirds of pre-pandemic levels.

Figure 2-2: Average Weekday Boardings (APC), February 2020-June 2021



The ridership changes from the pandemic were uneven, with ridership retention correlated with high proportions of low-income and minority riders. Routes that mainly serve white-collar commuters had very low ridership, while weekend and evening ridership had higher retention rates than the weekday peaks. In general, ridership throughout the day had much less peak-period demand and more consistency through the day.

2.2 Ridership Demand Forecast

The Fleet Plan Forecast provides a basis for evaluating the potential need for changes to the size of the Metrobus fleet based on projected changes to future passenger demand. The methodology and inputs used to develop the forecast, the forecast results and adjustments that were made to the forecast are described in this section. The forecast is a key input to the fleet size estimates developed in Section 3.

2.2.1 Farebox and Automatic Passenger Counters

Metro has two main sources of bus ridership data. The first, farebox data, is recorded by the fare system when passengers pay their fares. In some cases, the bus operator presses a button on the farebox to record a boarding, such as for those who display certain flash passes and those who evade the fare. The button presses are also part of the farebox ridership data.

The other source is from the automatic passenger counters (APCs) at each doorway of the vehicle. These sensors record passengers boarding and alighting using infrared beams or overhead cameras. The sensors are imperfect, however, and the data must be cleaned and processed to produce estimates of the average boardings and alightings at a given stop or on a given trip.

Since 2015, Metro has been transitioning from the use of farebox data to APC data as the system of record for bus ridership. APC ridership estimates tend to run higher than farebox estimates by 15-30%, depending on route. This difference likely is due to unreported fare evasion, malfunctioning farebox equipment, and other factors. Metro's APC estimates have been validated against data collected by human checkers. The fleet plan ridership forecasts are adjusted to align with APC ridership estimates, and all ridership data presented in the plan, either actual past counts or future forecasts, are adjusted to align with APC estimates unless another source is noted.

2.2.2 Short-Term Ridership Forecast

The Short-Term Ridership Forecast (STRF) was developed by Metro's Office of Planning in 2018 to forecast ridership for Metrobus and Metrorail for FY2018-2023. Based on demonstrated ridership drivers such as changes in population, employment, fares, and service levels, the STRF estimates ridership for the AM Peak, PM Peak, Midday, Average Weekday, Saturday, and Sunday time periods for each month of the year. Two forecasts are provided: an upper bound and a lower bound. Bus routes and lines are grouped into corridors for ridership forecasting periods, with forecasts available for each of 91 bus corridors. The STRF is based on historical farebox ridership data and the forecasts are on a farebox basis.

The forecasts were updated with FY2019 data at the conclusion of the fiscal year; no update was made at the end of FY2020 due to the pandemic's impact on FY2020 ridership and data availability.

Due to changes in circumstances and ridership trends since the development of the forecasts, the growth rates in the STRF are overly optimistic for fleet planning purposes. Simply extending the growth rate for the last years of the forecast out to 2038 would generate a forecast of over 550,000 boardings per day. This scenario was deemed unrealistic given recent declines. Other forecasting methods were applied, as described in the next section.

2.2.3 TPB Forecasts and Travel Demand Model

The National Capital Region Transportation Planning Board (TPB) is the Metropolitan Planning Organization for the Washington region. TPB maintains regional long-range forecasts for land use, population, and employment, called the Cooperative Forecast. They also maintain a regional travel demand model. Based on round 9.1A of the Cooperative Forecast, version 2.3.78 of the regional travel demand model, and assumptions about changes in travel from the 2020 amendment of the Visualize 2045 plan, Metrobus ridership was forecasted for 2040. Bus ridership is modeled at the systemwide level.

Transit ridership in the regional travel demand model is usually somewhat higher than actual ridership, which required the steps outlined below for adjustment.

2.2.4 Metrobus Fleet Plan Forecast Approach

A hybrid approach was used to generate ridership forecasts at the corridor level for the bus fleet plan. The forecast was developed as follows:

1. Based on the annual growth rate from FY2019-2023, extend the upper bound Short-Term Ridership Forecast out to 2038 for each corridor and time period.
2. Calculate the annual growth rate implied by the 2020 and 2040 TPB model outputs.
3. Apply the TPB growth rate to the systemwide FY2023 ridership from the STRF, out to 2038.
4. Allocate this systemwide growth among the 91 bus corridors proportionally based on the projected growth on each corridor from step 1.
5. Adjust the forecasted ridership from a farebox to an APC basis.

This method uses the systemwide growth rate forecasted by the TPB regional travel demand model and applies it to a more accurate ridership baseline, while allocating the growth among different corridors based on the STRF model.

2.3 Adjustments to Fleet Plan Forecast

2.3.1 Adjustments for New Projects

Many projects and initiatives may have an impact on bus ridership during the period covered by this fleet plan. They include:

The Silver Line Phase 2 extension, extending the heavy rail line from Wiehle-Reston East to Ashburn via Dulles International Airport, is scheduled to open in 2022. As most local bus service in the area is operated by Fairfax Connector and Loudoun County Transit, little impact on Metrobus ridership is expected.

The Purple Line, owned by the Maryland Department of Transportation Maryland Transit Administration (MDOT MTA), is a light rail line currently under construction from New Carrollton to Bethesda. Metro's Office of Bus Planning is conducting a study on the impact to local bus service; changes are not currently expected to have an impact on fleet expansion or contraction.

Bus priority efforts continue to expand around the region, including transit signal priority, bus stop consolidation, queue jumps, and dedicated bus lanes. These projects may both increase ridership, increasing fleet needs, and decrease running times, potentially reducing fleet needs. At this time, no direct impact to the fleet plan is anticipated from these interventions.

Bus Rapid Transit. Several projects planned for the region aim to add bus rapid transit and other high-quality transit services that are separate from Metrobus service. For example, MCDOT's Flash

BRT service on US 29 in Montgomery County began in the fall of 2020, potentially reducing demand for Metrobus service along the corridor. The impact of these projects will be studied over time.

Adjustments to individual bus routes affected by these projects were reviewed to determine whether they would have any impact either on the number or the composition of the bus fleet. The uncertainty of the status and timing of many of these projects presents challenges in determining whether, when, and to what degree their implementation would impact ridership and demand for vehicles. For this reason, it was determined that the ridership forecasts would not be adjusted to address these projects at this time. Metro will regularly review the potential fleet implication of these and other projects to determine whether they would result in any future impacts in the number, type, and distribution of buses in the system.

2.4 Metrobus Fleet Plan Forecast

Systemwide, the forecast projects that Metrobus ridership will increase by approximately 4.2% from 2019 to 2038, an annual rate of 0.23% annually through 2038. Ridership is projected to increase by about 19,000 daily trips, from about 425,000 weekday boardings in 2019 to 444,000 by 2038. The unaltered Fleet Plan forecast is shown in Table 2-1.

Table 2-1: Average Weekday Ridership for 2015–2019 and Unaltered Ridership Estimate Based on Fleet Plan Forecast for 2020–2038¹⁴

Year ¹⁵	Weekly Boardings (APC)
2015	549,428
2016	513,450
2017	480,516
2018	411,566
2019	425,104
2020	426,067
2021	427,031
2022	427,998
2023	428,967
2024	429,939
2025	430,912
2026	431,888
2027	432,866
2028	433,846
2029	434,828
2030	435,813
2031	436,800
2032	437,789
2033	438,780
2034	439,773
2035	440,769
2036	441,767
2037	442,767
2038	443,770

¹⁴ 2015–2018 Source: 2015–2018 Spring Pick average weekday. 2019 Source: May 2019 Average Weekday. 2019 Spring Pick average weekday was 403,061. 2020–2038 Source: Estimated average weekday forecast (without coronavirus impacts) based on estimate of annual rate of ridership increase between 2019 and 2038 (0.23%), derived from Fleet Plan Forecast.

¹⁵ 2020–2038 Source: Estimated average weekday forecast (without coronavirus impacts) based on estimate of annual rate of ridership increase between 2019 and 2038 (0.23%), derived from Fleet Plan Forecast.

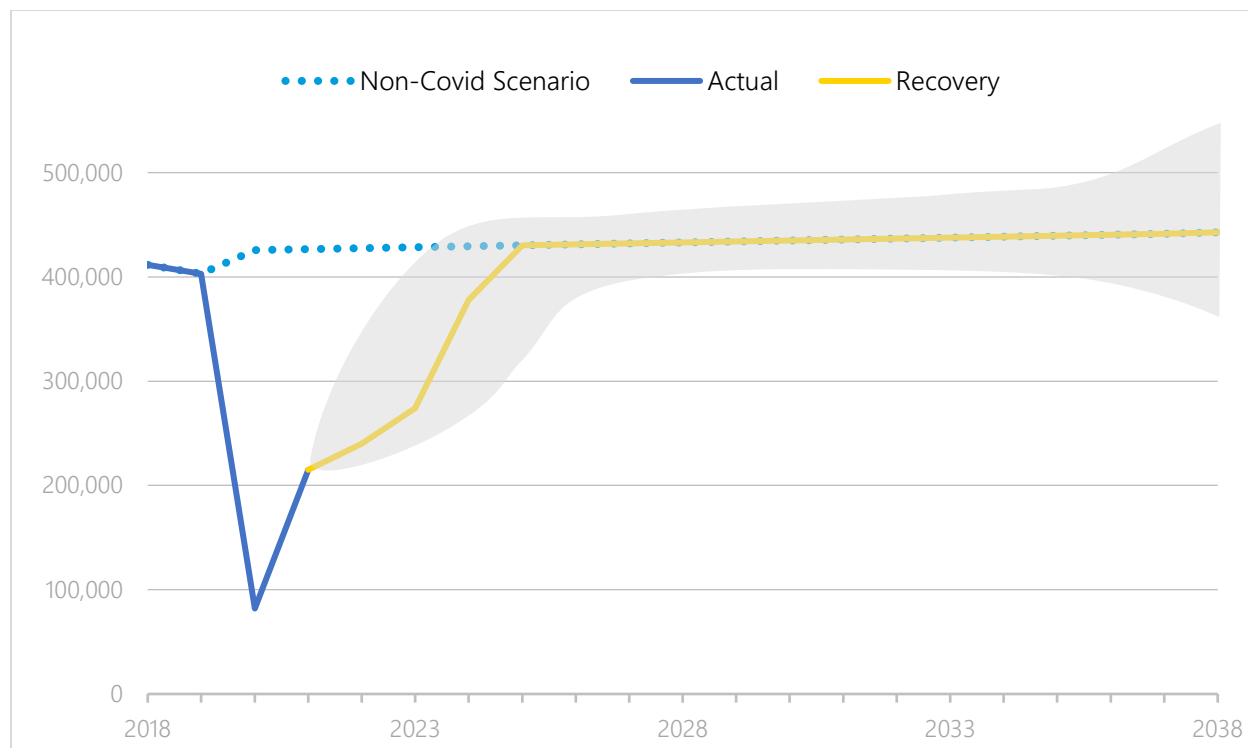
The forecast, adjusted to reflect recovery from the coronavirus pandemic, is shown in Figure 2-3. From a baseline of 2019 levels, ridership is shown having fallen in 2020 due to the pandemic. This figure also illustrates uncertainty in the path to ridership recovery.

The Fleet Plan forecast projects Metrobus network weekday ridership to grow by about 4.4 percent, between 2019 and 2038, but projected ridership changes vary considerably among the corridors. Nineteen corridors are projected to grow by more than 10% over the time period, with Lee Highway routes (3A and 3Y) growing by nearly 42% and Eastern Northern Virginia Routes (8S, 8W, 8Z and 11Y) growing by more than 38 percent. Corridors with the highest growth rates typically have relatively low existing ridership (fewer than 2,000 weekday passenger trips). The projected ridership change and percentage change for each corridor is shown in the appendix. Metro will continue to monitor ridership levels throughout the system, and service planning will not be based exclusively on these forecasts.

2.4.1 Adjustments for Pandemic Recovery

The fleet plan has been developed based on the assumption that ridership eventually will return to the pre-pandemic trajectory, and no adjustment is made for the later years of the forecast to account for long-term ridership impacts of the coronavirus pandemic. In the short term, however, the pace of ridership recovery is uncertain. Figure 2-3 depicts anticipated ridership recovery, with the shaded area intended to illustrate the uncertainty associated with this forecast. Metro's long-term planning assumes eventual recovery but will be revisited in coming years.

Figure 2-3: Metrobus Forecasted Average Weekday Ridership



2.4.2 Long-Term Ridership Forecast Summary

Ridership forecasts at both the system and corridor levels are critical to determining whether ridership change will influence demand for vehicles during the life of the plan. Metro’s Fleet Plan Forecast anticipates modest incremental growth in Metrobus ridership through 2038.

The forecast, which was prepared before the coronavirus pandemic, assumes a moderate rate of ridership growth. This projection is supported by recent ridership recovery, forecast growth in population and employment in the Washington metropolitan area, and other transit-supportive trends documented in the forecast model. Increasing fuel prices, environmental regulation, and transit’s potential to help address pollution and greenhouse gas emissions are further factors supporting future ridership growth.

Ridership growth is forecast to be uneven across the system, with robust growth in some corridors and minimal growth or ridership loss in others. Changes to ridership patterns in response to the Silver Line Extension, Purple Line project, and other transit corridor improvements and developments in the region, as well as the anticipated transit network redesign project, may impact ridership system wide and in specific corridors in the coming years.

Section 3. Fleet Requirements

Metro's planning efforts involve ensuring the availability of enough buses to meet anticipated ridership demand and service guidelines. Fleet size is determined largely by the headway and travel time on each route during the period of highest passenger demand (the PM peak period on most Metrobus routes). The number of buses required to operate a route is calculated by dividing the round-trip running time (including recovery time) by the headway. However, passenger demand and service guidelines determine where and when Metrobus routes will operate and at what headway. Routes that do not meet minimum service guidelines for crowding, service reliability, or service frequency may require more vehicles to provide sufficient capacity to meet those guidelines. Other guidelines establish the number of spare buses needed to support the fleet's ability to deliver service.

Demand for fleet size has been estimated by applying the ridership forecast from Section 2 and Metro's service guidelines for crowding, service reliability, and maximum headway to Metro's Fall 2019 operations. This section also evaluates the potential for increasing the size of Metro's articulated bus fleet to address crowding on key Metrobus routes, before reviewing the factors considered in evaluating potential Metrobus fleet expansion in the coming years.

3.1 Metrobus Service Guidelines

Metrobus Service Guidelines, adopted by the Metro board in December of 2020¹⁶, provide technical guidance for service planners in evaluating and planning services. The guidelines classify Metrobus routes into five major categories: Bus Rapid Transit (BRT), Framework, Coverage, Commuter, and Gap service. Routes also are classified by activity tier, based on the combined population and employment density of the areas that the route serves. The guideline standards that apply to routes differ according to the route's service classification and activity tier. Some guidelines also differ by time of day (AM and PM peak, mid-day, evening, etc.) and day of week (weekday/Saturday/Sunday). The five classifications are described below.

3.1.1 Bus Rapid Transit (BRT)

BRT involves the strategic application of coordinated strategies for design of routes, services, facilities and technology. BRT systems can include dedicated lanes; high-frequency service; simplified route structure; branded, dedicated, and higher-capacity vehicles; fewer stops than conventional bus routes and improvements at stops; off-vehicle fare collection; and other systems and technologies to improve bus operating speed and reliability.

3.1.2 Framework Service

Framework services are defined as local bus lines that provide direct alignments following key arterial corridors. Framework services also include potential future limited stop Metrobus services. Radial, crosstown and emerging corridor services are included in this category.

¹⁶ <https://www.wmata.com/initiatives/plans/upload/Final-MetroBus-Service-Guidelines-2020-12.pdf>

3.1.3 Coverage Routes

Coverage routes operate within neighborhoods, connecting to a nearby major routes and modes at a transit hub such as a Metrorail station. Circulating in local neighborhoods and connecting to nearby generators is the main focus of services under this category.

3.1.4 Commuter/Express Service

The services under this category are defined to operate between a residential area or park-and-ride and a business district or Metrorail station, or between a central business district and a peripheral employment area. These routes are designed to have one or more pickup locations in close proximity to each other before operating non-stop, often via a highway, to one or more destinations. Peak direction services connecting park and rides or neighborhoods to major employment center, reverse commute services operating from central areas to suburban employment centers and airport services fall under this category.

3.1.5 Gap Service

Gap service routes are operated for specific purpose to meet specific transit needs that cannot be met by Metro's more general bus and rail services. Examples include routes that serve a school, workplace or other destination with specific, focused demand; a shuttle replacing rail service during overnight hours, when rail service is not operating, or a route with its schedule tied to the operating hours of a specific tourist attraction. Gap service routes are designed to fit the needs of the situation and are not governed by standardized guidelines.

3.1.6 Activity Tiers

Metrobus routes are classified into one of three activity tiers based on the combined population and employment density of the areas served by the route. Combined population and employment density are commonly used as a measure of the accessibility and transit friendliness of development and the capacity of an area to support various levels of transit service. The three activity tiers are ranked by the percentage of bus stops along the route that have a combined population and employment density greater than 25 persons and/or jobs per acre. Tier 1 routes are those on which more than 50% of stops are surrounded by combined population and employment density greater than 25 persons and/or jobs per acre. This level of density surrounds between 15% and 50% of the stops along Tier 2 routes, and less than 15% of stops along Tier 3.

3.2 Peak Vehicle Requirement

Metro's peak vehicle requirement (PVR) is the maximum number of vehicles that Metro regularly deploys in service, excluding spare vehicles and vehicles set aside for other purposes. PVR is driven by Metro's peak level of passenger demand during weekday afternoon periods (Metro's highest demand period). Metro's PVR in December 2019 was 1,270 vehicles. Service volume on most Metrobus routes is demand driven, which requires monitoring and matching of service frequency and capacity to passenger demand. During weekday peak periods on most routes, and during other periods on the system's busiest routes, Metro's service frequencies are calibrated to provide capacity to support

passenger loading patterns. This enables Metrobus service to consistently meet passenger demand and ensures passenger comfort. Routes that consistently experience crowded conditions or lateness, as defined by Metro's service guidelines, are evaluated by Metro planners for possible changes to address these issues.

Possible changes to address crowding and late running include adjusting link running times (running times between scheduled time points), converting the route to articulated bus operation (which increases capacity while minimally increasing operating and maintenance costs), reducing the route headways (increasing service frequency) and increasing link travel time. Reducing headways or increasing travel time increases service volume (hours and miles of service) and may increase the number of vehicles required to operate the route. The implementation of additional bus priority corridors and measures by jurisdictions in the region represent an integral component of resolving these items as well.

Service levels during other periods are driven by established maximum headway guidelines. Weekday evening, night, and mid-day service as well as weekend services on many routes have fewer riders and operate policy maximum headways. New service initiatives, such as new routes or route extensions, often also operate policy maximum headways for a trial period as demand develops.

3.2.1 Fleet Sufficiency Analysis

Metro's service planners regularly monitor its performance and make service adjustments to address system deficiencies and enhance efficiency. Adjustments that result in changes to service volume often require increasing or reducing the number of buses on select lines. This can result in changes to the overall size and composition of the bus fleet.

This fleet plan uses the Metrobus Service Guidelines for evaluating services. The guidelines provide revised performance measures and target values for reviewing operations and monitoring service at the route, corridor and network levels. Productivity, reliability and level of crowding are the three key performance measures used by Metro.

Productivity measures how effectively the resources devoted to route operations are used, typically by calculating the number of boardings per hour, per mile, or per trip. Lines that have high productivity, carrying a relatively large number of boardings per unit of service, are potential candidates for service expansion, which could increase the number of peak vehicles required on that line or route.

Reliability is a critical service quality measure for customers, reflecting customers' expectation for on-time bus arrival and on-time completion of a bus trip. Bus lines with poor service reliability, particularly ones whose end-to-end travel time is regularly longer than the scheduled travel time during some or all periods, may require additional service volume to increase their scheduled running time. In most cases, this added time could not be provided without adding buses to the line.

Level of crowding is another service quality measure from a customer’s perspective, based on the customer’s reasonable expectations of comfort and safety on board the bus. Lines that experience regular overcrowding may require additional capacity, provided by operating more buses to provide more frequent service and/or longer running times, and/or the substitution of articulated vehicles on the route. These changes could lead to the need for additional buses, or articulated buses, on the route. Any changes to service volumes or vehicle type across Metro’s dozens of bus lines could result in a change in the number of vehicles in the fleet, as well as a change in the number of vehicles of each type in the fleet.

Metro’s service guideline for maximum headway ensures that each route provides at least a set service level during each period of the day. The maximum headway guideline is based on the route’s service classification and service tier, and varies by time of day, with shorter headways recommended for peak periods.

Each route that operated in Fall 2019 was analyzed to determine the potential need for additional vehicles based on crowding, service reliability, or maximum headway deficiencies during the PM peak period. The analyses determined that 68 Metrobus routes could require one or more additional vehicles to meet deficiencies in meeting Metro’s service reliability, crowding, and/or maximum headway guidelines based on their performance in in Fall 2019, with some routes deficient in more than one guideline. Nineteen routes would need one or more additional vehicles to address service reliability (late running) based on 2019 operations and ridership. These routes are listed in Table 3-1.

Table 3-1: Routes with Less than 69% of Departures Early or On-Time (“Not Late”) during PM Peak Period, Fall 2019

Route	Percent Not Late (2019)
17B	43.4%
7Y	49.6%
R2	50.6%
W8	51.7%
R1	52.7%
C4	52.8%
17M	52.9%
J4	53.2%
H6	55.5%
B8	55.7%
W6	56.4%
C2	57.9%
T14	58.4%
29N	59.4%
H1	59.7%
P12	60.8%
K6	61.0%
S4	61.3%
S2	63.0%

Eight routes likely would require at least one additional bus to address crowding based on 2019 operations and ridership patterns. These eight routes are listed in Table 3-2.

Table 3-2: Routes Experiencing Crowding (100% Seated Load) During One or More Peak Hour, in One Direction, Fall 2019¹⁷

Route	Division(s)	Jurisdiction(s)
30S	Andrews	MD
30N	Andrews	MD
V2	Southern	MD, DC
11Y	Four Mile	VA
W1	Shepherd	DC
54	Western	DC
79	Montgomery	DC, MD
S9	Montgomery	DC

Six additional routes would require at least one additional bus to meet crowding requirements by 2038 due to increased ridership. Table 3-3 lists these routes and the year in which the analysis indicated that ridership growth would prompt the need for more capacity on the route.

Table 3-3: Routes Projected to Experience Crowding (100% Seated Load) During One or More Peak Hour, in One Direction, Through 2038¹⁷

Route	Year	Division(s)	Jurisdiction(s)
42	2035	Western	DC
70	2037	Montgomery	MD
3Y	2038	West Ox	VA
8W	2031	Four Mile	VA
8Z	2026	Four Mile	VA
S4	2036	Montgomery	DC, VA, MD

Forty-three routes would require at least one additional bus to reduce headways to levels below Metrobus peak period maximum headway guidelines for their assigned service class and activity tier. These routes are listed in Table 3-4.

¹⁷ Metro’s service guidelines call for a maximum peak load factor of 120% of a seated load on BRT, Framework, and Coverage routes, and 100% on other route classes. A capacity of 100% was applied to simplify the analysis, and because routes that experience 100% loads over an hour in the peak period most likely experience 120% loads for some periods during that hour.

Table 3-4: Routes Operating Greater than Specified Maximum Headway during Fall 2019 PM Peak Period¹⁸

Route	Division(s)	Jurisdiction(s)
32	Andrews	DC
34	Andrews	DC
36	Andrews	DC
39	Andrews	DC
83	Landover	MD
86	Landover	MD
10A	Four Mile	VA
10B	Four Mile	VA
10E	Four Mile	VA
16A	Four Mile	VA
1A	West Ox	VA
1B	West Ox	VA
1C	West Ox	VA
22A	Four Mile	VA
23B	Four Mile	VA
23T	Four Mile	VA
26A	West Ox	VA
29K	Cinder Bed	VA
29N	Cinder Bed	VA
2B	West Ox	VA
30N	Andrews	DC
30S	Andrews	DC
7A	Four Mile	VA
7F	Four Mile	VA
A7	Shepherd	VA
C4	Montgomery	MD
C8	Montgomery	MD
D12	Andrews	DC
D13	Andrews	DC
D14	Andrews	DC
H2	Bladensburg	DC
H4	Bladensburg	DC

¹⁸ Further analysis at the line level would identify whether service is inadequate on a line by line basis.

Route	Division(s)	Jurisdiction(s)
J4	Montgomery	MD
K9	Bladensburg	DC, MD
NH2	Shepherd	DC
Q4	Montgomery	MD
R1	Bladensburg	DC, MD
R12	Landover	MD
V2	Southern	DC
X9	Bladensburg	DC
Y2	Montgomery	MD
Y8	Montgomery	MD
Z6	Montgomery	MD

Many of these routes could require multiple additional buses to meet Metro’s maximum headway guidelines during the PM peak period. Fleet adequacy analysis indicated that the 43 routes requiring additional buses to meet headway guidelines could require as many as 130 additional vehicles, with some routes requiring as many as eight additional buses to meet the maximum headway guidelines during the afternoon peak period.

Assuming the service reliability and crowding issues could be resolved by adding just one vehicle to each route identified in those analyses, 155 additional vehicles would be required (seven of the routes that have deficient headways also are listed among routes that require vehicles to address either service reliability or crowding), in addition to 30 spare vehicles (assuming a spare ratio of 19.5%).

3.2.2 Articulated Bus Fleet Considerations

Converting routes to articulated buses is an effective method of adding frequency to increase capacity on high volume, crowded routes. Articulated buses have 50% more seating and standee capacity than standard buses, but their operating cost is only slightly higher, because the largest part of the operating cost—the cost of the bus operator—is the same for both articulated and standard vehicles. Articulated buses also are helpful for adding capacity on corridors and routes where the headways already are so short that reducing them further is likely to result in bus bunching. Of note, articulated buses are not able to operate on all routes due to their length. Articulated buses do incur higher maintenance costs due to their increased size and mechanical complexity.

At the start of FY21, Metro had approximately 66 articulated vehicles in operation out of a total fleet size of over 1,500, an articulated bus fleet percentage of about 4%. A peer comparison analysis found that many other large urban transit agencies operate a higher percentage of articulated vehicles. Metro had the second lowest number of articulated buses among its peer group of large bus operators in 2018 (Table 3-5). While Metro’s decision making is not driven solely through this analysis, this review

offers helpful insight into potential expansion levels to study. The larger capacity of articulated buses means that agencies can increase peak and all-day capacity, addressing a significant share of customer crowding, with even a relatively minor increase in the proportion of articulated buses in the fleet.

Table 3-5: Articulated Bus Fleet Share at Metro and Peer Agencies¹⁹

Peer Agency	% Articulated
King County Metro	55%
New York City Transit	19%
Chicago Transit Authority	16%
Los Angeles County Metropolitan Transit Authority	16%
Southeastern Pennsylvania Transit Authority	13%
Miami Dade Transit	11%
Massachusetts Bay Transit Authority	10%
Maryland Mass Transit Administration	7%
Washington Metropolitan Area Transit Authority	4%
Metro Atlanta Rapid Transit Authority	3%

Five performance metrics were considered when identifying potential routes to be assigned articulated vehicles. The exact number of articulated buses in each considered scenario was partially determined by the number of articulated buses required to deliver service on the routes which most closely met the following criteria:

Completing articulated bus conversion of existing routes: Some routes not fully converted to articulated bus operation due to a shortage of articulated vehicles. Given the risk of unbalanced loads on the routes during peak period, converting these routes to articulated bus operations is a high priority.

Ridership: High passenger volume during peak periods are a key indicator of the desirability of articulated vehicles.

Service Frequency: Average number of trips per hour during the PM and AM peak periods. Routes meeting this criterion were already operating more than six trips per hour (10 minutes or headway or shorter) in 2019.

¹⁹ Source: Peer agency documents and National Transit Database information.

Crowding: Percentage of running time over 100% or 120% of capacity, depending on time of day and route service classification. Adding capacity is the most direct approach to relieving crowding on routes.

Schedule Reliability: Percentage of time points departed “not late” (including on-time and early departures, based on the assumption that Metro’s early departure statistics are overstated). Metro’s on-time performance guideline is 79% on-time operation. However, the standard was adapted to “not late” to address likely over-counting of early departures. Crowding and load imbalances, which are relieved by adding capacity, often are the cause of late running.

This fleet plan assumes that conversion of standard bus to articulated buses will be on a one-to-one basis and will not result in a reduction of fleet size. The main reason for making a one-to-one conversion is to accommodate existing demand and potential future ridership growth while maintaining approximately the same headways now operated using standard buses. The increased size of the articulated bus fleet is expected to increase related maintenance activities but will allow Metro to address crowding and schedule reliability issues caused by high passenger loads without reducing headways. If crowding or service reliability issues are identified in the future, the conversion of additional routes to articulated bus operation would represent one potential solution.

The following articulated bus fleet size scenarios were developed for purposes of comparison, reflecting pre-pandemic December 2019 service.

Table 3-6: Articulated Bus Fleet Share, Illustrative Scenarios

Scenario	Articulated Bus Fleet Share ²⁰	Total Articulated Bus Fleet Size	Routes Serviced by Articulated Buses	Incremental Routes Serviced
Scenario 1	4%	66 buses	2 routes full 3 routes partial	70, X2 S1, S2, W4 ²¹
Scenario 2	12%	180 buses	7 routes full 2 routes partial	79, 90, 92, S9, S1, S2 52/54 ²²
Scenario 3	15%	223 buses	13 routes full 1 route partial	A2, A6, A7, A8, 52, 54

²⁰ Based on Metro’s projected active fleet.

²¹ In Scenario 1, routes S1, S2, and W4 are operated with mix of articulated and standard buses. Metro is not currently operating route S1.

²² In Scenario 2, routes S1, S2 are operated fully with articulated buses. Routes 52/54 are operated with a mix of articulated and standard buses. Metro is not currently operating route S1.

To take advantage of the opportunities for adding capacity with limited cost increases²³, Metro plans to pursue a limited expansion of the articulated bus fleet to approximately 12% of the active Metrobus fleet (about 180 vehicles), as outlined in Scenario 2. This strategy, when paired with a stable overall fleet size, enables Metro to respond to crowding and service standards without a notable increase in overall fleet size.

The high ridership, short headway routes that now use articulated buses, and those proposed for conversion to articulated bus operations, mostly operate in dense corridors in the District of Columbia's urban core. To minimize deadhead and make the conversion of these routes cost effective, these additional articulated buses would ideally be assigned to garage facilities located in the core area of the District, such as Northern and Western. Western garage has no facilities for parking or maintaining articulated buses, and Metro does not currently plan to add articulated bus facilities there. Many of Metro's articulated buses were assigned to Northern division before its reconstruction began. These buses were reassigned to other divisions further away from the urban core, mostly Bladensburg and Montgomery, during Northern's reconstruction, which increased deadhead time and mileage on the routes using articulated buses.

Northern garage will have 75 articulated bus parking spaces and twelve articulated bus maintenance bays when it reopens in 2026. This would be enough for all of Metro's 66 articulated buses to be reassigned there, which would reduce deadhead mileage on every route that now uses articulated buses except W4. Bladensburg division is the nearest to the termini of route W4 and second nearest (after Northern) to the termini of both the other routes now assigned articulated buses, and those proposed for conversion in Scenario 2. Improvements at Bladensburg division now under construction will expand articulated parking there to 100 vehicles.

In Metro's previous fleet planning, an anticipated gap in articulated bus maintenance bays was identified. Upon the completion of construction efforts at Bladensburg and Northern operating divisions, the Metrobus system will have a total of 48 maintenance bays capable of servicing articulated buses²⁴. These developments enable Metro to support an expansion of to the level of 180 articulated buses, improving Metro's ability to deploy articulated bus service from garages with closer geographic proximity to their routes.

3.2.3 Priority and Emerging Corridor Networks

The previous Metrobus fleet plan recommended expanding Metro's PVR by 147 vehicles to provide increased service volume on Metro's Priority Corridor Network, a plan to expand and improve services in Metro's 24 most productive bus corridors. The previous plan recommended adding an additional 87 vehicles to increase volume on the Emerging Corridor Network, which were the next 18 most productive

²³ Largely driven by additional maintenance requirements.

²⁴ 9 bays at Andrews Federal Center, 11 bays at Bladensburg, 7 bays at Cinder Bed Road, 3 bays at Montgomery, 12 bays at Northern, and 6 bays at Shepherd Parkway.

corridors in the Metrobus network after those identified as priority corridors. Passenger volumes in most of these corridors had grown rapidly in the years before 2015 (the most recent year for much of the data used in preparing the 2017 plan), and peak period passenger capacity on many of the routes in Priority and Emerging corridors was inadequate, resulting in crowding and service reliability challenges on many routes. Corridor improvements potentially could include reduced peak headways to improve service quality and potentially increase the corridor peak vehicle requirement; conversion of routes to articulated vehicles; or transfer of routes or services from Metro to local jurisdictions, which potentially could reduce the corridor peak vehicle requirement.

Ridership trends in many of these corridors has been much more mixed since 2015, with ridership continuing to grow in some corridors, plateau in others, and decline in still others. Service frequencies were reduced on routes in many of these corridors between 2015 and 2019 due to falling demand. Pandemic-related impacts have further distorted ridership and service patterns since the Priority and Emerging corridors were identified.

Uncertainties about the relative status of each of these corridors given pre-pandemic and more recent ridership and service changes, and the priority and schedule for improvements in these corridors, present challenges in estimating how and when improvements might affect ridership and service in each corridor, or how and these changes might influence vehicle requirements at the corridor or network levels. Future planning may also impact the Metrobus network based on current and forecast demand patterns and agency priorities, especially in the context of the updated Bus Service Guidelines adopted in December 2020 and the bus network redesign.

3.2.4 Fleet Size Planning

Metro's bus PVR, based on PM peak period vehicle requirements for each route, was 1,270 in December 2019, shortly before service was disrupted by the coronavirus pandemic. The fleet sufficiency analysis indicates a potential need for additional vehicles to allow Metro to expand peak period bus service to address forecast ridership growth and to meet existing and future service reliability, crowding, and maximum headway requirements. Crowding could be addressed on some, but not all, Metrobus routes by conversion of routes to articulated vehicles, which increase capacity without requiring an increase in PVR. Completion of rail extension and bus priority improvement projects, the Bus Transformation Project and planned network redesign potentially could support an increased fleet size, as could regional-scale redevelopment projects and the conversion of Metro's bus fleet to electric buses.

However, this plan is being developed in a period of uncertainty which supports a cautious approach when considering fleet expansion. In March 2020, the pandemic caused a drop in ridership which has not yet been recovered. The fleet plan forecasts have assumed that Metrobus ridership will fully recover and match the forecast growth trend in the coming years. However, with ridership still significantly below late 2019 levels, the mid-to long-term impacts of the pandemic on transit ridership – and on regional transportation, development, economic and demographic trends that drive transit ridership –

remain unclear. One potential long-term impact is an increase in remote work. This could make hour-by-hour passenger demand more even throughout the day, reducing the need to increase service volumes to increase capacity during peak periods. It is possible that Metrobus could serve a less peaked future demand pattern with the same number of vehicles or fewer than it operates today, even with the same or higher total passenger demand.

Several additional factors support caution when considering fleet expansion. Before the pandemic, Metrobus ridership had fallen by nearly 150,000 weekday trips between Metro's 2014 bus ridership peak and 2019. Annual vehicle revenue hours fell from 3.97 million in 2014 to 3.78 million in 2019, and vehicle revenue miles from 40.2 million to 37.4 million²⁵. Rather than growing its fleet as proposed in the 2017 Metrobus Fleet Plan, Metro has maintained a generally consistent fleet size and paused implementation of Priority and Emerging bus corridor improvements. Metro assumes that service will return to 2019 levels as ridership recovers over the next several years, and continue growing at a modest rate through 2038, as described in Section 2. However, forecast ridership growth through 2038 still would leave Metro's ridership below 2014-2015 levels. The planned bus network redesign project will provide Metro with the opportunity to reallocate service volume and vehicles among routes and corridors based on current public, agency, and jurisdictional priorities and Metro's service guidelines, as well as current ridership patterns. Through the network redesign process and expanded use of articulated buses, Metro may be able to serve forecast ridership growth and meet service guidelines within the existing PVR.

Given these uncertainties and conflicting indicators, the Fleet Plan recommends planning for a steady state fleet based on the 2019 PVR of 1,270 vehicles operated in maximum service, through 2038.²⁶ This recommendation does not foreclose the possibility of adding vehicles if required based on market, project or technology needs. As noted earlier, the current fleet could accommodate significant demand growth through reallocation of service as part of the bus network redesign project, particularly if demand becomes less peak oriented and growth mostly occurs outside the PM peak period. Should additional vehicles be required to meet demand, the fleet can be expanded in the short term by retaining vehicles scheduled for retirement for an additional 1-2 years. New vehicles typically may be acquired with 2-3 years notice, depending on the technology. Even a modest increase of 3-5 vehicles to each year's annual bus procurement, coupled with retention of vehicles set to be retired, could substantially increase Metro's fleet size. Most of Metro's operating divisions have some latent capacity to accept moderate increases in the fleet size, and storage and maintenance capacity expansion could be explored if needed, including in conjunction with planned electric bus support improvements.

Metro will revisit the potential need for fleet size adjustments in future fleet plans in light of the uncertainty and volatility of potential future demand. The fleet plan does not recommend expanding

²⁵ Source: WMATA 2019 National Transit Database (NTD) Annual Agency Profile

https://cms7.fta.dot.gov/sites/fta.dot.gov/files/transit_agency_profile_doc/2014/30030.pdf

²⁶ Including 25 strategic buses, seven headway management buses, and four elevator buses.

the fleet due to the relatively low ridership forecast and recent ridership declines, the potential articulated buses and reallocation of vehicles among routes to address service guidelines, and other factors discussed in this section. However, the fleet plan also does not recommend reducing the size of the Metrobus fleet. Planning for a smaller future fleet would compromise Metro's ability to respond to future demand growth if and when it occurs. Despite recent declines, ridership growth could result from improved destination access, frequency, and travel speed in the bus network redesign and bus priority corridor projects, regional population and employment growth and new regional development projects, and other potential changes to the transit market and operating environment.

3.3 Projection of Fleet Demand

Metro maintains a number of buses to account for maintenance and breakdowns, to allow for buses to be used for training and emergency services, and for other purposes, such as rail replacement shuttles for scheduled maintenance operations. Strategic and Headway Management Buses and Elevator Service buses are in scheduled service and are included in the PVR to form the basis of calculating the spare ratio, as discussed in Section 3.3.3. Ready Reserve buses are older buses that are held in reserve in excess of the 19.5% spare ratio.²⁷ Each of these categories of buses is described in detail below.

3.3.1 Strategic and Headway Management Buses

Strategic and headway management buses play similar but distinct roles in maintaining schedule/headway adherence. Strategic buses are strategically placed to be available to support a variety of routes in the event of unforeseen delays or disruptions in the provision of service. Headway management buses fill in for late buses on specific headway-managed routes. Metro has continued its headway management strategy that was reported in the last fleet plan update. This strategy has improved service reliability. As of December 2019, Metro uses 25 strategic buses and 7 headway management buses.

3.3.2 Elevator Buses

In addition to strategic and headway management buses, Metro maintains a small number of buses (four in December 2019) to operate elevator shuttle buses, buses required to operate bus bridge service between adjacent Metrorail stations during times when their elevators are out of order.

3.3.3 Spare Buses

Spare buses are vehicles in a fleet expected to remain unused during peak service. These include buses requiring corrective or preventive maintenance, needed for training, removed from service for mid-life overhauls and buses utilized for special projects. This fleet plan proposes a spare ratio of 19.5%, to include:

²⁷ As described in FTA Circular 5010.1E. <https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/regulations-and-guidance/fta-circulars/58051/5010-1e-circular-award-management-requirements-7-16-18.pdf>

15.6% to support routine day-to-day maintenance issues as well as longer term repair actions (Preventive and Corrective Maintenance);

1.5% to support midlife overhauls; and

2.4% to support training, and special projects (fleet and sub-fleet improvement programs).²⁸

Recent operational realities and anticipated future fleet needs inform Metro's projected need for spare vehicles. On two occasions from 2017 to 2018, Metro pulled entire sub-fleets of approximately 100 to 150 buses from service due to significant unexpected vehicle issues. Metro has also undertaken major capital projects, such as the Platform Improvement Project,²⁹ which require the provision of alternative travel options such as bus shuttle service. In recent years, Metro's spare vehicles were not sufficient for the provision of this shuttle service. The Platform Improvement Project is ongoing.

In addition, articulated buses generally require more maintenance than standard-length buses. The same is true for electric buses in recent demonstrations at other transit agencies. Because Metro expects its articulated and electric bus fleets to grow in the coming years, additional spares available for maintenance purposes will help ensure the continued delivery of Metrobus service.

As the articulated share of the Metrobus fleet increases, and as new propulsion technologies are adopted, further maintenance operations adjustments are anticipated. While standard length vehicles can be stored and maintained at each Metro operation division, articulated buses may only be accommodated at 6 of these facilities. Currently, few divisions have the ability to offer fueling support for CNG buses or charging support for electric buses. Metro expects its future fleet to necessitate operational adjustments as a result of this reduced flexibility.

The proposed spare ratio is supported by extensive fleet operation experience and is deemed sufficient to support the various tasks for which spare buses are assigned. Table 3-7 below shows the fleet requirements by category through FY2038.

The Metrobus spare ratio is calculated in accordance with FTA guidance³⁰, as outlined below.

$$\text{Spare Ratio} = [\text{Spare Vehicles}] / [\text{Peak Vehicle Requirement}] = 19.5\%$$

²⁸ Metro's last fleet plan called for a spare ratio of 18.5%, to include 14.7% to support maintenance needs, 1.5% to support midlife overhauls, and 2.3% to support training and special projects. Additional spares are expected to be required to ensure the quality and reliability of Metrobus operations, but midlife overhauls are not expected to increase.

²⁹ Source: Metro Platform Improvement Project Site. <https://www.wmata.com/service/rail/PlatformProject/>

³⁰ Source: Federal Transit Administration.

<https://www.transit.dot.gov/funding/procurement/third-party-procurement/spares-ratio>

Table 3-7: Metrobus Total Vehicle Requirement

Category	Vehicle Count
Peak Vehicle Requirement ³¹	1,270
Spares (19.5% Spare Ratio)	248
Total Scheduled Buses	1,518
Ready Reserve Buses	75
Total Vehicle Requirement	1,593

3.3.4 Ready Reserve Buses

Metro maintains a Ready Reserve Fleet of overage buses, which consisted of 75 vehicles in December 2019. The Ready Reserve Fleet is composed of older vehicles, past their scheduled replacement, that nevertheless would be suitable for passenger service to support regular revenue operations or special events. The primary purpose of the Ready Reserve Fleet is to replace buses that are not economically feasible to repair, accommodate approved temporary service changes, replace buses that are removed from service for fleet failures and provide buses for emergency situations. These vehicles are preserved in stored condition and are ready for service. While Metro expects to maintain a Ready Reserve fleet of up to 75 buses through 2038, the number of vehicles in the Ready Reserve Fleet may vary from year to year depending on the number of accidents, the age of the Metrobus fleet, necessary safety campaigns and other circumstances.

In the future, the availability of a Ready Reserve fleet will enable improved continuity of Metrobus service.³² The ability to deploy Ready Reserve vehicles utilizing proven propulsion technology is helpful to fleet resilience as Metro begins deploying new technologies, such as electric buses, into the fleet. As these Ready Reserve vehicles are not included in Metro's Total Scheduled Buses, they are added to that figure to calculate Metro's Total Vehicle Requirement.

³¹ Sometimes defined as vehicles operated in maximum service. This value is used for the calculation of the spare ratio and includes strategic fleet, headway management, and elevator shuttle vehicles.

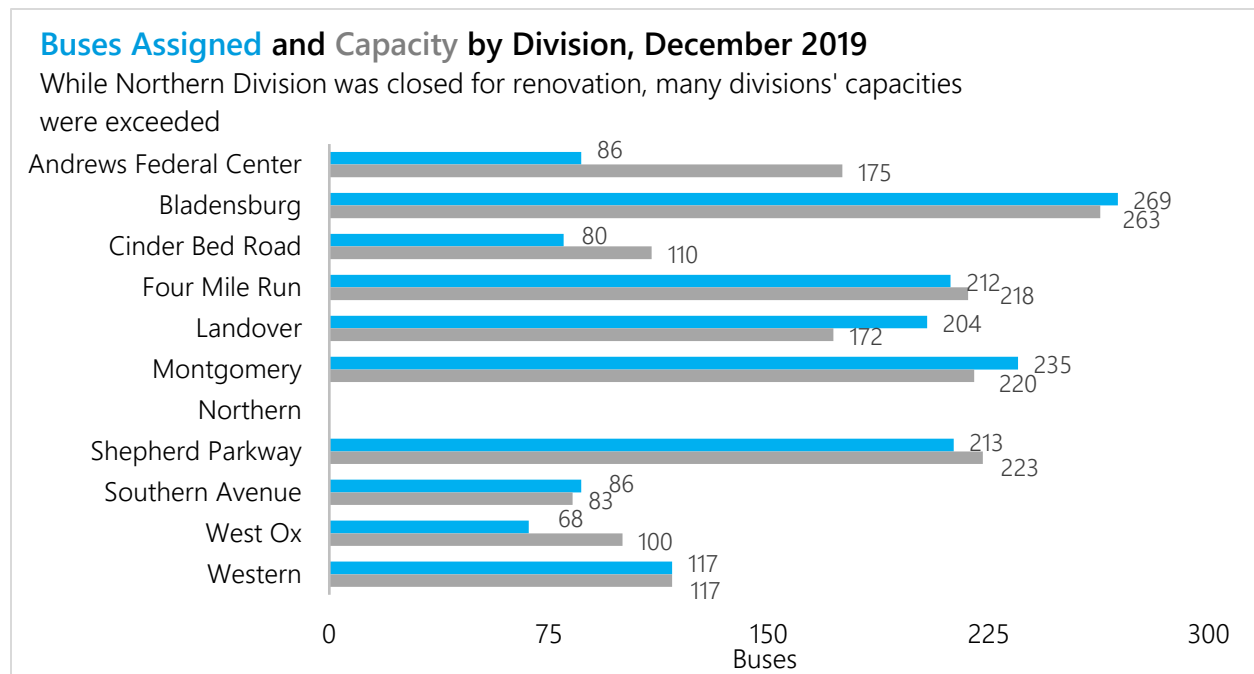
³² Ready Reserve vehicles, which will typically be legacy diesel- or CNG-fueled buses, will require continued fuel support at Metro operating divisions. The long-term makeup of the Ready Reserve fleet will require ongoing evaluation as Metro's fleet continues to evolve.

Section 4. Metrobus Fleet Supply

While Metrobus fleet size is driven by the volume and distribution of passenger demand and service requirements, the number of buses required to operate the Metrobus system is greater than the PVR, as described in Section 3. Routine scheduled replacement of the oldest buses is a fundamental component of a bus fleet management plan and helps ensure the quality and reliability of Metrobus services.

Metrobus vehicles have a useful life benchmark of 12 to 15 years,³³ and any temporary reduction in procurement plans would lead to longer-term fluctuations and service delivery challenges. This fleet plan projects the Metrobus PVR to remain constant at 1,270 vehicles through 2038. The total Metrobus fleet includes 248 spare buses, and up to 75 Ready Reserve buses, for a total fleet requirement of 1,593 buses as discussed in Section 3. Figure 4-1 shows how many buses were assigned to each operating division in December 2019, reflecting normal operations before the coronavirus pandemic. Facility capacity is included in this figure as well.

Figure 4-1: Metrobus Assignments and Capacity by Operating Division, December 2019³⁴



³³ 12-year useful life benchmark for articulated and electric buses, 15-year useful life benchmark for standard length vehicles.

³⁴ In December 2019, 13 Ready Reserve vehicles were assigned to Carmen Turner Facility, which is not a standard Metrobus operating division.

Four facilities in December 2019 had capacity of 200 or more vehicles. Several divisions were exceeding their bus capacity in Fall 2019 due to the temporary closure of the Northern Operating Division for reconstruction.

Rehabilitation, replacement and expansion of Metro's existing vehicle fleet are essential to delivering safe, reliable and comfortable service to Metrobus customers. Due to variance in the timing of the procurement and retirement of buses, the precise size of the Metrobus fleet does fluctuate somewhat over time. By planning to procure 100 new buses per year for the duration of this Fleet Plan³⁵, and retiring buses after they have exceeded their useful life benchmark, the Metrobus fleet will remain a generally constant size for the life of this Fleet Plan. Some buses are expected to be kept past their typical useful life benchmark in order to meet fleet demand requirements. Flexibility in procurement planning will enable Metro to adapt to changes in the size of its articulated bus fleet as well as the pace of advancement in bus propulsion technology, especially in electric buses. For example, the range of electric buses may present route planning or reliability challenges, so it is possible the Metrobus fleet would expand slightly in the future to address those issues while continuing to deliver reliable service.

4.1 Current Fleet Composition

As of July 2021, Metrobus has a total fleet of 1,557 buses. This includes Ready Reserve vehicles and represents the current overall size of the Metrobus fleet, which grows and contracts slightly as vehicles are procured and retired. After FY2021, the Metrobus fleet is expected to remain at or above a total fleet size of 1,593 in order to meet forecasted fleet demand.

The Metrobus fleet consists of buses of three length categories: small, standard, and articulated.³⁶ A summary of the composition of the Metrobus fleet as of July 2022 is available in this document's appendix.

4.2 Articulated Bus Fleet Procurement Plan

As discussed in Section 3, Metro plans to expand its articulated bus fleet beyond current levels. From the projected end-of-year FY2022 base of 75, Metro will be able to reach 182 articulated buses by 2028 by adding approximately 25 articulated buses to its fleet each year from FY2024 through FY2028. Table 4-1 shows Metro's planned articulated bus fleet expansion through 2028. Two of these articulated buses will be electric vehicles in Metro's upcoming Electric Bus Test & Evaluation Program.

³⁵ As Metrobus vehicles are generally expected to operate in service for 15 years, procuring 100 new vehicles per year helps ensure a continued steady state fleet size.

³⁶ Small buses are vehicles with a length of 30-35 feet. Standard buses are 35-42 feet in length. Articulated buses are 60 or more feet in length.

Table 4-1: Articulated Bus Expansion Through FY2028, End-of-Year Totals

Year	Articulated	Standard, Other Types	Total Fleet
2022	75	1518	1593
2023	77	1577	1654
2024	102	1491	1593
2025	127	1528	1655
2026	152	1441	1593
2027	177	1421	1598
2028	182	1411	1593

With this expansion of its articulated bus fleet size, Metro will be able to serve several more high-volume, high-frequency routes with expanded service capacity. This fleet plan assumes a steady articulated bus fleet size after FY2028, though Metro may choose to expand this fleet further as needed to respond to ridership demand patterns and service quality. The articulated fleet will reach a steady-state size of 180 buses after the two 60' test and evaluation electric buses retire.

4.3 Vehicle Lifecycle

4.3.1 Vehicle Useful Life

The Federal Transit Administration establishes standards for vehicle useful life, which begins on the date a vehicle is placed in revenue service and ends when the same vehicle is removed from revenue service. For purposes of grant applications and accounting, transit buses which have been purchased with federal assistance have a minimum useful life of 12 years.³⁷ Transit providers may also establish a National Transit Asset Management (TAM) Useful Life Benchmark, defined as the “expected lifecycle of a capital asset for a particular transit provider’s operating environment, or the acceptable period of use in service for a particular transit provider’s operating environment.”³⁸ Useful Life Benchmarks represent the anticipated years of service for a given vehicle type. Metro’s useful life benchmarks meet or exceed the minimum useful life standards established by the FTA.

³⁷ Source: FTA Circular 5010.

<https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/32136/5010-1e-circular-award-management-requirements-7-21-2017.pdf>

³⁸ Source: FTA Final Rule 2132-AB07. <https://www.federalregister.gov/documents/2016/07/26/2016-16883/transit-asset-management-national-transit-database>

4.3.2 Vehicle Lifecycle Analysis






The lifecycle assessment conducted for the fleet plan reviewed the capital and operating costs of known configurations of transit vehicles on the market. The assessment incorporated vehicle prices paid by major transit agencies in or around FY2020 and Metro operating costs (fuel and maintenance expenses). For propulsion types in which facility investments to expand capacity would be required to accommodate future procurements, construction cost estimates per vehicle were reflected based on recent facility investments by Metro and other major transit properties. These costs were depicted over a 12- or 15-year time frame, based on each vehicle's anticipated Useful Life Benchmark, to show an average annual lifecycle cost for that configuration. While Metro expects standard-length buses to operate in revenue service for 15 years, articulated buses have a Useful Life Benchmark of 12 years. Electric buses are also currently benchmarked to have a 12-year typical useful life, given the lack of available full lifecycle demonstrations for this evolving vehicle technology.

The figures included in this vehicle lifecycle analysis are directional in nature and represent best estimates using presently available information. As technologies develop and Metro's familiarity with new propulsion types grows, it is likely that these assumptions will require review. This analysis shows the potential for increased annual total costs for electric buses, driven largely by the anticipated increased capital costs associated with these vehicles. These capital costs include the significant facility modifications associated with the support of these new vehicles. Additional operating expenses, including the adaptation of Metro's maintenance operations, are also likely to be impacted. A more detailed breakdown of the assumptions of this analysis is available in this document's appendix.

Electric buses, based on present-day purchase costs, have higher capital cost when compared to conventional diesel, CNG, and hybrid vehicles. Because Metro's facilities are also not currently configured to support a large-scale electric bus fleet, significant capital costs associated with facility construction would also be anticipated. In the near-term, operating costs for electric buses are driven in part by issues with vehicle reliability as discussed later in Section 4. Fuel costs for electric and CNG buses are lower than those of other vehicles.

These estimates do not include potential future improvements in vehicle efficiency, costs, reliability or performance. Metro will continue to monitor the advancement of these technologies and the potential impact of their deployment on service delivery. Future vehicle procurements will rely on the improvement of electric bus technologies, which is anticipated based on current industry trends. Other propulsion systems, including hydrogen fuel cell buses, will also be evaluated for potential introduction to the Metrobus fleet in the future.

Figure 4-2: Bus Propulsion Technology Comparison, 40-Foot Buses³⁹

Bus Type	 Diesel	 Diesel Electric Hybrid	 Compressed Natural Gas ⁴⁰	 Battery-Electric	 Hydrogen Fuel Cell
Range	300+ miles	300+ miles	300+ miles	150+ miles ⁴¹	250+ miles
Useful Life Benchmark Assumption ⁴²	15 years	15 years	15 years	12 years	12 years
Existing Garage Capacity, % of Total	100%	100%	28% ⁴³	<1%	0%
Annual Greenhouse Gas (GHG) Emissions (tons), well-to-wheels ⁴⁴	124	99	CNG: 83 RNG: 15 ⁴⁵	25	74 ⁴⁶
Total Capital Cost ⁴⁷	\$710,000	\$900,000	\$800,000	\$1,425,000	\$1,475,000
Capital Cost—Vehicle ⁴⁸	\$710,000	\$900,000	\$800,000	\$1,025,000	\$1,375,000
Capital Cost—Facilities & Equipment ⁴⁹	No new build cost	No new build cost	No new build cost	\$400,000	\$100,000
Avg. Annual Operating Cost	\$56,832	\$55,967	\$49,891	\$54,436	\$81,022
Operating Cost—Maintenance	\$38,239	\$40,929	\$43,251	\$46,531	\$51,960
Operating Cost—Fuel	\$18,594	\$15,038	\$6,640	\$7,905	\$29,063
Avg. Annual Total Cost⁵⁰	\$104,165	\$115,967	\$103,224	\$139,853⁵¹	\$195,605
Avg. Annual Total Cost with One-Time Facility Cost	\$104,165	\$115,967	\$103,224	\$164,853	\$203,939

³⁹ Costs depicted on a per bus basis.

⁴⁰ Use of renewable natural gas (RNG) would further reduce CNG vehicle emissions.

⁴¹ Battery-electric bus range is especially impacted by weather and ambient temperature and can drop below this range under some conditions.

⁴² Useful life benchmark for standard 40' buses. All articulated 60' buses are assumed to have a 12-year useful life benchmark.

⁴³ Capacity will increase to 43.0% upon completion of active reconstruction work at Shepherd Parkway and Bladensburg Divisions.

⁴⁴ Information sourced from Argonne National Laboratory's AFLEET analysis, which sources data from the EPA's MOVES emission factor model (for diesel, hybrid, electric and fuel cell buses), and Argonne Lab's GREET Model for CNG.

⁴⁵ Renewable Natural Gas. Assumed emphasis on landfill gas as an energy source.

https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/03/Fact-Sheet_RNG_in_DC_vFINAL.pdf

⁴⁶ Assumes off-site steam-methane reforming production of gaseous H₂.

⁴⁷ Includes vehicle purchase capital costs and facilities and equipment expansion costs for low-emissions buses.

⁴⁸ Estimates for standard 40' buses, includes PPA warranty (if not standard for manufacturer inclusion) and midlife overhaul costs.

⁴⁹ Facility conversion not anticipated for Diesel, Hybrid or CNG buses.

⁵⁰ Average annual total cost is calculated to include operating and vehicle purchase capital costs. Capital costs are not incurred annually but are included on a per-year basis for purposes of comparison. Facility expansion costs are not included.

⁵¹ All new electric and hydrogen fuel cell buses would require facility expansion expenditures if pursued.

4.4 Projection of Fleet Supply

Metro's long-term fleet procurement plans will adopt a level procurement rate of 100 new vehicles per fiscal year. This steady approach will ensure stability in Metro's fleet over time, ultimately reducing variability in the fleet size due to previous years' procurement and retirement schedules. In the near term, some shifts will occur in the size of the Metrobus fleet, as vehicles may be retired at different rates than they are procured. In some cases, especially in the 2030s, vehicles are projected to be kept past their useful life benchmark in order to maintain a sufficient and fleet size to meet demand. The Metrobus fleet size may in some case exceed 1,593 vehicles due to the need to maintain this fleet level in future years.

As Metro evaluates the tradeoffs between various vehicle types, several factors must be taken into consideration. Metro's capacity to support CNG buses is limited to 481 vehicles in FY2021, though that figure grows to 704 in FY2023 with the completion of CNG capacity expansion at Shepherd Parkway. When the Bladensburg Operating Division's construction work is completed, this CNG support capacity will expand further to 741 vehicles. This expansion at Bladensburg is expected in FY2027.

Implementing electric bus capability at Metrobus operating divisions and deploying them in Metrobus operating territory requires extensive coordination within Metro and with other stakeholders. Existing facilities must be evaluated for operational constraints and required electrical capacity enhancements coordinated with local electric utility providers (including feeder extensions from local substations, redistricting and development of a transit rate class).

Given the timeframe needed to plan for and design the facilities—and procure the vehicles—to scale up electric bus service, Metro can reduce the emissions and improve the efficiency of the bus fleet by increasing the share of articulated buses and replacing outgoing diesel and hybrid buses with CNG-powered vehicles. The share of articulated buses in the fleet, which is well below that of most of Metro's peer transit agencies of its size⁵², will increase from approximately 4% in FY2021 to approximately 12% by FY2028. Increasing the articulated fleet will allow for capacity to be enhanced on high-density corridors without adding additional vehicles to the fleet.

4.4.1 Emissions

As a part of Metro's emission reduction goals, Metro's fleet procurement strategy will focus on the adoption of an expanded electric bus fleet. One of the key changes recommended in this plan is to use CNG as a transitional strategy to full electric bus implementation. While the long-term goal of Metrobus is to migrate solely to electric buses or other zero-emission technologies, Metro expects to use a period of transition to prepare its facilities and operations to accommodate these new vehicles. This approach can provide significant regional air quality benefits, without the long lead times and technology risks

⁵² Benchmarking of large transit agencies from National Transit Database.

associated with an accelerated electric bus adoption strategy. The emissions impacts⁵³ of Metro's planned bus procurement strategy are shown in Figure 4-3. Additional emissions details may be found in this document's appendix.

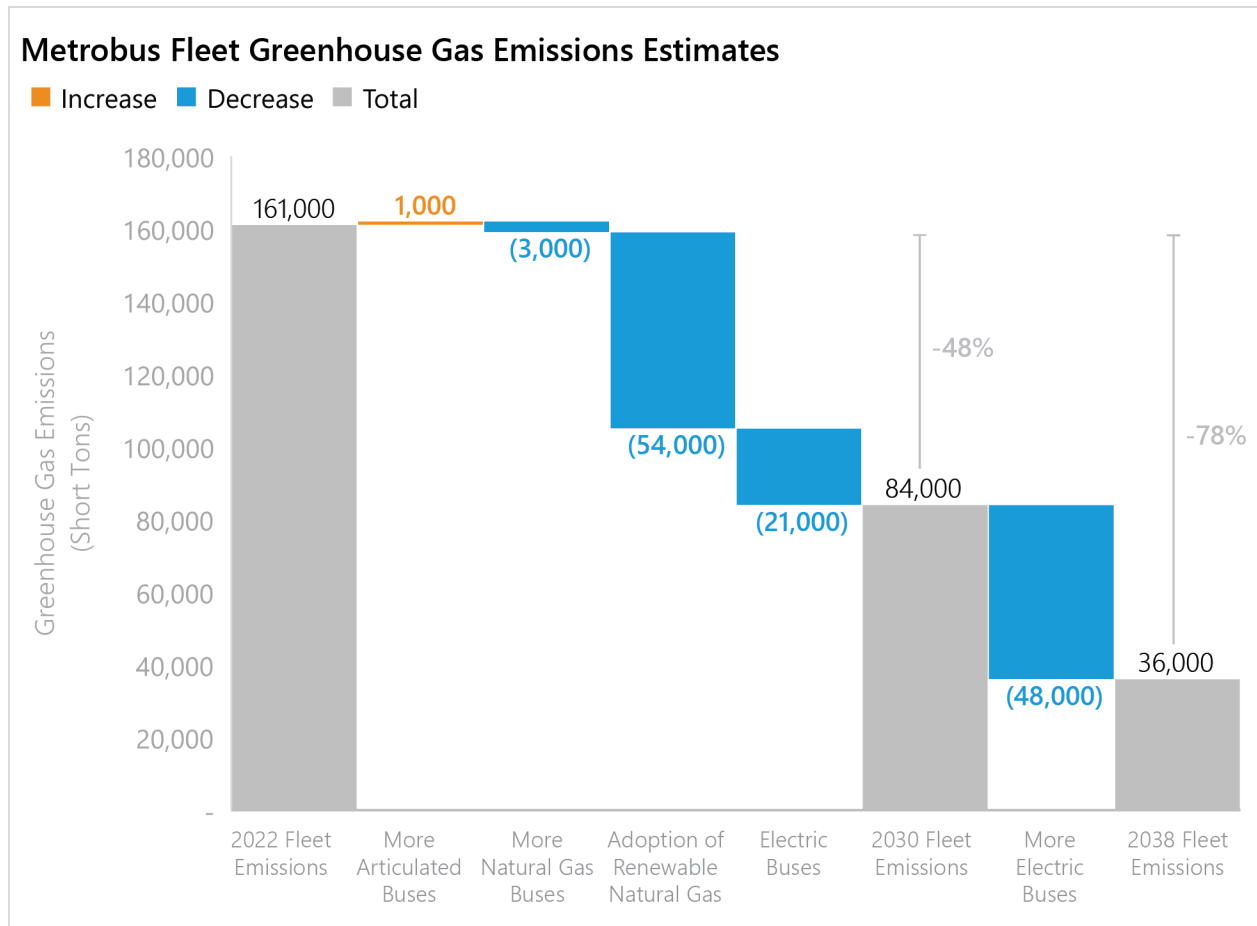
The use of renewable natural gas as a fuel source for CNG vehicles represents an opportunity for a reduction in fleet emissions as Metro transitions to a 100% electric bus fleet. Renewable natural gas is generated through the capture and processing of biogas, which is produced through the decomposition of organic matter. Potential biogas sources include methane from farming and animal waste, landfills and wastewater treatment facilities.⁵⁴ The United States Environmental Protection Agency has cited the potential benefits of the use of RNG, including reductions in upstream greenhouse gas emissions.⁵⁵ Metro has already initiated the procurement of renewable natural gas as an energy source.

⁵³ Figure 4-3 and Figure 4-4 emissions estimates generated through the U.S. Department of Energy's Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool, which utilizes emissions data from the U.S. Environmental Protection Agency's Motor Vehicle Emission Simulator (MOVES). Articulated bus emissions estimated by comparison of vehicle fuel efficiency.

⁵⁴ Source: United States Environmental Protection Agency. <https://www.epa.gov/agstar/renewable-natural-gas-agricultural-based-adbiogas-systems>

⁵⁵ Source: United States Environmental Protection Agency. <https://www.epa.gov/lmop/renewable-natural-gas>

Figure 4-3: Estimated Annual Metrobus Fleet Greenhouse Gas Emissions, Selected Years



Within Metro operating divisions, existing CNG capacity is currently utilized to nearly the full extent available. Once CNG fueling capacity is implemented at Shepherd Parkway and increased at Bladensburg Division, shifting procurement to predominately CNG acquisition will allow Metro to realize emissions reductions immediately with a proven vehicle configuration. During this time, electric bus procurement will gradually scale up, shifting entire to electric vehicles in 2030 when more Metrobus facilities have been modified to accommodate electric buses and Metro has deeper experience with these vehicles' performance and reliability in the region from the test and evaluation program.

Figure 4-4: Estimated Annual Metrobus Fleet Vehicle Operation Pollutant Emissions, Selected Years

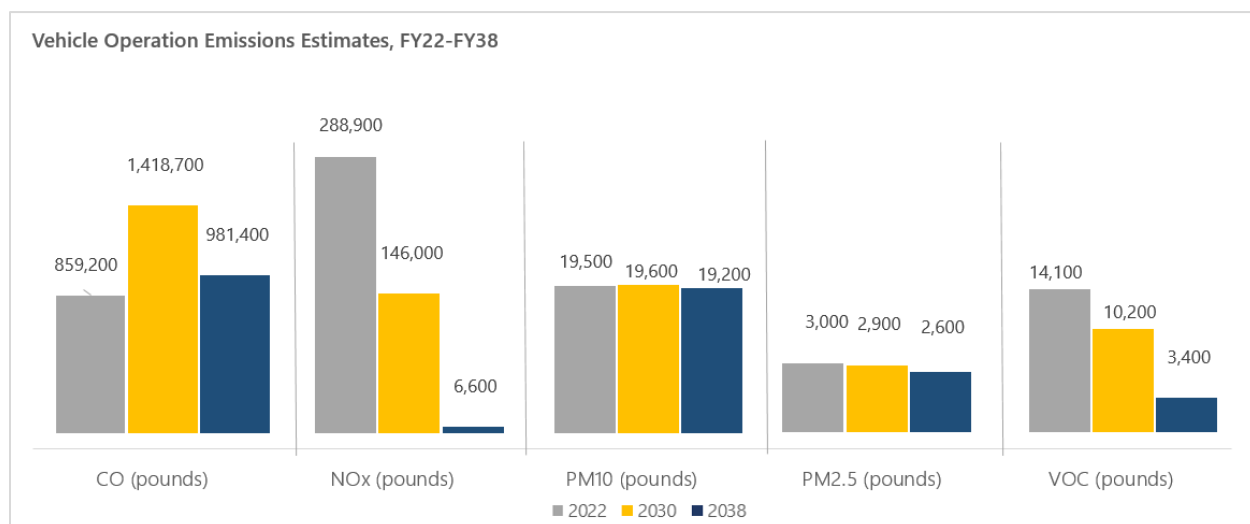


Figure 4-4 summarizes the total annual vehicle operation pollutant emissions estimated for the full Metrobus fleet in FY2022, FY2030, and FY2038.⁵⁶ Limiting these vehicle emissions represents an important factor in public health and air quality in the region. The Metropolitan Washington Air Quality Committee (MWACQ) and the National Capital Region Transportation Planning Board (TPB) have highlighted concerns regarding volatile organic compounds (VOCs) and nitrogen oxides (NOx) which combine to form ground-level ozone.⁵⁷ Particulate matter smaller than 2.5 micrometers in diameter (PM2.5) is also a noted public health concern.⁵⁸

Metro’s planned fleet composition is expected to have meaningful positive effects in these areas – with approximate reductions of up to 98% in NOx emissions, 75% in VOC emissions, and 15% in PM2.5 emissions from vehicle operations by 2038. These improvements are largely driven by the proposed future Metrobus fleet composition, especially the expanded use of CNG and electric buses. More detailed emissions data is available in the appendix of this document.

⁵⁶ Y-axes not to scale between charts. While carbon monoxide (CO) emissions in Figure 4-4 were generated using the U.S. Department of Energy’s AFLEET Tool, Metro expects to be able to significantly reduce CO emissions through the use of oxidation catalysts and other mitigation strategies.

⁵⁷ Source: Metropolitan Washington Council of Governments. <https://www.mwcog.org/transportation/data-and-tools/air-quality-forecasts/>

⁵⁸ While they do not produce tailpipe emissions as conventional vehicles do, electric and hydrogen fuel cell buses, like all transit buses, generate particulate matter emissions during vehicle operation. Sources of this particulate matter include those produced by friction on brakes, tires, and road surfaces, as well as the suspension of road dust.

4.4.2 Electric Bus Planning Considerations

4.4.2.1 Electric Bus Updates and Context

Expanding on the efforts of Metro's first Energy Action Plan in 2019 and the Washington Area Bus Transformation Project, Metro is engaging in planning to integrate electric buses into the Metrobus fleet. The introduction of these buses will reduce regional emissions from Metrobus operations and some operating costs like fuel expenditures while aligning Metro with the sustainability priorities of the region.

Metro's 2020 Zero-emission Bus Update⁵⁹ catalogues the actions the agency and region must take to enable adoption of zero-emission buses, including the expansion of energy infrastructure, establishment of regional electric utility policy for transit and a transit-specific energy rate class, and the securing of funding to procure zero-emission buses and convert maintenance and operating divisions to enable the fueling and maintenance of these vehicles.

An Electric Bus Alternatives Assessment study and a Low-or-No Emission Grant from the FTA has enabled the establishment of the test and evaluation program for 12 electric buses at the Shepherd Parkway operating division, which will help assess the functionality and interchangeability of different vehicle and charging brands at Metrobus operating divisions. This pilot will include the purchase of articulated buses, with the introduction of these vehicles into service concluding in FY2023. Situated in Southeast Washington, close to Prince George's County in Maryland and Northern Virginia, Metro will be able to test the pilot fleet on a variety of operating profiles, including variable service block length and topography.

This fleet plan builds upon these assessments of electric buses, outlining pathways to scale the share of electric buses in vehicle procurements and to convert facilities in alignment with programmed construction plans. For the purposes of this report, battery-electric and fuel cell buses were evaluated for zero-emission bus implementation. Battery-electric bus technology has wider demonstrated adoption to date, including at Metro.

Current reconstruction activities at Northern and Bladensburg Divisions enable those facilities to be electric-bus ready, though charging infrastructure planning would still require procurement and installation at Bladensburg. While no additional electric-ready facilities have been identified, Section 6 details the considerations and challenges for each Metrobus division's conversion to support electric buses.

4.4.2.2 State and Local Jurisdiction Standards

Several regional jurisdictions have committed to policy and planning targets to prioritize and scale zero-emission vehicle acquisition in the immediate future. These jurisdictions have expressed these targets

⁵⁹ Source: Metro Zero-Emission Bus Update.

https://www.wmata.com/initiatives/sustainability/upload/WMATA_Zero_Emission_Bus_Update-02122020-FINAL.pdf

through signed/pending clean energy legislation, regional “cap and invest” programs, climate action and environmental planning documents recommended for board adoption, and local planning documents.

Metro is coordinating with other regional transit operators and other key stakeholders, such as the Metropolitan Washington Council of Governments (MWCOG) and electric utility companies, to determine a common approach and collaboratively shape regional policy concerning the adoption of zero-emission vehicles and the requisite utility upgrades required, including the development of a transit bus fleet-specific rate class. Opportunities for coordination will increase as transit properties that overlap or are immediately adjacent with the Metrobus operating territory begin deploying zero-emission buses and developing the requisite charging infrastructure.

4.4.2.3 Metrobus Procurement Schedule

Implementing electric bus capability at Metrobus operating divisions and deploying them in Metrobus operating territory requires extensive coordination within Metro and with other stakeholders. Existing facilities must be evaluated for architectural constraints, and Metro must coordinate with local electric utility providers to achieve required electrical capacity enhancements—including feeder extensions from local substations, redistricting and development of a transit rate class. Bus purchases should be aligned with design plans to ensure that Metro does not receive buses it cannot charge and operate.

Although it will take years to scale up electric bus service fully—which entails planning for and designing facilities as well as procuring vehicles—Metro can already begin to reduce its emissions and improve the efficiency of its bus fleet by increasing the share of articulated buses in the fleet and replacing retiring buses with CNG-powered vehicles. The share of articulated buses in the fleet will increase to approximately 12% by FY2028. Increasing the articulated fleet will allow for capacity to be enhanced on high-density corridors without adding additional vehicles to the fleet.

Existing CNG capacity is currently utilized to nearly the fullest extent. In immediate years, diesel bus procurement will occur at a lower capital cost and build a fleet of vehicles that will be on hand during the electric bus deployment. Once CNG fueling capacity is implemented at Shepherd Parkway and increased at Bladensburg Division, shifting procurement to predominately CNG acquisition will allow Metro to realize emissions reductions with a proven vehicle configuration. During this time, electric bus procurement will gradually scale up, increasing in the 2030s when more Metrobus facilities have been configured to accommodate electric buses and Metro has greater awareness of performance and reliability in the region from the test and evaluation program.

4.4.2.4 Electric Bus Adoption Factors

The following factors are crucial components of electric bus technology and infrastructure. These factors are expected to develop over the coming years as electric bus technology matures and more vehicles are deployed.

Bus Range: In FY2021, battery-electric buses are demonstrating typical ranges of approximately 100-150 miles in revenue service. While battery weight is anticipated to decline over the course of the decade, allowing for potential efficiencies of diesel gallon-equivalent fuel economy and range, the advancement in battery range will remain an area to study and evaluate. Battery-electric bus range is a function of battery pack size, vehicle weight, passenger loading, geography, temperature and operating conditions. In recent Altoona testing of electric buses by the FTA^{60,61,62}, energy efficiency has ranged between 1.6-2.5 kWh/mile without accounting for the impact of passengers, HVAC, hills, and traffic.

Electric bus configurations published by several states (including California⁶³, Maryland, and Washington State⁶⁴) have included battery-electric buses with battery capacity between 440 and 660 kWh. Vehicles with comparable battery capacity are estimated to have range estimates that fall between 2.5kWh/mile and 4.0kWh/mile. A survey of these vehicles currently on the market suggests that battery offerings in FY2021 may allow an operating range as low as 90 miles and as high as over 200 miles, depending on operating conditions. While battery weight is anticipated to decline over the course of the decade, allowing for potential efficiencies of diesel gallon-equivalent fuel economy and range, the advancement in battery range will remain an area to study and evaluate.

Conditions that may cause buses to perform on the lower end of the range include very cold temperatures, maximum HVAC loading and frequent stops and door cycling. Battery systems often need to be warmed before they can commence charging, which shortens available charging windows and may cause other operational impacts. The variable seasonal weather conditions in the Washington metropolitan region will result in cold-weather impacts to electric bus operations on some colder winter days. A 2018-2019 study of District Department of Transportation battery-electric bus performance in Washington, DC found significant variance in vehicle range related to ambient temperature, dropping to as low as 60 to 90 miles per charge in freezing temperatures.⁶⁵

⁶⁰ Source: Altoona Test, New Flyer XE40, July 2015

<http://apps.altoonabustest.psu.edu/buses/reports/458.pdf?1441118410>

⁶¹ Source: Altoona Test, Proterra CAT40DP, September 2020

<http://apps.altoonabustest.psu.edu/buses/reports/519.pdf?1602161615>

⁶² Source: Altoona Test, BYD Electric Bus, 2014

<http://apps.altoonabustest.psu.edu/buses/reports/441.pdf?1423598436>

⁶³ Sources: California Department of General Services Price Book

<https://www.dgs.ca.gov/-/media/Divisions/OFS/Pricebooks/Current-Year-Price-Book/FY-2020-2021-Price-Book.pdf> and Contract Pricing Bulletin

<https://www.dgs.ca.gov/-/media/Divisions/PD/PTCS/Broadcast-Bulletins/2019/K-35-19-Zero-Emission-Transit-Buses.pdf>

⁶⁴ Source: Washington State Bus Price Analysis.

⁶⁵ Source: Center for Transportation and the Environment et al. <https://cte.tv/wp-content/uploads/2019/12/Four-Season-Analysis.pdf>

Reliability: Initial deployments of battery-electric buses were characterized by lower bus availability and higher corrective maintenance. Transit agencies have observed some improvement in terms of reliability, availability and battery storage capacity with newer deployments.⁶⁶ These elements are anticipated to improve as the technology matures and more manufacturers enter the market.

For example, the first five battery-electric buses delivered to Los Angeles County Metropolitan Transportation Authority in 2014 experienced approximately 10% of the mean miles before failure of the diesel bus fleet, major issues with door systems and experienced multiple roadcalls from service during most weeks. Some transit agencies, such as Los Angeles County Metropolitan Transportation Authority⁶⁷ and Albuquerque Rapid Transit, required manufacturers to repurchase these vehicles due to deficiencies below the contractually agreed standard of performance. Los Angeles utilized trade-in credits to acquire a newer generation fleet of electric buses that offered better performance in service.

Foothill Transit in Southern California was among the first operator to utilize electric buses in service in the United States, beginning in 2009. In the initial analysis period from 2014-2015, miles between roadcalls from service for these electric buses was approximately 20-30% of that of fully-commercialized CNG buses.⁶⁸ Foothill subsequently conducted a follow-up analysis of second-generation battery-electric buses in 2015-2016, which exhibited a significant improvement in availability between first-generation and second-generation battery-electric buses, improving from 66% availability to 79% in just one year⁶⁹, compared to 90% for CNG buses in that same period. However, a subsequent phase of that evaluation in 2020 depicted comparable miles between roadcalls between first- and second-generation electric buses, suggesting that electric buses still face reliability issues.⁷⁰

More recent fleet deployments demonstrate improvements, but still are not consistently performing at the level of legacy bus configurations. The initial evaluation of electric buses in service with King County Transit in Seattle from 2016-2017 concluded that electric buses were available for service 80.6% of the time, opposed to 90.5% for the hybrid fleet and 86.4% for the diesel fleet, noting that issues resulted

⁶⁶ Source: Transit Cooperative Research Program, Battery Electric Buses State of the Practice.
<https://www.nap.edu/catalog/25061/battery-electric-buses-state-of-the-practice>

⁶⁷ Source: Los Angeles County Metropolitan Transportation Authority.
https://media.metro.net/board/items/2016/09_september/20160914atvcitem4.pdf

⁶⁸ Source: Foothill Transit Battery Electric Bus Demonstration Results, January 2016.
<https://www.nrel.gov/docs/fy16osti/65274.pdf>

⁶⁹ Source: Foothill Transit Battery Electric Bus Demonstration Results: Second Report, June 2017.
<https://www.nrel.gov/docs/fy17osti/67698.pdf>

⁷⁰ Source: Foothill Transit Agency Battery-Electric Bus Progress Report, March 2020.
<https://www.nrel.gov/docs/fy20osti/75581.pdf>

with the electric drive system.⁷¹ If the electric buses in Metro’s fleet were to experience reliability issues at this scale, it would represent a major disruption to Metro’s ability to deliver service to the region.

The deployment of limited pilot fleets of electric buses by transit agencies, with data collection and assessment conducted by entities such as the Federal Transit Administration and NREL (National Renewable Energy Laboratory) has allowed manufacturers to improve bus production, in addition to informing electric bus operation to transit agencies. NREL’s evaluation of low-voltage batteries at Foothill Transit revealed that electric buses required significantly more service than CNG buses due to the lack of an auto-shutoff feature for bus accessories that continually draw power, such as fareboxes and camera systems. Manufacturers are integrating auto-shutoff features into future designs, and are retrofitting in-service vehicles facing this issue.⁷²

AC Transit in Northern California purchased a group of comparable battery-electric and hydrogen-fuel cell buses from the same manufacturer in 2019, with the intention of using the operating performance of these vehicles to inform the subsequent scaling of their zero-emission fleet.⁷³ The agency concluded electric buses have not yet matured to the point they can “easily replace current diesel and CNG technologies on a large scale” but is expecting further improvement due to continuing advancements.

Battery Degradation: Batteries currently on the market are anticipated to degrade to no less than 80% of their design capacity. Battery manufacturers offer 12-year warranties up to this level, allowing transit properties to mitigate some level of battery degradation risk. Lithium batteries for transit battery-electric buses, excepting early-stage pilots, have only been in service for about 5 years. As a result, there is limited demonstration of full battery lifecycles in this application. Manufacturers suggest that retaining 80% of design capacity through the end of their 12-year life is a reasonable expectation, as stated by their warranty offerings.

Fuel cells, like batteries, also degrade over time, and a mid-life rebuild of a hydrogen fuel cell stack has been anticipated in year 6 or 7 in this fleet plan’s analyses.

Energy densities for transit bus batteries continue to evolve at a rapid rate, and corresponding range limitations are likely to continue improving during the analysis period of this fleet plan. Battery energy density, measured in kilowatt hours per kilogram, has been improving by about 10% annually, with vehicles becoming lighter at the same time they demonstrate potential expanded range. The U.S.

⁷¹ Source: FTA Zero-Emission Bus Evaluation with King County Metro. <https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/115086/zero-emission-bus-evaluation-results-king-county-metro-battery-electric-buses-fta-report-no-0118.pdf>

⁷² Source: Foothill Transit Agency Battery-Electric Bus Progress Report, March 2020. <https://www.nrel.gov/docs/fy20osti/75581.pdf>

⁷³ Source: AC Transit Zero-Emissions Bus Rollout Plan. https://www.actransit.org/website/uploads/AC-Transit-ZEB-Rollout-Plan_06102020.pdf

Department of Energy has established goals for lighter weight batteries with greater energy density at a 15-year lifespan.

Electric Utility Support: Close coordination with local electric utility providers will be needed to make requisite improvements to the grid and connections to Metrobus operating locations. Metro and other regional transit operators may benefit from the establishment of a transit-specific rate class to price appropriately mass transit use of utility capacity.

Training and Development: The maintenance and operation of new propulsion technology will require updated training practices and protocols. Significant training support will be required to support the success of Metro's electric fleet. The scope of these efforts will include charging systems and infrastructure as well as vehicle operation.

Grid Analysis: Charging 100 battery-electric buses requires approximately nine megawatts (MW) of electricity—about the same amount demanded by 6,000 homes. The Capital Grid project in Northwest Washington may enable Northern Division, upon completion of its construction work mid-decade, to accommodate 150 electric buses. Other sites would require build-outs and feeder extensions to increase capacity and connect with nearby substations and may potentially need to be redistricted to a different electric utility provider to accommodate the increased load of electric buses. In other instances, such as where local load growth continues to rise but is already at capacity, the installation of on-site solar power could be considered, along with the parallel incorporation of alternative fuel technology such as CNG.

Facility Layout Planning: Many facilities currently supporting electric buses utilize overhead charging, with pantograph gantries that connect to the bus from a structure above. Plug-in charging, in which the vehicle is plugged into an electrical socket, is also utilized common. Inductive charging, in which the bus connects to an electricity source plate below it, is less common and currently undergoing early evaluations at select agencies. While on-route charging has not been demonstrated on a wide scale, and can be more costly than depot charging due to the utility enhancements and land use acquisition and conversion required to establish it, some transit properties attempt to augment their depot charging capacity by co-locating these facilities with existing power sources and real estate. If Metro implements on-route charging, locations such as Metrorail stations and existing bus terminals may provide adequate electrical capacity and parking space for operators to "fast-charge" the bus in between runs.

Contingency and Resiliency: Retaining diesel fueling capabilities for training and ready reserve purposes in the near term may protect against mechanical failures and grid outages. Gradually scaling up electric bus infrastructure and deployment with low-emission vehicles such as CNG buses will allow Metro to build redundancy and enable flexibility in the forward direction of the fleet. Metro will need to consider the emergency preparedness of its fleet in the event of potential future use of its bus fleet in evacuation

scenarios. If an electric or other zero-emission bus were to travel outside the Metro service area in such a situation, re-charging or re-fueling locations would be required.

Route Analysis and Block Assignment: The majority of Metrobus operative blocks assessed are within the current estimated range of a 500-kWh electric bus. Block assignments will need to consider the appropriate threshold at which a battery-electric bus typically returns to the depot for charging—usually around 20%. The impacts of adverse weather conditions on range will also need to be evaluated.

Disadvantaged Communities: Metrobus provides service throughout the Washington metropolitan region and has varying capabilities at its 10 operating divisions in the area. Some divisions only accommodate certain propulsion types, and some do not accommodate articulated buses. Processes such as Title VI will be integrated into Metro’s planning for the development of charging infrastructure for zero- and low-emissions infrastructure, as well as for the routing and deployment of newer and cleaner bus fleets. Under Metro’s Title VI Program, Metro will continue to monitor vehicle deployment to ensure equity among fleet age and, in the case of zero-emissions, vehicle type. This review is conducted periodically, as rider demographics, the assignments of vehicles to a given route, and capacities and capabilities at facilities change over time. Table 4-2 details the demographics of riders served by each bus division using route assignments as of fall 2019.⁷⁴

Table 4-2: Minority and Low-Income Riders as Share of Riders Served by Bus Division

Division	Minority Riders as Share of Riders Served	Low-Income Riders as Share of Riders Served
Andrews Federal Center	87.3%	47.3%
Bladensburg	81.3%	45.4%
Cinder Bed	66.7%	34.1%
Four Mile Run	65.1%	31.9%
Landover	92.8%	49.6%
Montgomery	81.5%	45.5%
Northern	71.3%	35.3%
Shepherd Parkway	91.9%	57.6%
Southern	91.6%	59.0%
West Ox	65.9%	36.8%
Western	60.2%	30.1%
Weekday Average, System-Wide	80.1%	44.7%

⁷⁴ Figures for Northern Division calculated as of Fall 2018, as this facility was closed for rehabilitation in 2019.

4.4.2.5 Electric Bus Considerations Summary

By transitioning to zero-emission buses, Metro will be able to support a clean and sustainable region, reduce greenhouse gas and on-the-road vehicle emissions, decrease vehicle noise, and improve the overall customer experience.

Transitioning beyond Metro's initial test and evaluation to a larger overall electric bus fleet will require close coordination with local, regional, and federal partners. The facility and utility support required to house, maintain, and operate electric buses is significant, and Metro is closely studying advancements in bus technology. Metro is also working to identify the needs, costs and funding sources required to make this transition. Collaboration with regional partners in the development of relevant rate structures and policies represents another key step in this process.

Electric buses involve increased capital costs as manufacturers charge more for these vehicles when compared to CNG, diesel and hybrid buses.⁷⁵ Metro's operating facilities are not currently configured to support a larger electric bus fleet. Battery-electric vehicles require dedicated charging equipment and support infrastructure, and often other facility reconfigurations such as parking lane adjustments and ceiling height changes.

Other significant challenges exist to full conversion of the Metrobus fleet to electric or other zero-emission bus technologies, including current industry trends of operating limitations. Existing battery-electric buses do not currently offer the same travel range on a single charge when compared to other propulsion technologies. Reliability is another anticipated hurdle; electric buses are expected to continue to require more frequent corrective maintenance in the near-term. Adjustments to battery life issues are anticipated as electric bus batteries degrade over their lifetime and cold weather has been shown to reduce the longevity of a single charge.

Metro will continue to monitor and evaluate advancements in electric bus technology, performance, reliability, range and costs. The procurement schedule outlined in this plan reflects anticipated developments in these areas as manufacturers and transit agencies improve their familiarity with this technology. If battery-electric or other zero-emission technologies support more rapid adoption and deployment in the future, Metro plans to adjust its procurement approach accordingly.

Metro is working to transition its procurement strategy to focus on electric bus technology in the future. Primary considerations for Metro to evaluate during the scale-up of the electric bus program include:

Battery-Electric Bus Constraints: The rate at which Metro can transition to electric buses will be largely constrained by facility and charging system capacities, and both areas will take a decade or more to build out. A secondary consideration is that even the longest-range battery-electric buses may not be able to operate on some bus routes. Current electric bus range is estimated to be approximately 150 miles, with reduced performance under certain weather conditions. While most current Metro blocks

⁷⁵ As do hydrogen fuel cell vehicles.

fall under 150 miles, performance during the test and evaluation program will provide insight on observed range in Metrobus territory.

Flexibility & Anticipated Technology Improvements: This Bus Fleet Management Plan focuses on bus replacement scenarios that were most cost effective, provide the maximum near-term emission benefits to the region, and fit within existing facility plans and constraints.

Bus technologies are evolving rapidly, and are expected to continue evolving in the upcoming years. Metro plans to maintain as much flexibility as possible to adjust its fleet replacement plans, as different technologies and capabilities become available and/or more cost effective in the future.

Near Term Benefits of CNG Fleet Expansion: Given the timeframes anticipated for electric bus adoption, Metro plans to expand its CNG fleet in the near term as a bridging strategy. Currently available Low NOx CNG engines, along with use of renewable natural gas (RNG)⁷⁶, can provide immediate air quality and greenhouse gas (GHG) benefits for the DC region.

4.4.3 Fleet Procurement Strategy

The considerations and analyses above inform the approach Metro plans to implement in its future procurement plans, which begin in FY2024.

In June of 2021, the Metro Board of Directors adopted zero-emission fleet goals⁷⁷ which inform Metro's strategy for bus procurements in the coming years. In accordance with these goals, Metro plans to purchase only lower-emission and electric buses in its next bus procurement, beginning in FY2024, and transition to the purchase of only zero-emission vehicles beginning in FY2030. By FY2045, these goals direct Metro to be fully transitioned to a zero-emission bus fleet.

In order to provide quality, reliable service while working to reduce greenhouse gas emissions and transition the Metrobus fleet to new technologies, Metro plans to procure a mix of lower-emission and electric buses through a phased approach. This will also allow opportunity for the conversion of Metrobus operating divisions to be able to support electric buses, which are a key identified need in this fleet plan.

While this fleet plan anticipates procurement of lower-emission compressed natural gas buses, Metro may also procure hybrid buses, another lower-emission vehicle technology. Exact procurement plans, fleet composition, and purchase timing will be impacted by facility capacity, bus support infrastructure, maintenance requirements, vehicle technology performance, and other factors. Metro's projected

⁷⁶ Additional information available from the US Department of Energy's Alternative Fuels Data Center.

https://afdc.energy.gov/fuels/natural_gas_renewable.html

⁷⁷ Source: June 10, 2021 Metro Board materials.

<https://www.wmata.com/about/board/meetings/board-pdfs/upload/3A-Sustainability-Vision-Goals-and-Bus-Fleet.pdf>

procurement plans are detailed in the table below and entail a steady procurement of 100 vehicles per fiscal year. Metro will continue to study and evaluate vehicle propulsion technology and performance as it evolves in the coming years and intends to remain flexible in its approach to vehicle acquisition in alignment with Board-established fleet goals.

Table 4-3: Total Projected Bus Procurement by Fuel Type, FY2024-FY2038

Fuel Type	FY24–FY28	FY29	FY30–FY38
Compressed Natural Gas Buses Procured	75 per year	50 per year	0 per year
Electric Buses Procured	25 per year	50 per year	100 per year
Total Buses Procured	100 per year	100 per year	100 per year

Metro plans to procure approximately 75 CNG buses per year from FY2024 through FY2028, along with approximately 25 electric buses in each of these years. These apportionments will shift to an equal split in FY2029. Beginning in FY2030, Metro plans to focus its bus procurement exclusively on electric or other zero-emission vehicles. These plans may adjust or accelerate as technologies develop, and Metro will continue to evaluate advancements in other zero-emission bus technologies such as hydrogen fuel cell vehicles. The projected fleet mix implications of this strategy are shown in Table 4-4 and Table 4-5, as total fleet counts as well as percentages. By the end of FY2038, Metro’s fleet would be projected to consist of 34% CNG vehicles and 66% electric buses.

Metro’s CNG support capacity is current expected to peak at 741 vehicles after reconstruction efforts at Bladensburg are completed. While Metro’s CNG fleet may slightly exceed this programmed capacity in FY2027 and FY2028, Metro expects to be able to accommodate these vehicles through storage at other facilities or adjustments to bus parking configurations. The procurement of hybrid vehicles represents another option if CNG bus support reaches capacity.

Table 4-4: Metrobus Fleet by Propulsion Type, FY2021-FY2038, End-of-Year Totals

FY	Diesel	Hybrid	CNG	Electric	Total Annual Fleet Level
2021	260	861	435	1	1557
2022	318	857	417	1	1593
2023	368	809	464	13	1654
2024	368	648	539	38	1593
2025	368	610	614	63	1655
2026	368	448	689	88	1593
2027	357	364	764	113	1598
2028	357	343	755	138	1593
2029	341	323	741	188	1593
2030	341	223	741	288	1593
2031	341	123	741	388	1593
2032	341	40	725	487	1593
2033	299	0	707	587	1593
2034	299	0	620	687	1606
2035	274	0	620	785	1679
2036	220	0	601	867	1688
2037	50	0	582	961	1593
2038	0	0	545	1048	1593

Table 4-5: Metrobus Fleet by Propulsion Type, FY2021-FY2038, End-of-Year Percentages

FY	Diesel	Hybrid	CNG	Electric
2021	17%	55%	28%	<1%
2022	20%	54%	26%	<1%
2023	22%	49%	28%	1%
2024	23%	41%	34%	2%
2025	22%	37%	37%	4%
2026	23%	28%	43%	6%
2027	22%	23%	48%	7%
2028	22%	22%	47%	9%
2029	21%	20%	47%	12%
2030	21%	14%	47%	18%
2031	21%	8%	47%	24%
2032	21%	3%	46%	31%
2033	19%	-	44%	37%
2034	19%	-	39%	43%
2035	16%	-	37%	47%
2036	13%	-	36%	51%
2037	3%	-	37%	60%
2038	-	-	34%	66%

Figure 4-5: Projected Share of Vehicles in Metrobus Fleet by Propulsion Technology

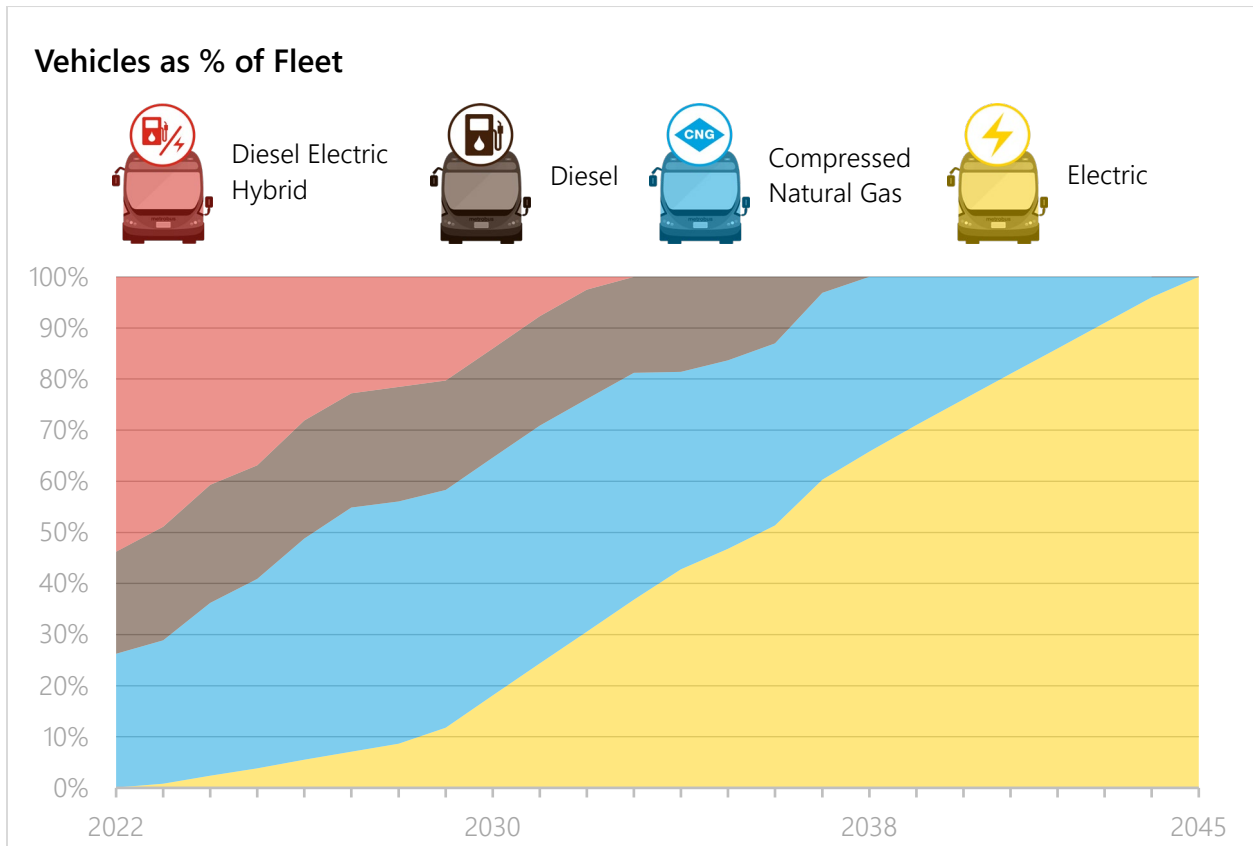
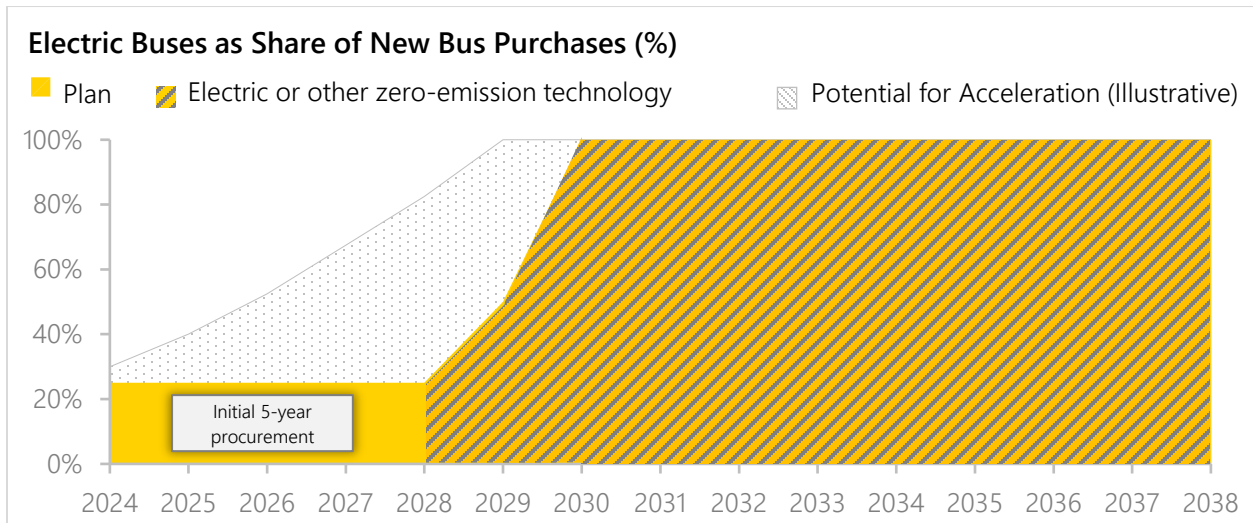


Figure 4-5 charts the share of the Metrobus fleet by propulsion type from FY2022 to FY2045. Metro’s current fleet of hybrid buses is expected to be retired by the end of FY2032 as they reach the end of their useful life benchmark. By the end of FY2038, Metro’s electric bus fleet is expected to include 1,048 vehicles, approximately 66% of the total fleet. All diesel buses in the fleet are projected to be retired by the end of FY2038. Metro expects to maintain its fleet of small buses (30 to 35 feet) to service specific routes with certain road geometry or turning radius requirements. Adjustments to this plan may be made in the future if these long-term requirements change.

Figure 4-6 demonstrates potential paths for an expedited transition to electric buses in Metro’s bus procurement plans.

Figure 4-6: Electric Bus Procurement Paths, FY2024–FY2038



Metro plans to adapt the pace of its conversion to electric buses in response to the progression and maturity of vehicle technology as well as the availability of the funding sources required to meet anticipated capital costs. As electric buses demonstrate the range and reliability required to replace conventional buses on a one-to-one basis, and as requisite funding support is made available, Metro will work to transition to full electric bus procurement as quickly as feasible. While this document assumes a specific schedule for planning purposes, Metro will adjust its approach to fleet management to ensure it reflects available vehicle technology and advancements. Other zero-emission technologies may be procured in addition to electric buses after FY2028.

Table 4-6 outlines the planned procurement and retirement schedule of the Metrobus fleet from FY2021 through FY2038. Due to previous years with variance in procurements and retirements, some fluctuation in the exact size of the Metrobus fleet is anticipated. In some cases, vehicles will be kept past the end of their useful life benchmark in order to meet the projected total vehicle requirement of 1,593 vehicles per year. In some years, the Metrobus fleet may also exceed 1,593 vehicles in order to ensure sufficient fleet size to meet fleet requirements in following years.

Table 4-6: Metrobus Fleet Procurement and Retirement Projection Through FY2038 (Summary)⁷⁸

	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Active Fleet (Start of Year)	1576	1557	1593	1654	1593	1655	1593	1598	1593	1593	1593	1593	1593	1593	1606	1679	1688	1593
Deliveries	171	170	112	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Retirements	190	134	51	161	38	162	95	105	100	100	100	100	100	87	27	91	195	100
Active Fleet (end of year)	1557	1593	1654	1593	1655	1593	1598	1593	1593	1593	1593	1593	1593	1606	1679	1688	1593	1593
Diesel as % of Fleet (end of year)	17%	20%	22%	23%	22%	23%	22%	22%	21%	21%	21%	21%	19%	19%	16%	13%	3%	0%
Hybrid as % of Fleet (end of year)	55%	54%	49%	41%	37%	28%	23%	22%	20%	14%	8%	3%	0%	0%	0%	0%	0%	0%
CNG as % of Fleet (end of year)	28%	26%	28%	34%	37%	43%	48%	47%	47%	47%	47%	46%	44%	39%	37%	36%	37%	34%
Electric as % of Fleet (end of year)	<1%	<1%	1%	2%	4%	6%	7%	9%	12%	18%	24%	31%	37%	43%	47%	51%	60%	66%
Average Fleet Age (End of Year)	6.8	6.3	6.6	6.5	6.9	6.7	6.8	7.0	7.2	7.1	7.2	7.2	7.3	7.4	7.8	8.0	7.7	7.8

⁷⁸ Projection based on fleet requirements, facility capacity, vehicle age, vehicle useful life benchmarks, and procurement plans. Fleet size expected to grow and contract as a result of past vehicle procurement timing. Assumes no vehicles are retired before the end of their 12-year minimum useful life. In order to maintain total fleet requirement of 1,593, some vehicles are expected to be kept past typical useful life benchmarks. Long-term fleet plans to be updated if electric buses demonstrate viability past currently assumed 12 years.

4.5 Metrobus Technology Strategy

Metro continues evaluate emerging on-board bus technologies and business practices. In the coming years, Metro plans to leverage these technologies as much as possible to provide safe, reliable service to its riders. The collection of accurate real-time data and information represents a significant opportunity to improve the overall Metrobus customer experience. Metro also plans to continue its consideration of other aspects of the rider experience, including adjustments to seat types and layouts, real-time information displays for customers, and fare payment infrastructure.

Targets for improvement include the following areas:

- Offering riders more frequently updated bus schedules
- Comprehensive inclusion of all trips in bus schedules
- Improved application of open source data standards in Metrobus information technology
- Increased share of Metrobus vehicles reporting real-time data and information
- Completely accurate location information for Metrobus stops
- Visible, real-time feedback and information for Metrobus operators
- Real-time access to onboard video footage
- Real-time processing of fare card transactions
- Improved automatic passenger counter data accuracy and availability of data in real-time

Metro is currently exploring changes in its scheduling tools and other software integrations to support the advancement of some of these goals.

4.5.1 Electric Bus Deployment Support

As Metro transitions its fleet to include electric vehicles in the coming years, technology and software to support this transition will be required. Electric buses have many functions and needs distinct from those of conventional vehicles. Software needs will include bus scheduling analysis, charge management and other maintenance-related tools. In advance of and during the upcoming electric bus test and evaluation, Metro will continue to evaluate its technology needs.

4.5.2 Autonomous Vehicle Technology

Metro is monitoring the development of autonomous vehicle technology and engaging on policy issues related to their operation. The nature of automated driving can range from minimal driver assistance to full vehicle automation. Metro expects to pursue collision avoidance technologies in the near term while continuing to evaluate the potential of other opportunities for automation. High or full Metrobus automation advancements are not anticipated in the early portion of this plan, but may have impacts on Metrobus planning and operations in the 2030s or beyond.

Section 5. Fleet Maintenance

Each Metrobus vehicle is a major capital investment which requires proper maintenance in order to maximize its service life and reduce capital and operating expenditures. Proper maintenance of the fleet is also essential to providing safe, reliable service.

However, a portion of the fleet will be out of service at any given moment due to unexpected failures. Transit buses, which operate an average of approximately 30,000 miles a year of high-intensity urban driving for Metrobus, occasionally fail in service, regardless of how well they are maintained. The ripple effect of a bus breakdown can include passenger delay, increased travel time and overcrowded buses. In the past, Metrobus had a large portion of older buses in active service, which increased the possibility of breakdown even despite a rigorous maintenance program.

Metro's maintenance needs and requirements will increase over the next decade due to a mix of different vehicle technologies, including the introduction of electric buses. These new technologies continue to evolve over time, demanding new equipment and best practices. Metro expects to develop additional trainings and protocols as its maintenance practice adapts to these new vehicles.

5.1 Overview of Fleet Maintenance

Metro's in-house maintenance functions include the full scope of normal operating maintenance, complete paint and body work, and full component overhaul. The mission of Metro's Office of Bus Maintenance (BMNT) is to provide safe, clean, reliable buses, service vehicles and support equipment to customers in an equitable and efficient manner. Maintenance procedures and practices are continuously reviewed and adjusted to stay ahead of impending issues that could affect future performance. In addition to regularly scheduled maintenance, risks that impact performance outside of BMNT's domain are also evaluated. BMNT uses a Risk Categorization table which enumerates all issues that may potentially reduce the fleet's performance during current and future years.

Metro's Bus Maintenance department has undertaken several initiatives that have improved the reliability and efficiencies of vehicles. Some of the initiatives include upgrading radiators to a product with better service life, upgrading of coolant level sensors, upgrading the original Energy Storage System provided by BAE to a more reliable Ultra capacitor system, and the installation of upgraded Cummins ECM (Engine Control Modules) on many buses. As a result of these initiatives and other improvements, Metro's fleet reliability has improved significantly.

Metro's maintenance functions follow procedures set forth by bus manufacturers' maintenance manuals and Metrobus standard operating procedures (SOPs). Completed maintenance activities are documented on the pertinent reporting forms, reviewed and certified by a supervisor, and entered into the specified reporting system. Metro has established an extensive support infrastructure and quality control process for the program, which allows crews to exercise control over the process. This helps ensure better body work, mechanical component overhaul and bus rehabilitation.

Metro uses an automated online record keeping system, Maximo, to track bus maintenance functions, parts inventory, and record keeping. Metro has both automated and manual systems for record keeping. The automated system catalogues a complete maintenance history on each vehicle and makes it possible to perform a thorough equipment reliability analysis. Using Maximo, maintenance crews are able to track all preventive and corrective maintenance actions. Metro also uses a manual record-keeping system. The combination of automated and manual systems assures the best possible vehicle maintenance at the lowest cost.

Metro follows its Standard Operating Procedure for Inventory Management to set up and/or modify an item in a storeroom within Maximo.⁷⁹ The SOP specifies:

- The responsible section for ensuring the sufficiency of stock levels to meet the operating needs of the divisions.
- Stock out rate shall be less than 5% at all locations.
- Target item availability for preventive maintenance (PM), ADA, bike rack, fare box, and other parts
- Storeroom locations shall not have more than 75 line items of "No Demand Material," defined as items which have not been issued to a work order in the past 24 months, to avoid overstock or excess inventory.
- Slow moving items shall be reviewed monthly and adjust ordering as appropriate.

Metro uses the industry standard "reorder point calculation" in order to optimize the reordering process for inventory items. This method captures the last three years' average of vendor lead times, plus the 45 days for internal administrative lead time as well as the demand (average daily usage) of the item. Reorder Point (ROP) is equal to Lead Time multiplied by Demand.

Metro also sets the economic order quantity (EOQ) to a six-month usage at its main distribution center. This is due to the administrative time and cost to complete more than two procurement actions each year. To maintain an acceptable level of inventory, Metro uses a Maximo report that reflects system-wide inventory usage to actual work orders. The Maximo report allows usage of a particular item across all departments. In addition, if a department is forecasting an increase in usage beyond past usage, the department is advised to notify their inventory planning team. In Bus Maintenance, the inventory planning team works closely with Bus Engineering to determine service levels of the fleet to optimize inventory, and attends relevant meetings to understand upticks in failures. In addition, the Bus Engineering and the inventory planning team collaborate to manage the bus fleet from warranty coverage from the manufacturers to operations and maintenance support.

Metro also stages tow trucks and service trucks throughout the system to respond quickly to vehicles that have failed while in service. Service trucks are equipped with fluids, air compressors, tool kits, jump

⁷⁹ This function is supported by Metro's Office of Supply Chain Management.

start equipment and spare parts. If service truck personnel are unable to return a disabled bus to service, it is towed to its home division for more extensive repair, and a replacement bus is put into service.

5.1.1 Future Electric Bus Maintenance

Metro's maintenance systems, policies and procedures continue to undergo further developments and refinements over time. Metro also follows guidelines set forth in manufacturers' manuals, in combination with standard practice.

In the coming years, the increased deployment of electric vehicles in the Metrobus system will lead to adjustments to maintenance practices, protocols, equipment, and training. Electric bus equipment is notably distinct from that of conventional vehicles, especially due to the differences between combustion engines and electric motors. While many aspects of electric bus equipment are similar to those of a conventional vehicle,⁸⁰ it is anticipated that maintenance adjustments will be required. Metro's Electric Bus Test and Evaluation will provide valuable experience with and insight into electric bus maintenance requirements and best practices.

5.2 Current Fleet Performance

Overall, Metrobus fleet performance has remained roughly consistent over the past few years. Review and update of the maintenance program is done every two years, but this subject to change with delivery of new buses, as well as when a notice of procedure change is received from the manufacturer. Metro also applies its Standard Operating Procedures (SOP) that establishes the requirements for the development and performance of the preventive and corrective maintenance procedures.

Metro recently conducted an effort to revise the terminology of failures and assesses them as:

- Service Interruption: Mechanical failure on the revenue vehicle that prevents the vehicle from completing a scheduled revenue trip, or from starting the next scheduled revenue trip because actual movement is limited, or safety concerns arise.
- Mechanical Failure: Failure of a mechanical element on the revenue vehicle. Some failures result in inconvenience or discomfort to customers, but do not always result in a service interruption (such as farebox or onboard technology equipment failures). A mechanical failure does require corrective maintenance.

5.2.1. In-Service Failures

Metro tracks bus failures on a daily, weekly, and monthly basis. The in-service failures displayed in Table 5-1 vary among buses using different technologies, though primarily driven by the age of the fleet.

⁸⁰ Such as wheels, tires, seats, fare payment systems, onboard technology, windows, windshields, etc.

Table 5-1: Top Causes of In-Service Failure, FY2020

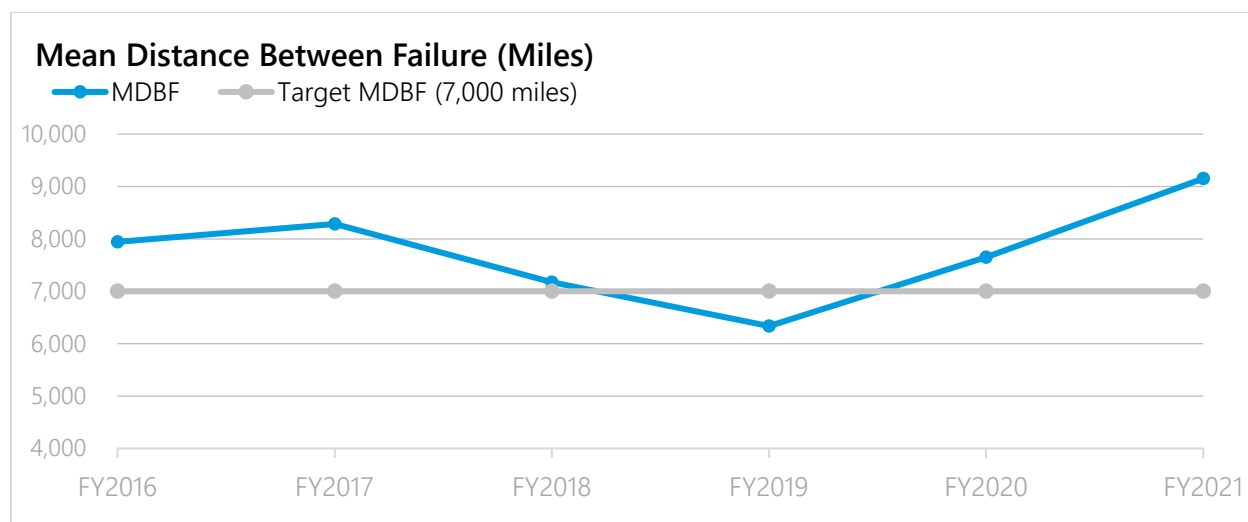
Cause	Counts
Engine/Transmission	784
Body	403
Fluid	359
Air	90
Electrical	76
Exhaust	71
Other	294
Total	2077

5.2.2 Mean Distance Between Failures

Mean Distance Between Failures (MDBF) is defined as the number of chargeable service interruptions during revenue service divided into actual miles. Metro has been able to limit the number of Metrobus failures by applying various operating and maintenance strategies. The replacement of older vehicles, together with standard maintenance practices, has enabled the fleetwide MDBF to remain roughly consistent.

As reported in previous plans, there is a relationship between MDBF, fleet composition, fleet age, and maintenance and operational practices. Metro continues to work to improve the reliability of its fleet through preventive maintenance, mid-life overhauls, fleet management, and other operational practices.

Figure 5-1: Metrobus Mean Distance Between Failures



Metrobus mean distance between failures reached 9,151 miles in FY2021, a 20% improvement compared to the previous fiscal year. This performance was due partly to the reduction in service during the pandemic. Metro was able to operate its most reliable buses on the road and prioritize the maintenance of some older vehicles in the fleet. Additional actions taken to sustain and improve performance included improved failure reporting in Metro’s asset management system to allow for more in-depth trend analysis as well as internal quality audits of preventive maintenance programs and service lane activities to identify areas for improvement.⁸¹

5.3 Types of Maintenance

Two types of maintenance are performed on the Metrobus fleet: Preventive and Corrective maintenance.

Preventive Maintenance (PM): is a scheduled maintenance program to keep equipment in good working order, prevent in-service failures, and meet certain vehicle regulatory requirements. The mid-life bus overhaul, part of the PM, is critical for maintaining the safety, performance, and reliability of the bus fleet throughout its life. The mid-life overhaul, developed in the 1994, was designed to maintain buses in a state of good repair, reduce in-service breakdowns, improve safety and reliability, and introduce standardization across the fleet as possible.

Corrective Maintenance (CM): is an unscheduled maintenance to respond to unexpected vehicle breakdowns, malfunctions and accidents.

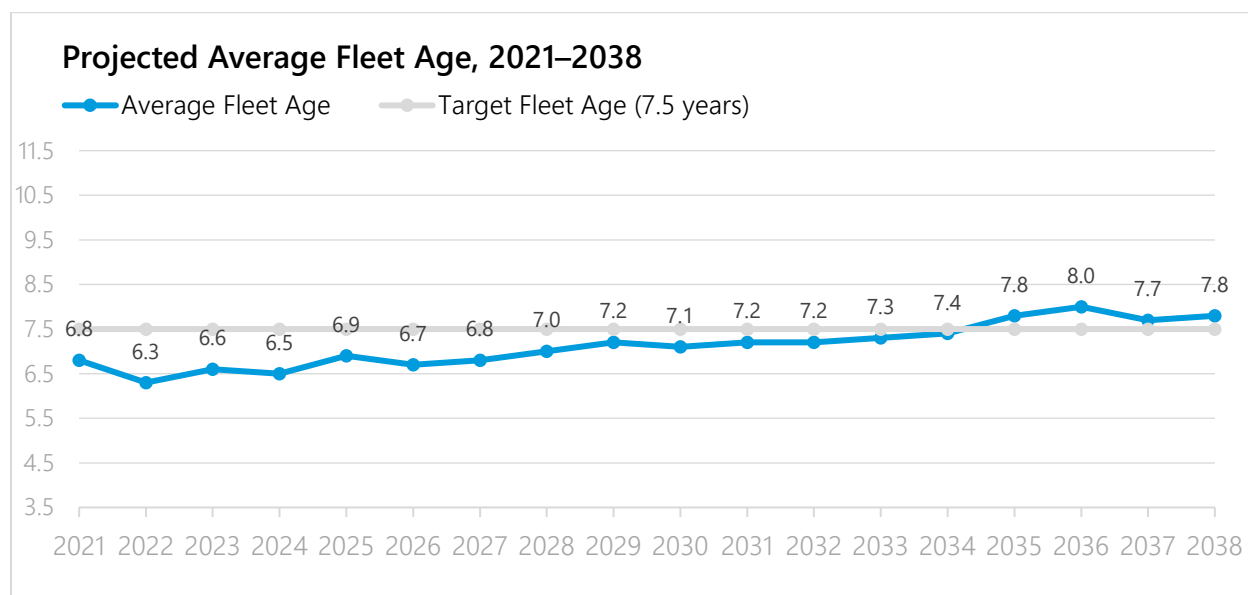
In recent years, significant improvements in fleet reliability has been made through a combination of bus replacements and a robust maintenance program. As a result, the failure rate of buses has been

⁸¹ Source: Metro FY2021 Performance Report.

<https://www.wmata.com/about/records/upload/Q4FY21MetroPerformanceReport.pdf>

reduced significantly, thereby improving the reliability of service. This fleet plan projects that Metro will need to keep some vehicles beyond their useful life benchmark in some cases in order to meet fleet requirements. Thus, average fleet age is projected to be slightly above Metro’s 7.5 average age target during later points of the analysis period of this plan. If electric vehicle technology demonstrates sustainable useful life beyond Metro’s current 12-year benchmark, the fleet’s average age may be lowered as older vehicles of other propulsion technologies could be retired sooner. By continuing to operate a fleet with generally consistent average vehicle age of 6 to 7 years in service, Metro anticipates positive ongoing contributions to fleet reliability.

Figure 5-2: Projected Average Fleet Age



5.3.1 Preventive Maintenance (PM)

The Metrobus scheduled PM program sustains bus reliability by detecting and correcting potential defects. Buses are withdrawn from service at regular mileage-based intervals for preventive maintenance actions including inspecting equipment and conducting routine service. The schedule is developed based on manufacturer recommendations and Metro experience. Measures include lubrication, replacing filters, replenishing fluids, making adjustments, cleaning of exterior and interior surfaces, and scheduled replacement of electrical and mechanical equipment. Table 5-2 shows schedules for the preventive maintenance program.

Table 5-2: Preventive Maintenance Schedule

Inspection Type	Inspection Interval	Labor Hours	Buses/Day
ADA Equipment Maintenance	90 days (ramp), 42 days (lift), and annual inspection	3.21	44
A-Inspection	6,000 miles	8.00	36
Bus Interior Cleaning	16 days	4.00	1501
Bus Steam Cleaning	6,000 miles	2.95	36
Camera Maintenance	Biannually	4.00	12
Clever Devices	Annually	2.00	6
Coolant and System Care	Ongoing	0.32	12
Engine Tune Up	36,000 miles	5.10	6
Fire Suppression	Biannually	5.00	12
Fluid Analysis—Various	Varies	0.52	36
GFI Farebox Maintenance	Varies	1.10	7
Heavy Maintenance Overhaul	7.5 years	-	20
HVAC Inspection	90 days/monthly	4.32	24
Interior Cleaning	Monthly	2.00	69
Service Lane Activity	Daily	0.32	1501

A-inspection provides the primary Metrobus vehicle inspection and service, completed every 6,000 miles. It covers the entire vehicle including driver’s equipment and controls, passenger interior, vehicle exterior, engine and engine compartment, transmission, battery, chassis, lubrication, and articulation equipment (if pertinent) and culminates with a complete road test.

Each bus goes through daily and bi-weekly regular inspections to ensure day-to-day operations. Service lane activity is a daily cursory inspection concurrent with the routine refueling and service of the vehicle. It includes checking the farebox, fluid levels, lights, doors and interlocks. The interior is also swept, and the exterior is washed.

B-Inspection is done bi-weekly and follows a checklist of bus equipment condition and operation inspection which includes safety and weather-related equipment, passenger seats, stop chimes, doors, floors, windows, wheelchair equipment, brakes, axles, tires, battery, fluid levels, wires and hoses.

5.3.2 Mid-Life Overhaul

Mid-life overhaul, an integral part of the PM program, is another component of the fleet management plan. After reaching its mid-life, a Metrobus will have traveled over 230,000 miles. Many critical parts will wear out and basic overhauls will not be sufficiently able to maintain the expected performance.

Initiated in 1994, the Heavy Maintenance Overhaul Program provides for the rehabilitation of bus mechanical and electrical systems, including overhaul of the engine, transmission, pneumatic equipment, doors, wheelchair lifts, destination signs, suspension, and other structural components. In addition, the interior and exterior of the bus are repainted and all upholstery is replaced.

Heavy overhaul incorporates new technology and safety enhancements, keeps the fleet in compliance with air quality requirements, and permits standardization of configuration across bus fleets of varying ages. Buses undergoing mid-life overhaul is a function of the number of new buses purchased in a given year, available funding and manpower to complete the overhaul, as well as the fleet spare ratio.

On average, Metro plans to replace approximately 100 of its oldest vehicles with new buses each year. Over the years Metro’s procurement of buses has varied in numbers – the procurement of over 120 buses per year from 2005 to 2015 has created a residual backup of the mid-life overhaul program, due to demand above the typical capacity of 100 vehicles per year. This backup has caused some mid-life overhauls to occur at least one year beyond the recommended 7.5-year interval.

Currently, 20 buses are in overhaul process at any given time, and each week, the program accepts two in-service buses and releases two buses completing rehabilitation. In some cases, overhauls have been delayed due to previous years with uneven procurement of new vehicles without commensurate expansion of Metro’s heavy overhaul capacity. With the transfer of the heavy maintenance overhaul to Andrews Federal Center, it is anticipated that more capacity will be available to address the need for mid-life overhauls in the coming years. Table 5-3 illustrates the mid-life overhaul timing as of FY2020.

Table 5-3: Mid-Life Overhaul Schedule⁸²

Year Manufactured	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Quantity	21	147	100	119	105	105	80	246	0	112	100
2020 Rehab	6	4	84								
2021 Rehab			15	85							
2022 Rehab				34	66						
2023 Rehab					38	62					
2024 Rehab						43	57				
2025 Rehab							12	78			
2026 Rehab							11	78			
2027 Rehab								90		10	
2028 Rehab										95	
2029 Rehab										7	86
2030 Rehab											14

⁸² Schedule as of FY2020, for existing fleet.

5.3.3 Corrective Maintenance (CM)

With a substantial preventive maintenance program, Metro is able to optimize the corrective maintenance requirement and minimize the accompanying service quality degradation. However, unexpected breakdowns will occur even on new systems and components, and all corrective maintenance is required to be completed within 48 hours, unless awaiting shop repair or deferral for parts acquisition.

5.4 Maintenance Capacity for Fleet

There are four categories of maintenance at Metro as outlined below: warranty, shop, garage and retrofit. The capacity of Metro's operating maintenance is a function of the capacity of the divisions. The following summarizes each of the scheduled maintenance activities.

Warranty Maintenance: Service and repair of systems and equipment that are still under the manufacturer's warranty. This work is specified by the equipment manufacturer and is required to be accomplished in order to preserve the warranty on the product.

Shop Maintenance: Heavy repair shop work involving activities such as accident repair, scheduled equipment overhaul and unscheduled corrective maintenance (e.g. engine or transmission replacement).

Garage Maintenance: The bulk of Metrobus preventive and corrective maintenance is accomplished at the individual garage level.

Retrofit Maintenance: Activities at this level include manufacturer's recall repairs, and special item retrofits.

On an average weekday, up to 214 buses are expected to undergo different categories of maintenance including heavy overhaul. Since the previous fleet plan, the opening of Andrews Federal Center and Cinder Bed Road Divisions, along with the temporary closure of Northern Division for reconstruction, have led to a total garage storage capacity of 1,681. Metro's daily maintenance capacity is 214 vehicles, as shown in Table 5-4.⁸³

⁸³ This is a standing portion of parking capacity at Metrobus operating divisions which Metro applies as a planning assumption to ensure a balance between vehicles stored and maintenance operation capacity.

Table 5-4: Current Maintenance Capacity

Maintenance Type	Maintenance Capacity (2021)	% of Storage Capacity (2021)
Warranty	17	1.0%
Shop	47	2.8%
Garage	142	8.4%
Retrofit	8	0.5%
Total	214	12.7%
Total Parking Capacity	1,681	100%

5.5 Distribution of Maintenance Functions

Since the 2017 fleet plan, Metrobus has begun utilizing Cinder Bed Road division for heavy overhauls and Andrews Federal Center for both operating maintenance and heavy overhaul. Upon the completion of reconstruction activities at Northern, Southern Avenue Division is expected to close in approximately FY2026. Table 5-5 shows a summary of current Metro maintenance facilities.

Table 5-5: List of Maintenance Facilities

Division	Location	Facility Type
Andrews Federal Center	Prince George's County, MD	Operating Division and Heavy Repair
Bladensburg	District of Columbia	Operating Division
Cinder Bed Road	Fairfax County, VA	Operating Division
Four Mile Run	Arlington County, VA	Operating Division
Landover	Prince George's County, MD	Operating Division
Montgomery	Montgomery County, MD	Operating Division
Northern	District of Columbia	Operating Division
Shepherd Parkway	District of Columbia	Operating Division
Southern Avenue	Prince George's County, MD	Operating Division
West Ox	Fairfax County, VA	Operating Division
Western	District of Columbia	Operating Division
Carmen E. Turner	Prince George's County, MD	Heavy Repair

Currently there are 1,681 vehicle storage spaces in the ten operating divisions, which is above the fleet requirements. This capacity will increase to 1,785 vehicles in approximately FY2027, upon the reopening of Northern Division⁸⁴ and the completion of reconstruction activities at Bladensburg Division.⁸⁵

Metrobus currently has 166 maintenance bays available for operating maintenance at the ten operating divisions, 31 of which are capable of servicing articulated buses. With the completion of construction work at Northern in FY2026 and Bladensburg in FY2027, total maintenance bays will number 176, with 48 of those capable of accommodating articulated buses. Standard length buses are able to be serviced in articulated bus maintenance bays as needed.

Table 5-6: Operating Maintenance Bays at Metrobus Divisions, Current and Programmed

Garage	Total Maintenance Bays, FY21	Articulated Maintenance Bays, FY21	Total Maintenance Bays, FY27	Articulated Maintenance Bays, FY27
Andrews Federal Center	19	9	19	9
Bladensburg	23	6	26	11
Cinder Bed Road	13	7	13	7
Four Mile Run	17	0	17	0
Landover	16	0 ⁸⁶	16	0
Montgomery	17	3	17	3
Northern ⁸⁷	-	-	19	12
Shepherd Parkway	26	6	26	6
Southern Avenue	12	0	-	-
West Ox	9	0	9	0
Western	14	0	14	0
Total	166	31	176	48

Table 5-6 summarizes current and programmed overall maintenance bay capacity as well as articulated vehicle maintenance bay capacity. As indicated in Section 5.4, the current operating maintenance capacity is 214 buses.

⁸⁴ Northern is expected to re-open in FY2026.

⁸⁵ Reconstruction activities at Bladensburg are expected to complete in FY2027.

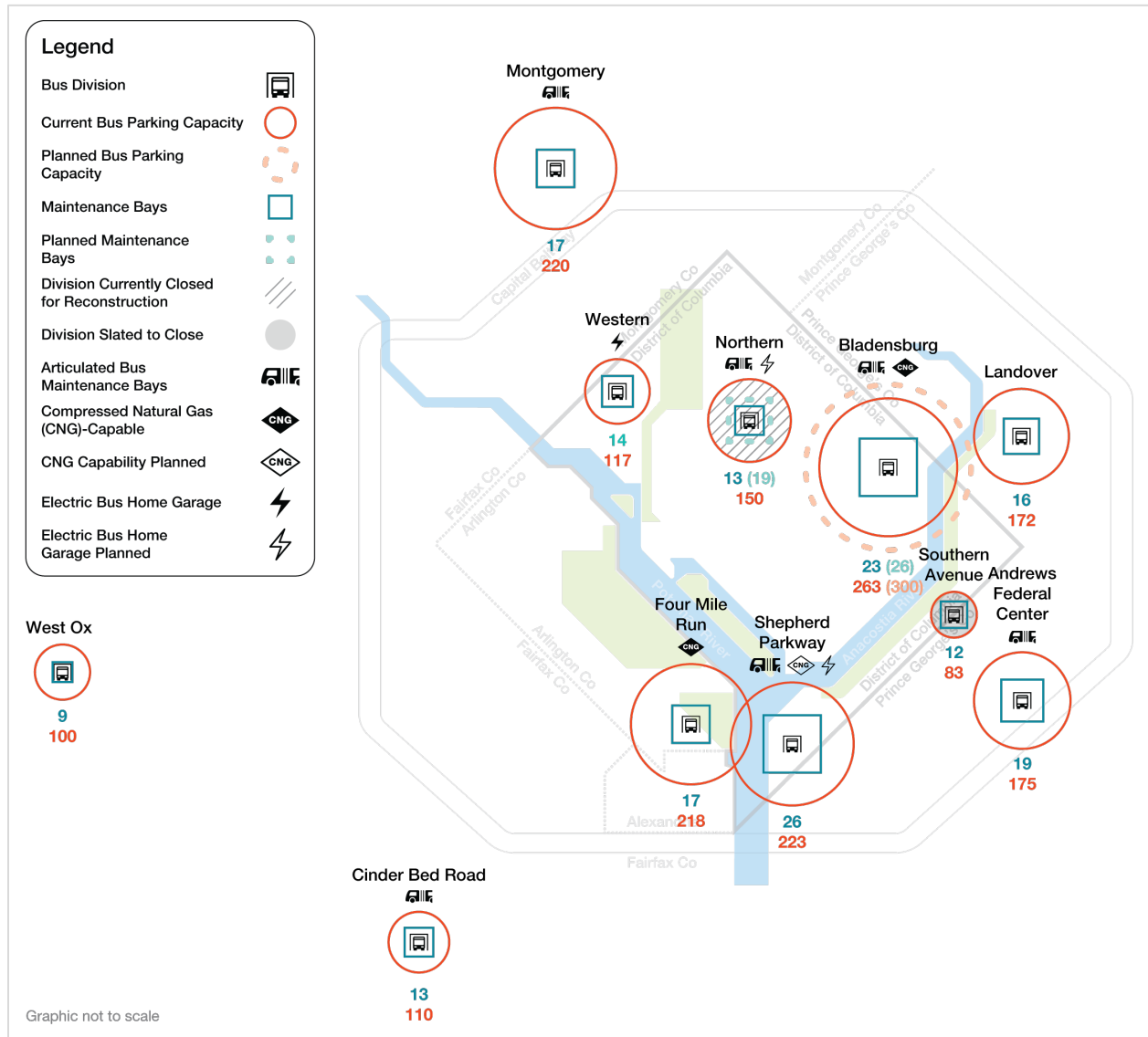
⁸⁶ Up to 8 articulated buses could be maintained on a temporary basis at Landover using portable lifts.

⁸⁷ Currently closed for reconstruction until FY2026.

Section 6. Facilities

This section documents Metrobus Facilities for operations, maintenance, heavy repair shop, heavy overhaul shop, and training facilities. Figure 6-1 shows the locations and functions of the facilities in the Metrobus system.

Figure 6-1: Metrobus Operating Divisions



6.1 Metrobus Facilities

As of December 2020, Metrobus vehicles are operated and maintained at ten operating and eleven maintenance facilities. Four operating and four maintenance facilities are located in the District of

Columbia, currently four operating and five maintenance facilities in Maryland and currently three operating and maintenance facilities in Virginia. Prior to the temporary closing of Northern Operating Division, Metro’s existing parking capacity was 1,831 buses. However, the 150-bus capacity at Northern division is currently unavailable while the facility is undergoing reconstruction, leading to a total existing garage capacity of 1,681. These construction efforts are expected to conclude in FY2026. Metro’s Bladensburg Operating Division is currently undergoing construction modifications, and its capacity will expand from 263 buses to 300 buses upon its completion in FY2027. After Northern construction is complete, Metro expects to discontinue operations at its Southern Avenue Operating Division, bringing its total parking capacity to 1,785 buses.⁸⁸

Two new Metrobus operating and maintenance facilities were opened in 2019: Cinder Bed Road, which currently houses 100 standard buses and 10 articulated buses, and Andrews Federal Center, which houses 148 standard buses and 27 articulated buses.

Metro has a compressed natural gas (CNG) capacity of 481 buses, or approximately 29% of the FY2021 fleet capacity, which will grow with the completion of CNG installation at Shepherd Parkway and expansion of CNG capacity at Bladensburg Road. The facility improvements currently programmed will allow up to 741 buses, or approximately 42% of Metro’s total fleet parking capacity, to be powered with CNG from approximately FY2027 onward.

Table 6-1: Compressed Natural Gas (CNG) Bus Fueling and Maintenance Capacity, as Programmed in FY2022

Fiscal Years	Facility Change	Total CNG Bus Fueling and Maintenance Capacity	Programmed Total Capacity	CNG as % of Total Capacity
FY20–FY22	None planned	481	1,681	29%
FY23–FY25	Shepherd Parkway CNG conversion completed in FY2023	704	1,681	42%
FY26	Northern re-opens, Southern closes	704	1,748	40%
FY27 onward	Bladensburg construction complete	741	1,785	42%

Two existing support facilities provide specialized maintenance services for the Metrobus System. The Carmen Turner Facility is a heavy maintenance and training facility in Prince George’s County in Maryland. Buses in need of major repairs are cycled through Carmen Turner Facility for major body work, paint and maintenance functions. The Andrews Federal Center Heavy Overhaul Shop, collocated

⁸⁸ Northern will add 150 spaces, Bladensburg will add 37 spaces, and the closure of Southern Avenue will reduce spaces by 83.

with the Andrews Federal Center Operating Division, is a heavy repair shop that serves as the home of the Metro Heavy Maintenance Overhaul Program.

6.2 Existing Metrobus Facilities

Metrobus divisions currently are designed and organized for a total parking capacity of 1,668 vehicles. In FY2026, Metrobus facilities will be able to accommodate a total of 1,785 vehicles, following the completion of reconstruction activities at Northern and Bladensburg Divisions. While seven Metro facilities are capable to store and maintain articulated buses, Landover Division is not configured to do so on a permanent basis.

Currently, Metro can store 174 articulated buses at six divisions. This capacity will increase to a total of 324 articulated buses upon the completion of reconstruction at Northern and Bladensburg Divisions.

Table 6-2: Parking Capacity by Division, as Programmed in FY2022

Division	Total Parking Capacity, FY22	Articulated Parking Capacity, FY22	Total Parking Capacity, FY27 onward	Articulated Parking Capacity, FY27 onward
Andrews Federal Center	175	27	175	27
Bladensburg	263	25	300	100
Cinder Bed Road	110	10	110	10
Four Mile Run	218	-	218	-
Landover	172	8	172	8
Montgomery	220	24	220	24
Northern	-	-	150	75
Shepherd Parkway	223	80	223	80
Southern Avenue ⁸⁹	83	-	-	-
West Ox	100	-	100	-
Western	117	-	117	-
Total	1,681	174	1,785	324

Andrews Federal Center: Andrews Federal Center Bus Garage is located in Forestville, Maryland. Operations began in July 2019, following the rerouting of bus routes that had previously terminated at the Southern Avenue facility. Heavy Overhaul functions, Central Warehouse, Non-Revenue Vehicle Service Shop, Bus Engineering, and the Signs & Shelters Shop that originally operated out of Bladensburg were transferred to this facility.

⁸⁹ Southern Avenue Division is expected close in FY26 upon the reopening of Northern Division.

Bladensburg: Bladensburg Bus Division located at 2251 26th Street NE in the District of Columbia. The original division was constructed in 1962 and is currently being reconstructed and replaced with a safe, modern facility built to LEED standards for storage and maintenance of Metro's bus fleet. The new facility will have CNG and diesel support capabilities. During the construction period, CNG fueling capability will become available at the Shepherd Parkway bus division. Bladensburg currently has capacity for 238 standard buses and 25 articulated buses. When the new facility opens in FY27 (the estimated opening date), it will have capacity for 200 standard buses and 100 articulated buses. Metro is working to ensure this facility is electric bus-ready when it re-opens, though additional infrastructure and planning steps would be required.

Carmen Turner Facility: The Carmen Turner Facility is a heavy maintenance and training facility in Prince George's County in Maryland. Buses in need of major repairs are cycled through Carmen Turner Facility for major body work, paint and maintenance functions. While buses used for training or special service are parked at Carmen Turner, which is located directly across Pennsy Drive from Landover Division, there are no plans to expand revenue bus parking and routine maintenance functions to Carmen Turner at this time.

Cinder Bed Road: Cinder Bed Road Division was built as a replacement for the Royal Street Division, which was closed in 2014. This division is located along Cinder Bed Road in the Newington area of Fairfax County. This facility currently has capacity for 110 buses (100 standard buses and 10 articulated buses).

Four Mile Run: Four Mile Run Division is located on South Eads Street between Four Mile Run and 32nd Street South in Arlington County, Virginia. The project site is split by South Glebe Road and the site was reduced in size due to adjacent roadway widening in the 1980s. This division is one of the two divisions where CNG buses can be fueled, stored, and maintained. This Division has a storage capacity of 218 standard buses and 17 maintenance bays.

Landover: Landover Division is located on Pennsy Drive between Landover and New Carrollton Metrorail Stations in Prince George's County, Maryland. Landover Division has capacity for 164 standard and 8 articulated buses and has 16 standard maintenance bays. A major service lane and storage area project was completed in 2016 that improved operations of the facility.

Montgomery: Montgomery Division is located on Marinelli Road between Citadel Avenue and Nebel Street near White Flint Metrorail Station in Montgomery County, Maryland. Montgomery Division has a capacity for 220 buses, including 196 standard and 24 articulated buses. This location also has 17 maintenance bays, 3 of which can accommodate articulated buses.

Northern: Northern Division is located on 14th Street NW between Buchanan Street NW and Decatur Street NW in Washington, DC. After its reconstruction, articulated buses will be stored and maintained at Northern. This division was closed in 2019 and is scheduled to be fully reconstructed – built to LEED standards – with a capacity of 75 standard buses and 75 articulated buses with an anticipated reopening

in FY2026. In September 2021, Metro announced plans for Northern to be its first all-electric bus garage upon reopening.⁹⁰

Shepherd Parkway: Shepherd Parkway Division was constructed and opened in 2012 and is located near the intersection of Blue Plains Drive SW and DC Village Lane SW in southwest Washington, DC. Shepherd Parkway Division has a capacity for 223 buses, including 143 standard buses and 80 articulated buses. There is a total of 26 maintenance bays, six of which can be used for articulated buses. A new CNG fueling facility is under construction at Shepherd Parkway which will add new capability to support the CNG fleet. Shepherd Parkway has been chosen to house a test pilot of 12 electric buses.

Southern Avenue: Southern Avenue Division is located near the intersection of Southern Avenue and Marlboro Pike in Prince George's County, Maryland, near the District of Columbia border. Southern Avenue Division has a capacity for 83 standard buses and has 12 maintenance bays. This division was planned for closure upon the opening of the new Andrews Federal Center Division but remains open to maintain the capacity lost from Bladensburg and Northern divisions when their reconstruction work began. Southern Division is expected to close after construction efforts at Northern conclude, but these plans have not been finalized.

West Ox: West Ox Division is located on Alliance Drive between Piney Branch Road and Fairfax County Parkway in Fairfax County, Virginia. This Division has a storage capacity for 100 standard buses, with nine maintenance bays. This location replaced the former Arlington Division. Metro has limited to no ability to initiate reconstruction at this Fairfax County-owned facility.

Western: Western Division is located near the intersection of Jenifer Street NW and 44th Street NW in the Friendship Heights neighborhood of Washington, DC. Western Division has a capacity for 117 standard sized buses and has a total of 14 maintenance bays.

6.3 Maintenance Facilities Requirements

Metro currently has a lower proportion of articulated buses in its fleet compared to nine similar large peer transit agencies, at around 4% of its total fleet. Its ability to house additional articulated buses is constrained by maintenance bay capacity (i.e. maintenance bays that can service 60' three axle buses), which major operators aim to keep at a ratio of 10 vehicles to each bay. Metro currently has 31 articulated-capable maintenance bays and a total parking capacity for 174 articulated buses. While the current fleet of articulated buses can be accommodated by the existing maintenance bays, the suggested capacity ratio would be exceeded if Metro grows the articulated fleet to meet total parking capacity. Tables showing the capacity of each operating division by propulsion type are found in this document's appendix.

⁹⁰ <https://www.wmata.com/about/news/First-all-electric-bus-garage-to-be-built-at-Northern-bus-facility.cfm>

Metro’s existing and programmed facilities will offer sufficient capacity to accommodate the planned increase in the size of the Metrobus articulated fleet. However, current Metrobus facilities and infrastructure are not sufficient to support the anticipated growth of the electric bus fleet. As a result, this plan has identified the facilities gaps expected through FY2038, and estimates the total number of facilities which will require conversion to accommodate these new vehicles. Table 6-3 summarizes these capacity gaps.

Table 6-3: Division Needs, Existing and Planned Vehicle Capacity, Selected Years

	FY25	FY30	FY35	FY38
Electric Bus Storage Capacity	13	163	163	163
Electric Bus Fleet Size	63	288	785	1,048
Electric Bus Capacity Gap	50	125	622	885

In September 2021, Metro announced plans to reopen Northern Bus Garage with the infrastructure and equipment needed to operate 100% electric vehicles.⁹¹ This facility’s 150-bus capacity will support the conversion of the Metrobus fleet to be fully zero-emission by 2045.

The average Metrobus operating division has a capacity of approximately 165 buses, with the smallest division having a capacity of 83 and the largest a capacity of 263. Starting in FY24 and continuing in FY25, Metro will require at least one additional partial facility conversion to accommodate the storage and fueling of its projected FY25 electric bus fleet size of 63 vehicles. The electric bus fleet will continue to grow over time, requiring the equivalent of five or more facility conversions by FY38.

Due to these identified facilities’ needs, significant capital investment will be required to support Metro’s transition to an electric fleet. Section 6.5 discusses the extent to which each operating division may be conducive to electric-capable reconstruction.

Metro’s existing and programmed CNG support capacity is generally expected to be able to support the anticipated size of the CNG fleet. Depending on ultimate vehicle delivery and retirement dates, some CNG buses may be decommissioned after 12 years in service.⁹² The CNG bus fleet’s unmet storage and fueling needs will peak in FY27, when the estimated CNG fleet size of 764 vehicles will outstrip programmed system capacity by 23 vehicles. In FY28, the fleet size will outstrip available capacity by 14 vehicles. Metro expects to be able to maintain and fuel its CNG fleet without the

⁹¹ <https://www.wmata.com/about/news/First-all-electric-bus-garage-to-be-built-at-Northern-bus-facility.cfm>

⁹² Metro generally plans to operate standard length vehicles in service for 15 years in accordance with its useful life benchmarks. The Federal Transit Administration establishes a minimum useful life of at least 12 years of service for large, heavy-duty transit buses.

construction of additional CNG facilities beyond programmed work at Shepherd Parkway and Bladensburg.

6.4 Electric Bus Facility Requirements

Metro is initiating an electric bus test and evaluation and is developing a transition plan for zero-emission buses. Metro envisions a scaled approach to the conversion to electric or other zero-emission technologies that will account for future technical advances, costs, scalability, current and future constraints, and all other aspects that can be foreseen and addressed. Metro will work to determine what can be accomplished within current power grid capabilities, as well as with power grid and facility upgrades that would support eventual conversion of the Metrobus fleet to 100% electric or other zero-emission operation at each facility. This plan will outline the key pieces of a coordinated approach across multiple regional agencies and stakeholders to support the successful evolution of the Metrobus fleet.

Metro currently has one electric bus based at Western Division and is planning to commence a 12-bus test and evaluation program at Shepherd Parkway. Upon the completion of construction work, Bladensburg Division is expected to have the potential to house electric buses, pending the completion of design work to install charging infrastructure and support equipment. Northern is planned to open with full electric bus support capabilities.

Metrobus facilities will require adjustments as fleet needs evolve in the coming years. Chargers, conduits, transformers, and other equipment will need to be installed in each garage offering electric bus support. Garage configurations in some cases may require modifications to ceiling height or parking and maintenance area dimensions. Electric bus technology is also expected to introduce new facility needs for parts and materials storage. Safety considerations and protocols must also be taken into account as new equipment is stored or installed at Metro facilities.

6.5 Electric Bus Expansion at Metrobus Facilities

Metro faces varying considerations when evaluating electric bus support at its existing operating divisions. The reconstructed Northern Division is expected to be completed in FY2026 and will reopen as Metro's first operating division capable of full all-electric bus support.⁹³ Considerations for electric facility conversion at Metrobus divisions include:

Andrews Federal Center: This new facility was not built to accommodate electric service. It may be a candidate for long-term retrofit to support electric vehicles.

Bladensburg: This division is undergoing reconstruction and rehabilitation. Metro expects this facility to be designed to be electric-bus ready, though installation of the required charging infrastructure and other support systems would be required, and continue to support CNG buses.

⁹³ <https://www.wmata.com/about/news/First-all-electric-bus-garage-to-be-built-at-Northern-bus-facility.cfm>

Cinder Bed Road: This newer facility is not electric bus-ready and may require a conversion of its parking lot to accommodate overhead charging.

Four Mile Run: While this division is located adjacent to a Dominion Energy substation, recent development in the area suggests it may not have the capacity to support electric bus charging requirements. In addition, space to expand the facility is limited. While it is likely the division will continue to house only CNG vehicles in the near future, it could be modified as part of substation upgrades with storage to accommodate limited electric bus layovers or fast-charging equipment.

Landover: Landover has been identified as a potential location to support electric buses, but a 1.35-mile extension of electric utility capability from a nearby BGE substation, as well as a potential redistricting to Pepco to operate the system's full capacity of electric vehicles, may be required to do so. Landover's location across Pennsy Drive from the Carmen Turner Facility has been identified as a strategic reason to consider prioritizing its conversion to electric bus support.

Montgomery: This division is directly adjacent to a planned upgrade of Pepco's White Flint substation. Connections between the substation and division with feeders may be feasible in the coming years. As the facility may already be a higher priority for renovation in the coming years, it could be considered for future garage electrification.

Shepherd Parkway: Shepherd Parkway has been chosen to house a test pilot of 12 electric buses, in part due to its strategic proximity to Metrobus operating territory in the District of Columbia, Northern Virginia and Prince George's County, Maryland. The implementation of new feeders could potentially be coordinated with any potential expansion of electrical capacity at the District of Columbia Public Schools bus storage site directly to the south of this division.

Southern Avenue: This division is expected to close following the completion of reconstruction efforts at Northern Division, though these plans have not been finalized. It is not currently targeted for upgrades to accommodate electric bus charging.

West Ox: Metro has limited ability to spearhead facility reconstruction at this facility, which is operated in partnership with Fairfax County.

Western: Western Division currently houses Metro's first and only electric bus, and its proximity to a Pepco substation and older condition, poising it for other reconstruction needs, suggest it may be a good site for conversion to accommodate additional electric buses. The facility likely does not have room to expand beyond its current footprint.

Appendix

Appendix A: Additional Materials and Information

Acronyms

ADA	Americans with Disabilities Act
APC	Automatic passenger counter
BMNT	Metro's Office of Bus Maintenance
BRT	Bus rapid transit
BTP	Bus Transformation Project
CM	Corrective maintenance
CNG	Compressed natural gas
CO	Carbon monoxide
CO ₂	Carbon dioxide
DDOT	District Department of Transportation
FTA	Federal Transit Administration
GHG	Greenhouse gas
MCDOT	Montgomery County Department of Transportation
MDBF	Mean distance between failures
MPDGE	Miles per diesel gallon equivalent
MWCOG	Metropolitan Washington Council of Governments
NO _x	Nitrogen Oxide
PCN	Priority Corridor Network
PM	Preventive maintenance
PM ₁₀	Particulate matter 10 micrometers or smaller
PM _{2.5}	Particulate matter 2.5 micrometers or smaller
PVR	Peak vehicle requirement
RNG	Renewable natural gas
SOP	Standard operating procedure
STRF	Short-term ridership forecast
TPB	Transportation Planning Board
VOC	Volatile Organic Compound
WMATA	Washington Metropolitan Area Transit Authority

Definition of Terms

Articulated Bus – A bus 60 feet or longer, typically with two sections linked together by a pivoting joint.

Authority – The Washington Metropolitan Area Transit Authority.

Corrective Maintenance – Unscheduled maintenance to respond to unexpected vehicle breakdowns, malfunctions and accidents.

Electric Bus – A bus which is powered by one or more on-board electric batteries rather than some other fuel source.

Elevator Bus – Shuttle buses required to operate bus bridge service between adjacent Metrorail stations during times when their elevators are out of order.

Headway Management Bus – Scheduled buses which fill in for late buses on specific headway-managed routes.

Maximo – Metro’s enterprise asset management system.

Mean Distance Between Failures – A measure which reports the number of miles between chargeable service interruptions. The higher the mileage for the mean distance between failure, the more reliable the bus fleet.

Mid-Life Overhaul – The rehabilitation of the mechanical and electrical systems of a bus, including overhaul of the engine, transmission, pneumatic equipment, doors, wheelchair lifts, destination signs, suspension, and other structural component overhauls and repairs.

Operating Division – A location where buses are stored, maintained, and serviced.

Peak Vehicle Requirement – The maximum number of vehicles that Metro regularly deploys in service, excluding spare vehicles and vehicles set aside for other purposes.

Preventive Maintenance – A program of scheduled maintenance intended to keep equipment in good working order, prevent in-service failures, and meet certain vehicle regulatory requirements.

Range – The distance a bus is able to travel in revenue service without requiring refueling or recharging.

Ready Reserve Bus – Older vehicles, not scheduled in regular service, which are suitable for passenger service to support regular revenue operations or special events, accommodate approved temporary service changes, replace buses that are removed from service for fleet failures and provide buses for emergency situations.

Spare Ratio – The number of spare vehicles (as defined by subtracting the Peak Vehicle Requirement from the total active fleet) divided by the Peak Vehicle requirement.

Strategic Bus – Scheduled buses which are placed to be available to support a variety of routes in the event of unforeseen delays or disruptions in the provision of service.

Zero-Emission Bus – A bus which does not emit pollutants at the tailpipe in operation.

A1: Socioeconomic and Demographic Changes in the Washington Metropolitan Area, 2010–2019

The following review of socio-economic and demographic changes in the Washington-Arlington-Alexandria, DC-MD-VA-WV Metro Area for the 2010-2019 period supports the discussion of Metrobus ridership in Section 2. The data used in the analysis is drawn from United States Census Bureau and American Community Survey (ACS) data.

As Table A-1 shows, population in the Washington-Arlington-Alexandria, DC-MD-VA-WV Metro Area (which is not coterminous with Metro’s service area), grew by nearly 12% between 2010 and 2019. The number of employed persons in the civilian workforce increased by 15% over the same period. The percentage of the population that was employed in the civilian workforce increased from 52.4% to 53.8% from 2010 to 2020.

Table A-1: Population in the Washington-Arlington-Alexandria, DC-MD-VA-WV Metro Area⁹⁴

Year	Population	Civilian Labor Force-Employed	% of Population Employed
2010	5.61	2.94	52.4%
2011	5.70	2.99	52.5%
2012	5.80	3.08	53.1%
2013	5.95	3.14	52.8%
2014	6.03	3.18	52.7%
2015	6.10	3.25	53.3%
2016	6.13	3.27	53.3%
2017	6.22	3.34	53.7%
2018	6.25	3.37	53.9%
2019	6.28	3.38	53.8%
Change, 2010–2019	11.9%	15.0%	
Change, 2014–2019	4.1%	6.3%	

⁹⁴ Source: United States Census Bureau American Community Survey (ACS).

Table A-2 shows that median income in the Washington region increased by 25% between 2010 and 2019, and 16% just since 2014. The increase from 2014 to 2019 was, nearly twice the rate of inflation over the same time period.

Table A-2: Median Income in the Washington Metropolitan Region⁹⁵

Year	Median Household Income
2010	\$84,523
2011	\$86,680
2012	\$88,233
2013	\$90,146
2014	\$91,193
2015	\$93,294
2016	\$95,843
2017	\$99,669
2018	\$102,180
2019	\$105,659
Change, 2010-2019	25.0%
Change, 2014-2019	15.9%

⁹⁵ Source: United States Census Bureau American Community Survey (ACS).

The number of households with incomes below \$25,000 per year—households in which a large share of Metrobus customers live—dropped between 2010 and 2019. As shown in Table A-3, the Washington region added nearly 210,000 households from 2010 to 2019—an increase of more than 10%. Over the same time period, the number of households with incomes less than \$25,000 declined by more than 14%, with almost all of that decline (13.6%) occurring since 2014. The percentage of households with incomes below \$25,000 declined from 12.2% in 2010 and 11.5% in 2014 to 9.5% in 2019.

Table A-3: Washington Metropolitan Region Households and Their Incomes, 2010–2019⁹⁶

Year	Total Households	Income <\$25,000	% of Households with an Income <\$25,000
2010	2,042,154	249,778	12.2%
2011	2,071,390	250,419	12.1%
2012	2,085,494	240,133	11.5%
2013	2,133,062	246,965	11.6%
2014	2,154,147	248,357	11.5%
2015	2,172,310	236,117	10.9%
2016	2,191,806	251,823	11.5%
2017	2,203,717	229,101	10.4%
2018	2,234,559	231,573	10.4%
2019	2,251,002	214,478	9.5%
Change, 2010–2019	10.2%	-14.1%	
Change, 2014–2019	4.5%	-13.6%	

⁹⁶ Source: Census Bureau American Community Survey (ACS).

Table A-4 shows the number of households in the region with access to one, two, and three or more vehicles, for each year between 2010 and 2019. While the number of households in the region increased by 10.2%, the number of households with access to at least one vehicle increased by 11.7% between 2010 and 2019. While the number of “zero-car households” in the region remained around 210,000 throughout the decade, the percentage of zero-car households fell from around 11.1% in 2010 to 9.9% in 2019.

Table A-4: Washington Metropolitan Region Households by Number of Accessible Vehicles, 2010–2019⁹⁷

Year	1 Vehicle	2 Vehicles	3+ Vehicles	At Least 1 Vehicle	% of Households
2010	666,634	733,570	415,605	1,815,809	88.9%
2011	695,390	747,294	409,924	1,852,608	89.4%
2012	699,486	745,955	423,844	1,869,285	89.6%
2013	701,047	782,166	436,312	1,919,525	90.0%
2014	726,223	774,708	443,652	1,944,583	90.3%
2015	723,518	784,926	445,395	1,953,839	89.9%
2016	719,214	784,674	465,551	1,969,439	89.9%
2017	725,490	804,757	463,373	1,993,620	90.5%
2018	732,567	804,696	481,843	2,019,106	90.4%
2019	743,339	806,894	478,170	2,028,403	90.1%
Change, 2010–2019	11.5%	10.0%	15.1%	11.7%	
Change, 2014–2019	2.4%	4.2%	7.8%	4.3%	

A2: Current Ridership Characteristics

Within the Metro service area, 5% of residents ride the bus to work during the morning peak period, according to the 2013-2018 American Community Survey 5-Year Estimates. This percentage includes both Metrobus and local bus service ridership. In areas of a quarter-mile walking distance to Metrobus lines, Metrobus commuting mode share reaches 9 percent. Since 2013, the mode share of commuters using bus transit has decreased from 7 to 5%, while the mode share of commuters using any mode of transit has decreased from 19 to 13 percent.

⁹⁷ Source: United States Census Bureau American Community Survey (ACS).

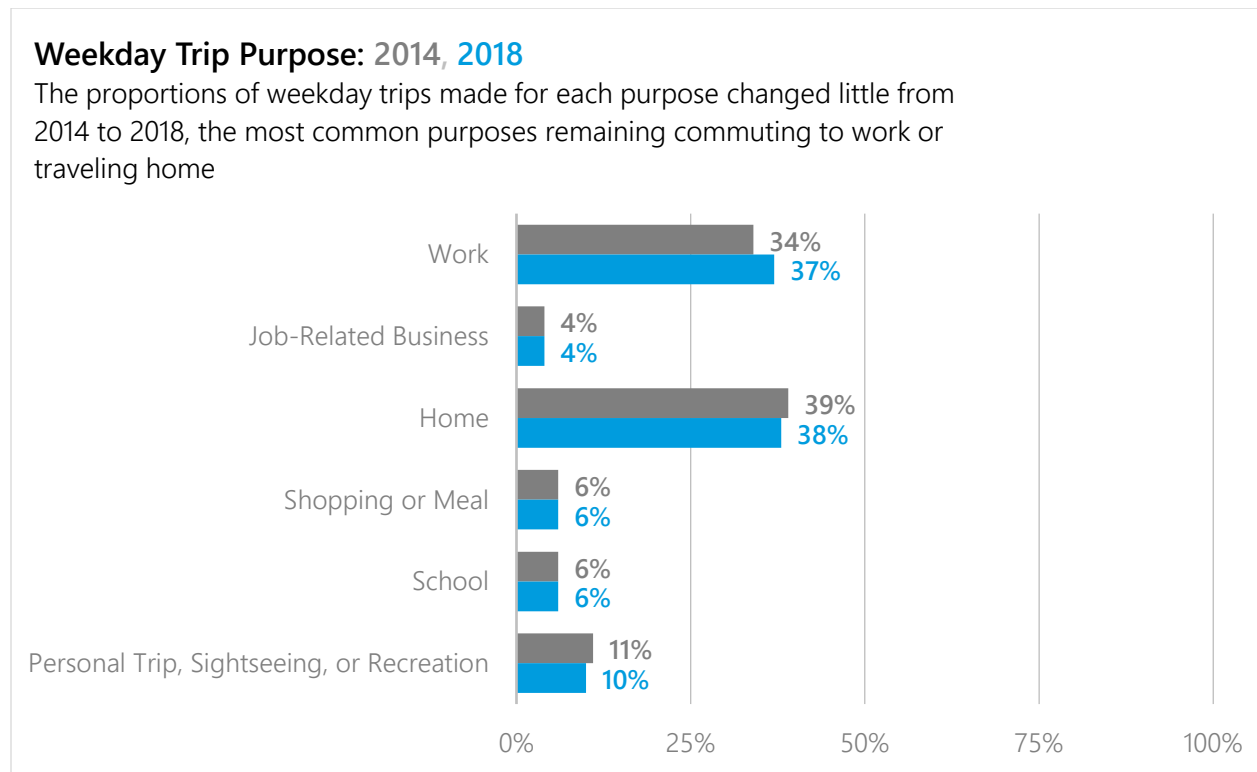
A Metrobus Passenger Survey was conducted in 2018, updating the previous surveys conducted in 2014 and 2008. The results of the survey illuminated many characteristics of Metrobus ridership, as discussed in this section.

In accordance with Metro's survey standardization practice, methodological updates occurred between 2014 and 2018 data reporting to improve comparability of metrics with other data collected by the Authority. Included in this practice is the reporting of valid survey percent instead of percent of total surveys. Unless otherwise specified, average weekday results are reported.

A3: Purpose of Metrobus Trips

The Metrobus Passenger Survey determined trip purpose by stated destination, tabulated into six categories: work, home, shopping or eating, school, job-related business, and personal trips/sightseeing/recreation. Results for 2014 and 2018 are shown in Figure A-2. Trips to work or work-related trips accounted for 41 percent of trips in 2018, or two-thirds of all trips if home-return trips (38 percent of the total in 2018) are eliminated. The percentage of work-related trips increased from 38 percent in 2014 to 41 percent in 2018, possibly reflecting the lower unemployment rate in the latter year. The percentage of personal, sightseeing or recreation trips declined from 11 to 10 percent between 2014 and 2018. The percentages of trips made for other purposes (school and shopping or meals) remained at 6 percent for 2014 and 2018.

Figure A-1: Weekday Trip Purpose, 2014 and 2018⁹⁸



A4: Characteristics of Metrobus Passengers—Ethnicity & Socioeconomic Factors

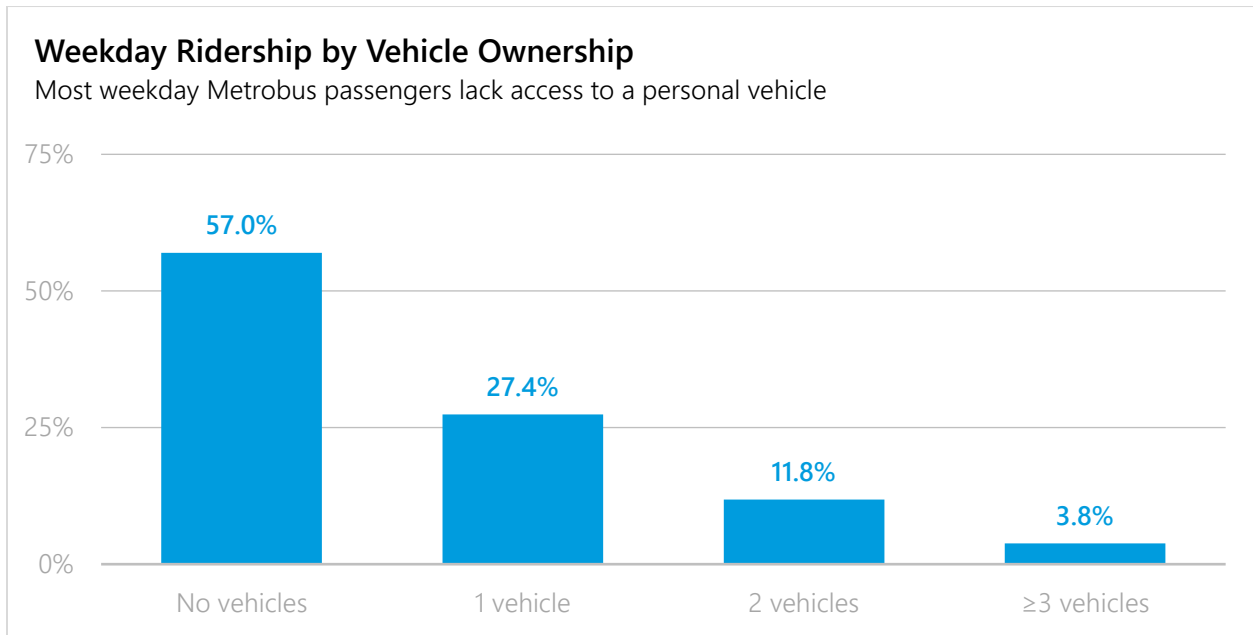
More than half (58%) of Metrobus riders are African American, though the proportion of African Americans fell, and the proportion of Hispanics and whites increased, between the 2014 and 2018 surveys. Metrobus riders span the income spectrum, with twelve percent reporting annual incomes of over \$100,000 per year in 2018. However, nearly half (45%) reported household incomes below \$30,000 per year. The proportion of riders with incomes below \$75,000 per year fell between 2014 and 2018, while the proportion with higher incomes increased.

A5: Vehicle Ownership

According to the 2018 Metrobus Passenger Survey, 43 percent of Metrobus riders are in household with at least one vehicle. Vehicle ownership for Metrobus riders is outlined in Figure A-2.

⁹⁸ Source: 2018 Metrobus Passenger Survey.

Figure A-2: Weekday Ridership by Vehicle Ownership⁹⁹



⁹⁹ Source: 2018 Metrobus Passenger Survey.

A6: Mode of Access

The 2018 Metrobus Passenger Survey used mode of access evaluate how passengers arrive at Metrobus stops prior to boarding the bus. Responses indicate that 70% of riders walked to Metrobus stops, whereas 27.5% arrived from Metrorail or other public transit service.¹⁰⁰ The remaining respondents used other modes of access to reach their destination, as shown in Table A-5.

Table A-5: Mode of Access for Weekday Ridership¹⁰¹

Access Mode	Percentage
Walked	70.0%
Wheelchair	0.7%
Metrorail	13.0%
Other bus service	12.0%
Drove a car and parked	2.0%
Dropped off by someone	2.0%
Ride-hailing service (e.g. Uber, Lyft, Via)	2.0%
Bicycle	0.6%
Rode own bicycle	0.6%
Bikeshare	0.5%
Amtrak, MARC or VRE	0.1%
Taxi	0.5%
Rode with someone who parked	0.5%
HOV or HOT Carpool	0.3%
Scooter-sharing service	0.1%
Vanpool	0.1%

¹⁰⁰ Including Metrobus, another bus service, Amtrak, MARC, or VRE.

¹⁰¹ Source: 2018 Metrobus Passenger Survey.

A7: Additional Information

Table A-6: Bus Comparison Chart, Lifecycle Cost Analysis¹⁰²

Length	40'	40'	40'	40'	40'
Propulsion Type	Diesel	Hybrid (Diesel)	CNG ¹⁰³	Battery-Electric Bus	Fuel Cell Bus
Lifespan (Years) ¹⁰⁴	15	15	15	12	12
Range (Miles)	>300	>300	>300	150 ¹⁰⁵	250
2021 Est. Capital Cost (Including Midlife Overhaul)	\$710,000	\$900,000	\$800,000	\$1,025,000	\$1,375,000
2021 New Facility Costs ¹⁰⁶	N/A	N/A	N/A	\$300,000	\$100,000
Total Capital Cost ¹⁰⁷	\$710,000	\$900,000	\$800,000	\$1,325,000	\$1,475,000
2020 Fuel Cost	\$2.09	\$2.09	\$0.72	\$0.085	\$7.5
Fuel/Energy Unit	gallon	gallon	diesel gallon eq.	kWh	kg
Miles/Fuel Unit (e.g. Miles/Gal)	3.48	4.31	3.36	0.33	8.00
Cost/Mile	\$0.60	\$0.49	\$0.21	\$0.26	\$0.94
Annual Fuel Cost	\$18,594	\$15,038	\$6,640	\$7,905	\$29,063

¹⁰² Costs are depicted on a per bus basis.

¹⁰³ Metro is currently issuing a procurement for Renewable Natural Gas (RNG), which would further reduce CNG emissions.

¹⁰⁴ Useful life benchmark assumption for standard 40' buses. All articulated 60' buses will have a 12-year assumed useful life benchmark.

¹⁰⁵ Battery-electric bus range is especially impacted by weather and ambient temperature, and can drop below this range under some conditions.

¹⁰⁶ Facility conversion not required for Diesel or Hybrid buses. Expansion of CNG capacity is not anticipated.

¹⁰⁷ Includes vehicle purchase capital costs and facilities and equipment expansion costs for low-emissions buses. Estimates for standard 40' buses, includes PPA warranty (if not standard for manufacturer inclusion) and midlife overhaul costs.

Table A-6: Bus Comparison Chart, Lifecycle Cost Analysis (Continued)¹⁰⁸

Length	40'	40'	40'	40'	40'
Propulsion Type	Diesel	Hybrid (Diesel)	CNG ¹⁰⁹	Battery-Electric Bus	Fuel Cell Bus
Labor/Mile	\$0.59	\$0.66	\$0.68	\$0.90	\$0.90
Materials/Mile	\$0.30	\$0.34	\$0.30	\$0.30	\$0.37
Services/Mile	\$0.20	\$0.20	\$0.31	\$0.20	\$0.31
Fluids	\$0.05	\$0.04	\$0.03	\$0.02	\$0.02
Tires	\$0.08	\$0.08	\$0.08	\$0.09	\$0.09
Annual Maintenance Cost	\$38,239	\$40,929	\$43,251	\$46,531	\$51,960
Total Annual Operating Cost ¹¹⁰	\$56,832	\$55,967	\$49,891	\$54,436	\$81,022
Total Capital Cost ¹¹¹	\$710,000	\$900,000	\$800,000	\$1,325,000	\$1,475,000
12 Year Lifecycle Cost Est.	N/A	N/A	N/A	\$1,978,232	\$2,447,267
15 Year Lifecycle Cost Est.	\$1,562,485	\$1,739,511	\$1,548,365	N/A	N/A
Average Annual Total Cost ¹¹²	\$104,166	\$115,967	\$103,224	\$139,853	\$195,606
Average Annual Total Cost with One-Time Facility Cost ¹¹³	\$104,166	\$115,967	\$103,224	\$164,853	\$203,939
Average Annual Cost Increase over Clean Diesel	N/A	11%	-1%	34%	88%
Average Annual Cost Increase over Clean Diesel (Including Facilities)	N/A	11%	-1%	58%	96%

¹⁰⁸ Costs are depicted on a per bus basis.

¹⁰⁹ Metro is currently issuing a procurement for Renewable Natural Gas (RNG), which would further reduce CNG emissions.

¹¹⁰ Annual maintenance and fuel cost.

¹¹¹ Includes vehicle purchase capital costs and facilities and equipment expansion costs for low-emissions buses. Estimates for standard 40' buses, includes PPA warranty (if not standard for manufacturer inclusion) and midlife overhaul costs.

¹¹² Average annual total cost is calculated to include operating and vehicle purchase capital costs. Capital costs are not incurred annually, but are included on a per-year basis for purposes of comparison. Facility expansion costs are not included.

Table A-7: Detailed Vehicle Emissions by Fuel Type¹¹⁴

Bus Type	Diesel	Diesel Electric Hybrid	Compressed Natural Gas	Renewable Natural Gas ¹¹⁵	Battery-Electric ¹¹⁶	Hydrogen Fuel Cell
Annual Total Greenhouse Gases						
Annual Total Pollutants						
GHG (short tons)	122.2	97.6	87.8	16.5	25.0	63.0
CO (pounds)	186.3	102.9	1861.4	1687.4	21.1	96.4
NOx (pounds)	299.0	287.5	115.5	-11.4	35.3	161.2
PM10 (pounds)	16.0	15.3	14.0	0.4	16.3	32.5
PM2.5 (pounds)	5.1	4.5	3.2	-10.3	3.7	11.6
VOC (pounds)	28.9	25.2	31.8	-57.5	6.0	27.4

¹¹⁴ Emissions values derived from Argonne National Laboratory’s AFLEET analysis, which sources data from the EPA’s MOVES emission factor model (for diesel, hybrid, electric and fuel cell buses), and Argonne Lab’s GREET Model for CNG.

¹¹⁵ Renewable Natural Gas. Assumed emphasis on landfill gas, which Washington Gas notes as the most readily available in the region. [Link](#).

¹¹⁶ Battery-electric and hydrogen fuel cell buses may emit non-exhaust PM2.5 and PM10 through tire wear, brake wear, etc.

Table A-7: Detailed Vehicle Emissions by Fuel Type (Continued)

Bus Type	Diesel	Diesel Electric Hybrid	Compressed Natural Gas	Renewable Natural Gas ¹¹⁷	Battery-Electric ¹¹⁸	Hydrogen Fuel Cell
Annual Vehicle Operation Pollutants¹¹⁹						
CO (pounds) ¹²⁰	154.7	77.4	1779.6	1779.6	0.0	0.0
NOx (pounds)	239.0	239.0	12.0	12.0	0.0	0.0
PM10 (pounds)	12.1	12.1	12.1	12.1	11.7	11.7
PM2.5 (pounds)	1.9	1.9	1.9	1.9	1.5	1.5
VOC (pounds)	9.7	9.7	6.1	6.1	0.0	0.0

¹¹⁷ Renewable Natural Gas. Assumed emphasis on landfill gas, which Washington Gas notes as the most readily available in the region.

https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/03/Fact-Sheet_RNG_in_DC_vFINAL.pdf

¹¹⁸ Battery-electric and hydrogen fuel cell buses may emit non-exhaust PM2.5 and PM10 through tire wear, brake wear, etc.

¹¹⁹ Battery-electric and hydrogen fuel cell buses may emit non-exhaust PM2.5 and PM10 through tire wear, brake wear, etc.

¹²⁰ Past Altoona Bus Research and Testing Center evaluation

<https://mjbradley.com/sites/default/files/CNG%20Diesel%20Hybrid%20Comparison%20FINAL%2005nov13.pdf> has suggested CNG buses have annual CO emissions of approximately 350-950 pounds per year, depending on make, model, average vehicle speed and other operating conditions. Past testing of Metrobus vehicles (<https://www.nrel.gov/docs/fy03osti/33280.pdf>) with enhanced CO mitigation technology suggested the potential for improvements in this area.

Table A-7: Detailed Vehicle Emissions by Fuel Type¹²¹ (Continued)

Bus Type	Diesel	Diesel Electric Hybrid	Compressed Natural Gas	Renewable Natural Gas ¹²²	Battery-Electric ¹²³	Hydrogen Fuel Cell
Annual Upstream Pollutants						
CO (pounds)	31.6	25.5	81.8	-92.2	21.1	96.4
NOx (pounds)	60.0	48.5	103.5	-23.3	35.3	161.2
PM10 (pounds)	3.8	3.1	1.9	-11.7	4.6	20.8
PM2.5 (pounds)	3.2	2.6	1.3	-12.2	2.2	10.1
VOC (pounds)	19.2	15.5	25.7	-63.7	6.0	27.4

¹²¹ Emissions values derived from Argonne National Laboratory’s AFLEET analysis, which sources data from the EPA’s MOVES emission factor model (for diesel, hybrid, electric and fuel cell buses), and Argonne Lab’s GREET Model for CNG.

¹²² Renewable Natural Gas. Assumed emphasis on landfill gas, which Washington Gas notes as the most readily available in the region.
https://washingtongasdcclimatebusinessplan.com/wp-content/uploads/2020/03/Fact-Sheet_RNG_in_DC_vFINAL.pdf

¹²³ Battery-electric and hydrogen fuel cell buses may emit non-exhaust PM2.5 and PM10 through tire wear, brake wear, etc.

Table A-8: Facility Capacity by Propulsion Type, FY2021-FY2038

Garage	Fuel Type	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Andrews	Diesel	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Andrews	Hybrid	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Andrews	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrews	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bladensburg	Diesel	263	263	263	263	263	263	300	300	300	300	300	300	300	300	300	300	300	300
Bladensburg	Hybrid	263	263	263	263	263	263	300	300	300	300	300	300	300	300	300	300	300	300
Bladensburg	CNG	263	263	263	263	263	263	300	300	300	300	300	300	300	300	300	300	300	300
Bladensburg	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinder Bed	Diesel	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
Cinder Bed	Hybrid	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
Cinder Bed	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cinder Bed	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Four Mile Run	Diesel	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Four Mile Run	Hybrid	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Four Mile Run	CNG	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Four Mile Run	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landover	Diesel	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
Landover	Hybrid	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
Landover	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Landover	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table A-8: Facility Capacity by Propulsion Type, FY2021-FY2038 (Continued)

Garage	Fuel Type	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Montgomery	Diesel	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Montgomery	Hybrid	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Montgomery	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Montgomery	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern	Diesel	0	0	0	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150
Northern	Hybrid	0	0	0	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150
Northern	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Northern	Electric	0	0	0	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150
Shepherd	Diesel	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
Shepherd	Hybrid	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
Shepherd	CNG	0	0	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
Shepherd ¹²⁴	Electric	0	0	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Southern	Diesel	83	83	83	83	83	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Hybrid	83	83	83	83	83	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Ox	Diesel	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
West Ox	Hybrid	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
West Ox	CNG	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Ox	Electric	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

¹²⁴ The impact of the electric bus test and evaluation on overall garage capacity is to be determined.

Table A-9: Total Capacity and Gaps by Propulsion Type, FY2021–FY2038

Garage	Fuel Type	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Total Capacity	Diesel	1681	1681	1681	1681	1681	1748	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785
Total Capacity	Hybrid	1681	1681	1681	1681	1681	1748	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785
Total Capacity	CNG	481	481	704	704	704	704	741	741	741	741	741	741	741	741	741	741	741	741
Total Capacity	Electric	1	1	13	13	13	163	163	163	163	163	163	163	163	163	163	163	163	163
Total Fleet Level	Diesel	260	318	368	368	368	368	357	357	341	341	341	341	299	299	274	220	50	0
Total Fleet Level	Hybrid	861	857	809	648	610	448	364	343	323	223	123	40	0	0	0	0	0	0
Total Fleet Level	CNG	435	417	464	539	614	689	764	755	741	741	741	725	707	620	620	601	582	545
Total Fleet Level	Electric	1	1	13	38	63	88	113	138	188	288	388	487	587	687	785	867	961	1048
Capacity Gap	Diesel	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capacity Gap	Hybrid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Capacity Gap	CNG	0	0	0	0	0	0	-23	-14	0	0	0	0	0	0	0	0	0	0
Capacity Gap	Electric	0	0	0	-25	-50	0	0	0	-25	-125	-225	-324	-424	-524	-622	-704	-798	-885

Table A-10: Garage Capacity by Bus Length, FY2021–FY2038

Garage	Fuel Type	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Andrews	Standard	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148	148
Andrews	Artic	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27	27
Andrews	Total	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
Bladensburg	Standard	238	238	238	238	238	238	200	200	200	200	200	200	200	200	200	200	200	200
Bladensburg	Artic	25	25	25	25	25	25	100	100	100	100	100	100	100	100	100	100	100	100
Bladensburg	Total	263	263	263	263	263	263	300	300	300	300	300	300	300	300	300	300	300	300
Cinder Bed	Standard	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Cinder Bed	Artic	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Cinder Bed	Total	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
Four Mile Run	Standard	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Four Mile Run	Artic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Four Mile Run	Total	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218	218
Landover	Standard	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164	164
Landover	Artic	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Landover	Total	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172	172
Montgomery	Standard	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196	196
Montgomery	Artic	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
Montgomery	Total	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220	220
Northern	Standard	0	0	0	0	0	75	75	75	75	75	75	75	75	75	75	75	75	75
Northern	Artic	0	0	0	0	0	75	75	75	75	75	75	75	75	75	75	75	75	75
Northern	Total	0	0	0	0	0	150	150	150	150	150	150	150	150	150	150	150	150	150

Table A-10: Garage Capacity Table by Bus Length, FY2021–FY2038 (Continued)

Garage	Fuel Type	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Shepherd	Standard	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143	143
Shepherd	Artic	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Shepherd	Total	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223	223
Southern	Standard	83	83	83	83	83	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Artic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Southern	Total	83	83	83	83	83	0	0	0	0	0	0	0	0	0	0	0	0	0
West Ox	Standard	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
West Ox	Artic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
West Ox	Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Western	Standard	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117
Western	Artic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Western	Total	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117	117
All	Total	1681	1681	1681	1681	1681	1748	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785	1785

Table A-11: 2019 and 2038 APC Adjusted Weekday Ridership and Ridership Change by Corridor

Corridor ID	Corridor Name	APC Adjusted Weekday Ridership May 2019	APC Adjusted Weekday Ridership 2038 Forecast	Ridership Change 2019–2038
1	Columbia Pike	12,193	12,544	2.9%
2	Richmond Hwy Express	2,588	2,327	-10.1%
3	Crystal City / Potomac Yard	2,867	2,633	-8.2%
4	Georgia Ave / 7th St (DC)	21,498	23,244	8.1%
5	National Harbor	2,578	2,412	-6.4%
6	Route 410 West	5,765	6,412	11.2%
7	Pennsylvania Ave / Wisconsin Ave	21,854	22,811	4.4%
8	Sixteenth St	15,553	16,492	6.0%
9	Leesburg Pike	5,227	5,519	5.6%
10	Veirs Mill Rd	6,078	6,806	12.0%
11	H St / Benning Rd	16,286	16,713	2.6%
12	New Hampshire Ave-MD	6,458	6,520	1.0%
13	U St / Garfield	13,612	13,712	0.7%
14	Georgia Ave (MD)	7,046	6,850	-2.8%
15	Anacostia / Congress Heights	19,227	19,169	-0.3%
17	Route 410 East	7,113	7,827	10.0%
18	Little River Turnpike / Duke St	3,275	3,308	1.0%
19	Rhode Island Ave (Metro to Laurel)	5,130	5,368	4.6%
20	Rhode Island Ave (DC)	4,717	5,150	9.2%
21	Eastover / Addison	6,085	5,992	-1.5%
22	Colesville Rd / Columbia Pike (MD US 29)	7,413	7,233	-2.4%
23	Fourteenth St	13,950	14,916	6.9%

Corridor ID	Corridor Name	APC Adjusted Weekday Ridership May 2019	APC Adjusted Weekday Ridership 2038 Forecast	Ridership Change 2019–2038
24	North Capitol St	6,845	7,508	9.7%
25	MacArthur Blvd / K St / Trinidad	12,642	13,920	10.1%
26	Tysons	378	424	12.1%
27	Brookland	7,247	7,793	7.5%
28	Maryland Ave	1,139	1,418	24.4%
29	Fort Washington	1,893	1,721	-9.1%
30	Central Ave	1,868	2,183	16.8%
31	Kings Park	1,281	1,351	5.5%
32	Springfield	2,048	1,928	-5.8%
33	Wilson Blvd	3,851	4,369	13.5%
34	Landmark	643	647	0.6%
35	Ballston / Pentagon	4,653	4,619	-0.7%
36	Petworth	8,894	9,021	1.4%
37	Lincolnia	5,838	6,068	3.9%
38	Bowie	2,232	2,263	1.4%
39	Connecticut Ave (DC)	4,434	4,674	5.4%
40	Connecticut Ave (MD)	2,022	2,036	0.7%
41	Greenbelt	3,019	3,135	3.9%
43	Hunting Point	4,169	4,229	1.4%
44	Chain Bridge Rd	288	267	-7.3%
45	Washington Blvd	2,937	3,464	17.9%
46	Lee Hwy	1,049	1,490	42.0%
48	Capitol Heights / Marshall Heights / Benning Heights	1,096	1,270	15.9%
49	Bladensburg Road-Anacostia	9,366	9,668	3.2%

Corridor ID	Corridor Name	APC Adjusted Weekday Ridership May 2019	APC Adjusted Weekday Ridership 2038 Forecast	Ridership Change 2019–2038
50	Anacostia-Eckington	4,672	4,702	0.7%
51	District Heights	3,081	3,608	17.1%
52	Riggs Rd	5,219	5,220	0.0%
53	Fairfax Village	0	0	0.0%
54	Shipleigh Terrace-Ft. Drum	2,070	1,893	-8.6%
55	United Medical Ctr / Anacostia	3,844	3,747	-2.5%
56	Alabama Ave	8,306	8,013	-3.5%
57	Garfield / Anacostia	3,073	3,022	-1.7%
58	P Street-LeDroit Park	1,613	1,932	19.7%
59	Park Rd / Brookland	4,008	4,208	5.0%
60	Clinton	2,281	2,541	11.4%
61	Forestville	3,392	3,507	3.4%
62	270 / Twinbrook / Silver Spring	0	0	0.0%
63	Mt Pleasant	5,780	6,335	9.6%
64	East Capitol	5,855	6,097	4.1%
65	Oxon Hill	4,266	4,671	9.5%
66	Military Rd	4,772	4,429	-7.2%
67	Annapolis Rd	5,656	5,956	5.3%
68	Minnesota Ave / M St	19,129	19,460	1.7%
69	Massachusetts Ave	3,475	3,457	-0.5%
70	MLK Hwy-DC	2,476	2,750	11.0%
71	Takoma-Fort Totten	663	694	4.6%
72	Central NOVA	1,665	2,056	23.5%
73	Central PGC	3,175	3,552	11.9%
74	College Park-White Flint	2,626	2,738	4.3%

Corridor ID	Corridor Name	APC Adjusted Weekday Ridership May 2019	APC Adjusted Weekday Ridership 2038 Forecast	Ridership Change 2019–2038
75	Eastern NOVA	1,681	2,327	38.4%
76	Fort Lincoln / Brookland	2,312	2,364	2.2%
77	Northern PGC	4,144	4,517	9.0%
78	Stanton Road	0	0	0.0%
79	Western DC	1,650	1,632	-1.1%
80	River Road	1,195	1,127	-5.7%
81	Western NOVA	4,694	4,963	5.7%
82	South Dakota/18th St NE	1,433	1,514	5.6%
100	University Blvd	9,151	9,888	8.0%
400	Airport	1,401	1,597	14.0%
600	Special	0	0	0.0%
	Total	425,104	443,770	4.4%

Table A-12: Metrobus Fleet Procurement and Retirement Schedule Through FY2038 (Standard Length Buses)

Vehicle Type		FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Standard Diesel	Fleet Owned by Metro (Start of Year)	168	218	276	326	326	326	326	315	315	299	299	299	299	299	299	274	220	50
Standard Diesel	Retirements	4	112	0	0	0	0	11	0	16	0	0	0	0	0	25	54	170	50
Standard Diesel	Deliveries	54	170	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Standard Diesel	Vehicles on Site (End of Year)	218	276	326	326	326	326	315	315	299	299	299	299	299	299	274	220	50	0
Standard Hybrid	Fleet Owned by Metro (Start of Year)	888	824	824	776	615	577	415	331	331	311	211	123	40	0	0	0	0	0
Standard Hybrid	Retirements	64	0	48	161	38	162	84	0	20	100	88	83	40	0	0	0	0	0
Standard Hybrid	Deliveries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Standard Hybrid	Vehicles on Site (End of Year)	824	824	776	615	577	415	331	331	311	211	123	40	0	0	0	0	0	0
Standard CNG	Fleet Owned by Metro (Start of Year)	443	435	417	464	520	576	632	666	625	611	611	611	595	577	490	490	490	490
Standard CNG	Retirements	83	18	3	0	0	0	0	84	64	0	0	16	18	87	0	0	0	18
Standard CNG	Deliveries	75	0	50	56	56	56	34	43	50	0	0	0	0	0	0	0	0	0
Standard CNG	Vehicles on Site (End of Year)	435	417	464	520	576	632	666	625	611	611	611	595	577	490	490	490	490	472
Standard Electric	Fleet Owned by Metro (Start of Year)	1	1	1	11	30	49	68	80	94	144	244	332	431	489	589	689	752	827
Standard Electric	Retirements	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	12	0	7
Standard Electric	Deliveries	0	0	10	19	19	19	12	14	50	100	88	100	58	100	100	75	75	75
Standard Electric	Vehicles on Site	1	1	11	30	49	68	80	94	144	244	332	431	489	589	689	752	827	895

Table A-13: Metrobus Fleet Procurement and Retirement Schedule Through FY2038 (Articulated Buses)

Vehicle Type		FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38	
Articulated Diesel	Fleet Owned by Metro (Start of Year)	0	42	42	42	42	42	42	42	42	42	42	42	42	0	0	0	0	0	
Articulated Diesel	Retirement	0	0	0	0	0	0	0	0	0	0	0	0	42	0	0	0	0	0	
Articulated Diesel	Deliveries	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Articulated Diesel	Vehicles on Site (End of Year)	42	42	42	42	42	42	42	42	42	42	42	42	0	0	0	0	0	0	
Articulated Hybrid	Fleet Owned by Metro (Start of Year)	54	37	33	33	33	33	33	33	12	12	12	0	0	0	0	0	0	0	
Articulated Hybrid	Retirement	17	4	0	0	0	0	0	21	0	0	12	0	0	0	0	0	0	0	
Articulated Hybrid	Deliveries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Articulated Hybrid	Vehicles on Site (End of Year)	37	33	33	33	33	33	33	12	12	12	0	0	0	0	0	0	0	0	
Articulated CNG	Fleet Owned by Metro (Start of Year)	22	0	0	0	19	38	57	76	95	95	95	95	95	95	95	95	95	76	57
Articulated CNG	Retirement	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	19	19	
Articulated CNG	Deliveries	0	0	0	19	19	19	19	19	0	0	0	0	0	0	0	0	0	0	
Articulated CNG	Vehicles on Site (End of Year)	0	0	0	19	38	57	76	95	95	95	95	95	95	95	95	76	57	38	
Articulated Electric	Fleet Owned by Metro (Start of Year)	0	0	0	2	8	14	20	26	33	33	33	45	45	87	87	85	104	123	
Articulated Electric	Retirement	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	6	6	6	
Articulated Electric	Deliveries	0	0	2	6	6	6	6	7	0	0	12	0	42	0	0	25	25	25	
Articulated Electric	Vehicles on Site (End of Year)	0	0	2	8	14	20	26	33	33	33	45	45	87	87	85	104	123	142	

Table A-14: Metrobus Fleet Procurement and Retirement Schedule Through FY2038 (Small Buses)

Vehicle Type		FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	FY35	FY36	FY37	FY38
Small Diesel	Fleet Owned by Metro (Start of Year)	27	27	27	27	27	27	27	5	0	0	0	0	0	0	0	0	0	0
Small Diesel	Retirements	0	0	0	0	0	0	22	5	0	0	0	0	0	0	0	0	0	0
Small Diesel	Deliveries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Diesel	Vehicles on Site (End of Year)	27	27	27	27	27	27	5	0	0	0	0	0	0	0	0	0	0	0
Small Hybrid	Fleet Owned by Metro (Start of Year)	19	19	19	19	19	19	19	12	0	0	0	0	0	0	0	0	0	0
Small Hybrid	Retirements	0	0	0	0	0	0	7	12	0	0	0	0	0	0	0	0	0	0
Small Hybrid	Deliveries	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Hybrid	Vehicles on Site (End of Year)	19	19	19	19	19	19	12	0	0	0	0	0	0	0	0	0	0	0
Small CNG	Fleet Owned by Metro (Start of Year)	6	6	0	0	0	0	0	22	35	35	35	35	35	35	35	35	35	35
Small CNG	Retirements	0	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small CNG	Deliveries	0	0	0	0	0	0	22	13	0	0	0	0	0	0	0	0	0	0
Small CNG	Vehicles on Site (End of Year)	6	0	0	0	0	0	22	35	35	35	35	35	35	35	35	35	35	35
Small Electric	Fleet Owned by Metro (Start of Year)	0	0	0	0	0	0	0	7	11	11	11	11	11	11	11	11	11	11
Small Electric	Retirements	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Small Electric	Deliveries	0	0	0	0	0	0	7	4	0	0	0	0	0	0	0	0	0	0
Small Electric	Vehicles on Site (End of Year)	0	0	0	0	0	0	7	11	11	11	11	11	11	11	11	11	11	11

Table A-15: Composition of Metrobus Fleet, Start of FY2022¹²⁵

Manufacturer	Model Year	Fuel Type	Length	Fleet Code	Buses in Fleet
Orion	2005	CNG	Small	Fleet 32	6
New Flyer	2006	Diesel	Standard	Fleet 37	112
New Flyer	2007	CNG	Standard	Fleet 38	15
New Flyer	2009	Hybrid	Standard	Fleet 42	20
New Flyer	2008-2009	Hybrid	Standard	Fleet 43	160
New Flyer	2009	Hybrid	Articulated	Fleet 44	4
New Flyer	2010	Hybrid	Standard	Fleet 45	140
New Flyer	2011-2013	Hybrid	Standard	Fleet 46	210
New Flyer	2012	Hybrid	Standard	Fleet 47	52
Orion	2012	Diesel	Small	Fleet 48	27
Orion	2012	Hybrid	Small	Fleet 49	19
New Flyer	2013	Hybrid	Standard	Fleet 50	9
NABI	2014	Hybrid	Standard	Fleet 52	94
NABI	2014	Hybrid	Standard	Fleet 53	10
New Flyer	2015	Hybrid	Articulated	Fleet 54	21
New Flyer	2015-2016	CNG	Standard	Fleet 55	164
New Flyer	2015-2016	Hybrid	Standard	Fleet 56	56
New Flyer	2016	Hybrid	Standard	Fleet 57	54
New Flyer	2016	Electric	Standard	Fleet 58	1
New Flyer	2018	CNG	Standard	Fleet 59	100
New Flyer	2018	Hybrid	Articulated	Fleet 60	12
New Flyer	2019	CNG	Standard	Fleet 61	75
New Flyer	2019	Diesel	Standard	Fleet 62	25
New Flyer	2020	Diesel	Standard	Fleet 63	25
New Flyer	2020	CNG	Standard	Fleet 64	75
New Flyer	2020	Diesel	Articulated	Fleet 65	10
New Flyer	2021	Diesel	Articulated	Fleet 66	32
New Flyer	2021	Diesel	Standard	Fleet 67	29
Total					1,557

¹²⁵ Includes training and Ready Reserve buses.

Appendix B: Fleet Demand Estimates, Additional Detail

B1: Productivity

Metro tracks four productivity measures: minimum passengers per revenue hour, mile, bus trip, and minimum percentage of unique ridership. Productivity guidelines differ by service type and service Tier 2, but not by time period. Lines or routes that fail to meet productivity guidelines may be modified to improve productivity. Changes could include the reduction of frequencies, which could reduce the number of buses required to operate the line or route.

Tables C-1 and C-2 show the guidelines for minimum passengers (boardings) per revenue hour and mile. These guidelines are the same for all time periods and thus are applicable to the PM Peak period, when Metro operates its highest number of vehicles.

Table B-1: Metrobus Minimum Passengers per Revenue Hour Target¹²⁶

Zone	BRT	Framework	Coverage
Tier 1	35	30	20
Tier 2	25	20	15
Tier 3	20	15	10

Table B-2: Minimum Passengers per Revenue Mile Target¹²⁷

Zone	BRT	Framework	Coverage	Commuter
Tier 1	5.0	4.0	4.0	1.5
Tier 2	2.0	2.0	2.0	1.0
Tier 3	2.0	1.0	1.0	1.0

Based on these guidelines, of the routes that operated in Fall 2019, about 29 routes fell below their assigned minimum passengers per revenue hour guideline, and 48 were below the minimum passengers per mile guideline.

B2: Reliability

Reliability of bus operations is defined by the difference between actual travel time and the scheduled travel time at the trip-link level. Routes are considered to have poor reliability if they fail to meet Metro's

¹²⁶ Source: Metrobus Service Guidelines December 2020. <https://www.wmata.com/about/board/meetings/board-pdfs/upload/4A-Metrobus-Service-Guidelines-CORR.pdf>

¹²⁷ Source: Metrobus Service Guidelines December 2020. <https://www.wmata.com/about/board/meetings/board-pdfs/upload/4A-Metrobus-Service-Guidelines-CORR.pdf>

service reliability guideline, departing from the time point no more than two minutes early or seven minutes late from the scheduled departure time. For headway-based service, reliability is measured as the percentage of timepoint pull-outs that are no greater than the scheduled service headway plus three-minutes after the pull-out time of the bus ahead. The current guideline is for the bus to depart on time 79% of the time. This guideline percentage applies for all Metrobus line classifications and all time periods.

Late running can be caused by many factors including unbalanced passenger loading, irregular headways, misallocated link travel time—that is, too much time on some links and not enough on others—and inadequate recovery time at the ends of each run. Usually, late running is caused by inadequate scheduled end-to-end running time. Several strategies exist for correcting late running that do not require adding service volume, such as correcting headway or link running time imbalances and improving travel speed by consolidating and moving bus stops or implementing bus signal priority along the bus route. Often, though, the only effective option for addressing late running is adding service volume to increase link running times and recovery time, in which case additional buses usually are required to operate the route.

Planners regularly assess whether routes have adequate travel time and address travel time using several operational strategies including monitoring the service by Service Operation Managers, reducing route length, and adding running time—which usually requires adding buses to the route.

Based on performance analysis on Fall 2019 Metro operations. For this analysis, routes that operated less than 69% of departures “not late” during the PM period were identified as potentially requiring an additional bus to provide reliable service. This more relaxed standard was used to account for potential over-counting of early departures, and the potential to address the late running using approaches that do not require additional vehicles. Based on this analysis, 19 routes potentially would require an additional bus to meet service reliability guidelines. The routes are listed in Table B-3.

Table B-3: Routes with Less than 69% of Departures Early or On-Time (“Not Late”) during PM Peak Period, Fall 2019

Rank	Route	Percent Not Late (2019)
1	17B	43.4%
2	7Y	49.6%
3	R2	50.6%
4	W8	51.7%
5	R1	52.7%
6	C4	52.8%
7	17M	52.9%
8	J4	53.2%
9	H6	55.5%
10	B8	55.7%
11	W6	56.4%
12	C2	57.9%
13	T14	58.4%
14	29N	59.4%
15	H1	59.7%
16	P12	60.8%
17	K6	61.0%
18	S4	61.3%
19	S2	63.0%

B3: Level of Crowding

Vehicle load factor is a performance measure used to determine crowding on a specific bus route and trip. Vehicles are considered “crowded” when they are running over 100-120% of their seated capacity. Excessive crowding onboard buses is unpleasant and potentially dangerous for passengers, and can slow the route, making it less reliable. The load factor is the number of people on the bus at the maximum load point divided by the vehicle capacity, usually expressed as a percentage of the number of seats on the buses used to operate the route. The load factor for service and vehicle adjustments in the current service guidelines varies by vehicle classification, headway and time period. Most routes, at most times, are considered over-crowded when passenger volume exceeds 100% of the seats on the bus (i.e., 40 passengers aboard a 40-foot bus, which typically has 40 seats) for more than 15% of their running time. This means that a bus operating on a route with a 60-minute end-to-end trip running time would exceed the guideline if it carried more than 40 passengers for more than nine minutes.

Buses operating headways less than 20 minutes have a more lenient crowding guideline of 120% (48 passengers aboard a 40-seat bus) for more than 15% of the trip running time. All commuter bus routes have a load target of no more than 100% of the seats due to the danger to passengers of standing while the bus operates at higher speeds.

Crowding is caused by a shortage of capacity at the bus routes peak load location and time period. However, crowding can occur even if sufficient capacity is being operated if delays are preventing sufficient capacity reaching the peak load point at the proper time. As with late running, schedule and stop location adjustments can be considered to address crowding before adding capacity. However, crowding usually only can be addressed by adding capacity during the peak time period, either by reducing headways or adding travel time to the routes. This usually requires adding buses to the route to operate the additional capacity.

Passenger crowding is a component of service quality that receives significant attention from Metro planners. They continuously monitor passenger feedback on this issue and regularly review data to determine the degree of crowding throughout the system. Lines that have a relatively large number of boardings per unit of service, are candidates for service expansion, which requires adding vehicles to the route.

A more detailed analysis and a stricter standard was applied in which routes were identified whose average peak load exceeded the average available seats during any PM peak hour, in any direction, in the Fall 2019. To avoid the variability of different route classes having different load factors, and to provide a stricter standard, a 100% load factor was applied to all routes. Eight routes were identified as having insufficient seats during at least PM peak hour. These routes are identified in Table B-4.

Table B-4: Routes Experiencing Crowding (100% Seated Load) During One or More Peak Hour, in One Direction, Fall 2019

Rank	Route	Division(s)	Jurisdiction(s)
1	30S	Andrews	MD
2	30N	Andrews	MD
3	V2	Southern	MD, DC
4	11Y	Four Mile	VA
5	W1	Shepherd	DC
6	54	Western	DC
7	79	Montgomery	DC, MD
8	S9	Montgomery	DC

Forecasts percentages of annual ridership increase were applied to the peak average peak loads by PM peak hour and direction to determine whether additional routes would experience crowding due to forecast ridership increases during the 2020-2038 period. Six additional routes were identified as potentially requiring additional buses to address crowding through 2038: Table B-5 lists the routes and the year in which the route likely would begin experiencing crowding based on ridership increase.

Table B-5: Routes Experiencing Crowding (100% Seated Load) During One or More Peak Hour, in One Direction, Through 2038

Route	Year	Division(s)	Jurisdiction(s)
42	2035	Western	DC
70	2037	Montgomery	MD
3Y	2038	West Ox	VA
8W	2031	Four Mile	VA
8Z	2026	Four Mile	VA
S4	2036	Montgomery	DC, VA, MD

B4: Service Design Measures

Service frequency or headway is used as the primary service design measurer, together with span of service and duplication of service. Service frequency, or headway, is the service interval between buses on a bus route. For demand-driven routes carrying high ridership, headway is determined by the number of vehicles required to provide enough capacity to serve demand during peak, and in many cases during mid-day periods. For policy driven routes with lower ridership, frequency is determined based on the service guidelines that correspond to the route’s classification, service tier, and the time period during which it is operating. Weekday maximum headway guidelines are shown in Table B-6.

Table B-6 Maximum Weekday Service Headway (Minutes)¹²⁸

Zone	BRT Peak	BRT Off-Peak	Frame-work Peak	Frame-work Off-Peak	Frame-work Premium	Coverage Peak	Coverage Off-Peak	Commuter
Tier 1	10	15	15	15	12	30	60	Varies based on demand
Tier 2	15	20	20	20	15	30	60	Varies based on demand
Tier 3	30	30	30	60	30	60	60	Varies based on demand

Headway directly determines the number of vehicles required to operate a bus route (the number of buses required to operate a route can be calculated by dividing the running time, including of layover or recovery time, by the headway). Thus, headway has a direct impact on the fleet size, and even minor changes to Metro’s peak period headway guidelines, when extended across Metro’s more than 200 bus routes, can profoundly influence the number of buses that would be required to operate the Metrobus network.

Metro has 43 routes that operate longer peak period headways than indicated by the relevant service guideline, based on the routes’ service classification and activity tier. These routes are listed in Table B-7.

Table B-7: Routes Operating Greater than Specified Maximum Headway during Fall 2019 PM Peak Period

Route	Division(s)	Jurisdiction(s)
32	Andrews	DC
34	Andrews	DC
36	Andrews	DC
39	Andrews	DC
83	Landover	MD
86	Landover	MD
10A	Four Mile	VA
10B	Four Mile	VA
10E	Four Mile	VA

¹²⁸ Source: Metrobus Service Guidelines December 2020. <https://www.wmata.com/about/board/meetings/board-pdfs/upload/4A-Metrobus-Service-Guidelines-CORR.pdf>

Route	Division(s)	Jurisdiction(s)
16A	Four Mile	VA
1A	West Ox	VA
1B	West Ox	VA
1C	West Ox	VA
22A	Four Mile	VA
23B	Four Mile	VA
23T	Four Mile	VA
26A	West Ox	VA
29K	Cinder Bed	VA
29N	Cinder Bed	VA
2B	West Ox	VA
30N	Andrews	DC
30S	Andrews	DC
7A	Four Mile	VA
7F	Four Mile	VA
A7	Shepherd	VA
C4	Montgomery	MD
C8	Montgomery	MD
D12	Andrews	DC
D13	Andrews	DC
D14	Andrews	DC
H2	Bladensburg	DC
H4	Bladensburg	DC
J4	Montgomery	MD
K9	Bladensburg	DC, MD
NH2	Shepherd	DC
Q4	Montgomery	MD
R1	Bladensburg	DC, MD
R12	Landover	MD
V2	Southern	DC
X9	Bladensburg	DC
Y2	Montgomery	MD
Y8	Montgomery	MD
Z6	Montgomery	MD

B5: Summary of Network Performance and Fleet Requirements

As of December 2019, Metrobus' Peak Vehicle Requirement (PVR) for weekday roll-out was 1,270 buses.

Table B-8 shows the PVR by bus division and the system total as of December 16, 2020. PVR is calculated on the division level because many routes require a different number of buses in the AM and PM peak period service. When different routes with different AM and PM bus requirements are housed in the same bus division, buses that serve one route in the AM peak can be repurposed to serve another route in the PM peak. Balancing the supply and demand of buses at the division level reduces the actual total number of buses required to maintain an adequate level of revenue service.

Table B-8: Peak Vehicle Requirement (PVR) by Division, December 2019

Division	PVR
Bladensburg	216
Shepherd Parkway	166
Southern Ave	72
Andrews	71
Landover	148
Four Mile Run	178
West Ox	59
Cinder Bed	69
Montgomery	190
Northern ¹²⁹	0
Western	101
System Total	1,270

The PVR column shows the peak vehicle requirement for scheduled buses per operating division, which is the greater of the AM or PM peak vehicle requirement. Strategic fleet and headway management buses provide operational redundancy to assist in schedule/headway adherence, while elevator buses provide bus bridge service for Metrorail stations with elevator outages to serve riders who require elevators to access the stations.

Spares are calculated by multiplying the Total Maximum Scheduled Vehicle Count of 1,270 by 19.5%. This adds 248 vehicles to the fleet, bringing the total scheduled bus count to 1,518. To this total, Metro

¹²⁹ Northern Division closed for reconstruction until FY2026.

adds additional vehicles in ready reserve to the 1,270 Total PVR and 248 spares brings the total fleet need to 1,593.

B6: Estimate of Fleet Adequacy

The estimate of fleet adequacy analyzed the performance of Metrobus routes operating in Fall 2019 to determine whether the routes were meeting service guidelines for reliability, crowding, and maximum headway during the PM peak period, whether additional buses might be required for routes to meet the guidelines, and the number of buses that might be required to meet the guidelines. Service reliability, passenger crowding, and maximum headways considerations inform Metro's long-term planning of estimated total fleet demand. Through the deployment of an expanded articulated bus fleet, Metro expects to be able to respond to ridership demand and continue providing quality bus service to the region.

Appendix C: Cost Comparisons of Fleet Procurement Scenarios

C1: Procurement Approach Considerations

Metro's procurement approach must balance several factors: the capital costs of purchasing vehicles, the operating costs of fueling and maintaining those vehicles, the costs and time needed to upgrade existing operating divisions to accommodate new propulsion technologies (with temporary capacity loss during those reconstruction activities), the social cost of emissions to the Washington metropolitan region, as well as the challenges associated with utilizing emerging technologies.

Hybrid diesel-electric buses are not expected to be prioritized in future Metrobus procurements due to high capital costs and the development of cleaner alternatives. Diesel buses, while the least expensive to purchase, emit the highest level of pollutants, which runs counter to Metro's sustainability goals and those of other transit operators in the District of Columbia, Maryland and Virginia. The incorporation of new low NOx engines will also allow for reduced emissions from conventional levels. Compressed Natural Gas (CNG) buses have been proven to be a reliable vehicle for Metrobus, which offers moderate capital and operating costs with significantly reduced emissions from conventional diesel. Latest generation "Low NOx" CNG engines reduce Oxides of Nitrogen (NOx) emissions by 90% compared to existing diesel and hybrid buses. Metrobus is planning to incorporate Renewable Natural Gas (RNG) fueling into its fleet in the near future, which offers additional emissions reductions, particularly for carbon dioxide (CO₂). RNG, when made from waste that would usually emit methane, is in some cases considered "carbon negative" because the emissions that are avoided from the waste's conversion to RNG outweigh any emissions that would be caused from fuel production, transportation and use in a transit vehicle¹³⁰.

While zero-emission buses, such as those operating with battery-electric or hydrogen fuel cell power, entail the highest capital costs for Metro to purchase and require facility investments to be accommodated, operating cost savings and reduction of fleet emissions are possible with the incorporation of these vehicles, especially as the powertrain and battery technology continues to mature.

C2: Procurement Scenario Methodology

In comparing potential procurement paths, Metro evaluated several potential future fleet procurement, retirement, and composition scenarios. Metro's previous Board-adopted fleet procurement strategy called for even 50/50 procurement of diesel and CNG vehicles. For analysis purposes, this appendix compares that baseline scenario against the strategy adopted in this plan, which calls for the procurement approach described in Section 4 of this document.

¹³⁰ Source: US EPA AgSTAR. <https://www.epa.gov/agstar/renewable-natural-gas-agricultural-based-adbiogas-systems>

Vehicles are generally expected to be retired according to their useful life benchmark: 15 years of service for non-electric 40' buses, and 12 years of service for electric buses and all 60' (articulated) buses. In some instances, bus retirements may be delayed beyond the Useful Life Benchmark to ensure the fleet maintains a level size at or above the total fleet requirement of 1,593 vehicles.

After FY2023, when 112 buses are procured to account for the 12 additional electric buses dedicated to the Shepherd Parkway Test and Evaluation Program, vehicle deliveries remain smooth at 100 buses per year. The intention of this constant delivery schedule is to avoid instances in which a surplus of buses will retire in one year, followed by a shortage of retirements in a subsequent year, which causes fleet age, reliability, availability and spare availability to be inconsistent over time. The delayed retirements of some vehicles beyond their useful life benchmarks reduces unevenness in retirements, and thus the total fleet level.

All scenarios include procurement of 60' (articulated) buses that increase the size of the articulated bus fleet to 180 buses from FY2028 onwards. This recommendation, which will scale the articulated bus fleet to comprise approximately 12% of the active Metrobus fleet, is consistent with the analysis in Section 3 of this report.

From FY2024 onwards, the distribution of the 100 deliveries per year varies based on that scenario's chosen fuel mix proportion. Table C-1 depicts procurements by propulsion type for each scenario. The two scenarios discussed will be referred to as the "Baseline" scenario and the "2021 Metrobus Fleet Management Plan" scenario.

Table C-1: Bus Procurement Scenarios Summary, by Fiscal Year

Scenario	Fuel Type	FY24–FY28	FY29	FY30–FY33	FY34–FY38
Baseline	Diesel	50	50	50	50
	CNG	50	50	50	50
	Electric	0	0	0	0
2021 Metrobus Fleet Management Plan	Diesel	0	0	0	0
	CNG	75	50	0	0
	Electric	25	50	100	100

Tables C-2 through C-4 depict the comparative cost impacts of the analyzed scenarios.

Table C-2: Bus Fleet Propulsion Technology Scenario Comparison, Summary

	Baseline Scenario	2021 Metrobus Fleet Management Plan
Scenario Procurement Timeline	FY24-FY38 50% diesel / 50% CNG	FY24-28 75% CNG / 25% Electric FY29 50% CNG / 50% Electric FY30-38 100% Electric
Capital Cost (Vehicles)—Variance from Baseline Scenario ¹³¹	N/A	\$398M
Capital Cost (Facilities and Equipment)—Variance from Baseline Scenario ¹³²	N/A	\$579M
Operating Cost—Variance from Baseline Scenario ¹³³	N/A	(\$37M)
Total Cost—Variance from Baseline Scenario ¹³⁴	N/A	\$940M
Facility Conversion Needs ¹³⁵	N/A	6 or more electric bus facilities
Final Diesel Procurement/ Retirement	N/A N/A	FY2023 FY2038
First Year Full Electric Procurement	N/A	FY2030

¹³¹ Includes initial vehicle purchase and midlife vehicle overhaul. Inflated on 2% per annum basis, per Federal Reserve Guidelines.

¹³² Rough order of magnitude estimates for facility conversion costs per bus sourced from peer agency depot conversion assessments in California, Maryland and New Jersey.

¹³³ Includes fuel and maintenance costs, derived from Metrobus observed cost per mile data in FY 2019 and FY 2020.

¹³⁴ Sum of capital (vehicle acquisition and facilities expansion) and operating cost.

¹³⁵ Base CNG capacity, per current facility planning, is 741 vehicles beginning in FY2024. Base electric bus capacity is assumed to be 13 buses, including the Shepherd Parkway test and evaluation program, beginning in FY2023.

Table C-3: Metrobus Fleet Management Plan Annual Incremental Cost from Baseline Fuel Mix Scenario (USD \$000)

Value	FY2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Operating Costs	-	-	(396)	(807)	(1,235)	(1,679)	(2,164)	(2,351)	(2,267)	(2,462)	(2,375)	(3,315)	(3,240)	(2,293)	(3,480)	(3,800)	(4,675)
Capital Costs - Vehicles	-	-	14,459	14,496	14,531	14,564	14,840	16,007	31,998	35,104	27,168	38,674	26,091	32,970	52,064	39,185	25,709
Capital Costs - Facilities	5,100	10,404	10,612	10,824	11,041	16,892	34,461	46,866	47,206	46,850	48,409	49,757	44,500	43,191	46,208	51,754	54,983
Capital Costs - Total	5,100	10,404	25,071	25,320	25,572	31,457	49,301	62,873	79,205	81,954	75,577	88,431	70,591	76,161	98,272	90,939	80,692
Total Incremental Cost in Year	5,100	10,404	24,676	24,513	24,337	29,778	47,137	60,523	76,938	79,492	73,202	85,116	67,351	73,868	94,791	87,139	76,017

Table C-4: Metrobus Fleet Management Plan Cumulative Incremental Cost from Baseline Fuel Mix Scenario (USD \$000)

Value	FY2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Operating Costs	-	-	(396)	(1,202)	(2,437)	(4,116)	(6,280)	(8,631)	(10,897)	(13,359)	(15,734)	(19,049)	(22,289)	(24,582)	(28,062)	(31,862)	(36,537)
Capital Costs - Vehicles	-	-	14,459	28,955	43,486	58,050	72,890	88,897	120,896	155,999	183,167	221,841	247,932	280,902	332,966	372,150	397,860
Capital Costs - Facilities	5,100	15,504	26,116	36,940	47,981	64,874	99,334	146,201	193,407	240,257	288,665	338,423	382,923	426,114	472,322	524,076	579,059
Capital Costs - Total	5,100	15,504	40,575	65,895	91,467	122,924	172,225	235,098	314,302	396,256	471,833	560,264	630,854	707,016	805,288	896,226	976,918
Total Cumulative Incremental Cost	5,100	15,504	40,180	64,693	89,030	118,808	165,944	226,467	303,405	382,897	456,099	541,215	608,566	682,434	777,225	864,364	940,381