Metro Transit

Zero-Emission Bus Annual Report
2023

July 2024

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Prepared by Metro Transit in collaboration with AECOM.

Zero-Emission Bus Program Overview

Over the past two decades, Metro Transit has been continuously pursuing different initiatives to aid in sustainable transit operations. As part of Metro Transit's long-standing efforts to move toward greener operations, Metro Transit established a battery electric bus (BEB) pilot program as part of its implementation of the METRO C Line, an arterial Bus Rapid Transit (BRT) route traveling from downtown Minneapolis to Brooklyn Center that launched in June 2019. This battery electric bus pilot was Metro Transit's first implementation of Zero Emission Buses (ZEB). This pilot program included the purchase of eight New Flyer 60-foot Xcelsior Charge battery electric buses with 466 kilowatt-hour (kWh) batteries in addition to two on-route overhead conductive chargers installed at the Brooklyn Center Transit Center (BCTC), the route's northern terminus, and eight plug-in garage chargers and other associated charging infrastructure installed at the Fred T. Heywood (Heywood) Garage.

As of 2023, Metro Transit's Zero-Emission technology inventory includes:

- (8) 60-foot New Flyer Xcelsior Charge BEBs (466 kWh),
- (8) Siemens plug-in chargers (150 kW) located at the Heywood Garage.

Metro Transit's two one-route overhead conductive chargers (300 kW) located at BCTC were retired in 2023.

Zero-Emission Bus Transition Plan

Under state statute, the Metropolitan Council is responsible for developing a Zero-Emission Bus and electric vehicle transition plan and revising the plan at least once every three years (Minnesota Session Laws 2024 Regular Session Chapter 127 – HF 5247 Article 3 Section 106).[1] Metro Transit's initial Zero-Emission Bus Transition Plan (ZEBTP) was submitted to the Legislature in February 2022. The Transition Plan identifies short- (2022-2027), medium- (2028-2032), and long- (beyond 2033) term opportunities, risks, and implementation strategies to transition Metro Transit's bus fleet towards zero-emission technology. Refer to Section 2 of Metro Transit's Zero-Emission Bus Transition Plan (February 2022) for further discussion of the Transition Plan's purpose and context.

Transition Progress

Key progress in 2023 and early 2024 towards Metro Transit's zero-emission transition include:

- Purchasing 5 battery electric buses, 4 chargers, and charge management software to enter revenue service in 2025 as part of the Gold Line project (2023).
- Purchasing 20 40' battery electric buses, 22 chargers, and charge management software in support of local service routes (2024).
  - 12 buses and 15 chargers funded in part by a successful 2023 Low Emissions or No Emissions grant from the Federal Transit Administration (FTA).
  - Matching funds for 2023 Low Emissions or No Emissions grant provided by Minnesota Department of Transportation (MnDOT) Infrastructure Investment and Jobs Act (IIJA) match Program.

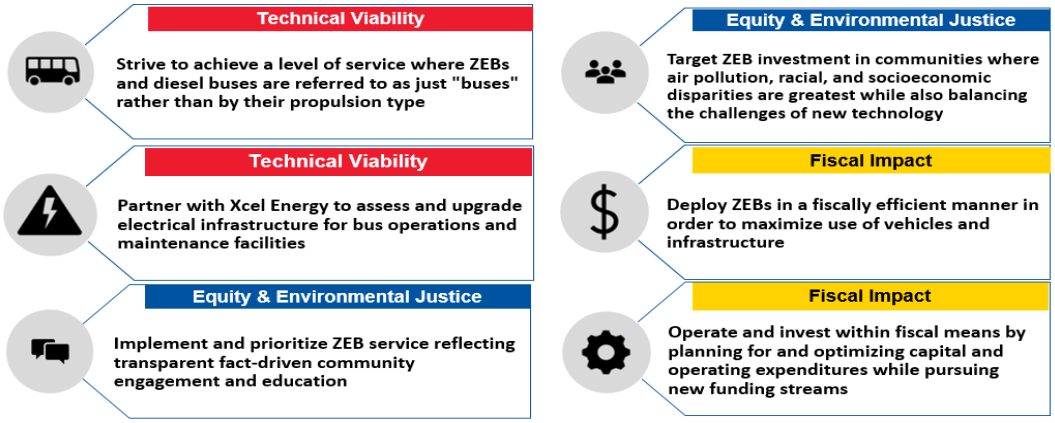
[1] When the ZEBTP was originally developed, state statute (Minn. Stat. 473.3927) required the Metropolitan Council to revise the plan at least once every five years. New state statute (posted 6/5/2024) requires plan revision at least once every three years.

- Projecting 21.5% of 40’ bus replacement as battery electric buses through 2024 (20% vehicle procurement target outlined in the transition plan).

Guiding Principles

Three guiding principles and six supporting actions were established as the framework for the Transition Plan and for use in defining what a successful transition towards ZEBs would look like (Figure 1). The guiding principles are: Technical Viability, Equity and Environmental Justice, and Fiscal Impact.

Figure 1: Zero-Emission Bus Transition Plan (2022) Guiding Principles and Supporting Actions



Key Performance Indicators (KPIs)

The Transition Plan established eight key performance indicators (KPIs) for annual reporting in alignment with the Transition Plan’s guiding principles (Table 1). This 2023 Annual Report documents the performance of Metro Transit’s Zero-Emission program from launch in 2019 through calendar year 2023. As of 2023, all of Metro Transit’s ZEB’s are battery electric buses (BEBs). A summary of the 2023 KPIs is presented in Table 2 followed by a more detailed summary of each indicator.

Table 1: Zero-Emission Bus Transition Plan Key Performance Indicators

KPI	Guiding Principle		
	Technical Viability	Equity & Environmental Justice	Fiscal Impact
Fleet Mileage	◆		◆
Bus Availability	◆		◆
Bus Reliability	◆	◆	◆
Environmental Impact		◆	
Equity and Environmental Justice (EEJ)		◆	
Energy Cost/Mile	◆		◆
Infrastructure Availability	◆		◆
Infrastructure Reliability	◆	◆	◆

Table 2: 2023 Annual KPI Summary

KPI	BEB 2022	BEB 2023*
Fleet Mileage*	175,300	117,400
Bus Availability *(% of BEBs Available for Use in Revenue Service)*	71%	49%
Bus Reliability *(Mean Distance Between Chargeable Road Calls)*	4,870	2,668
Environmental Impact** *(GHG [CO_2e] Reduction in Metric Tons)*	145	60
Equity and Environmental Justice (EEJ) *(% of BEB Deployments on "High Priority" EEJ Blocks)*	100%	100%
Energy Cost/Mile	$1.17 *($1.02 for diesel bus)*	$1.21 *($0.76 for diesel bus)*
Infrastructure Availability *(Avg. Full Days Available to Charge a Bus for Use in Revenue Service)*	Garage: 99.8%	Garage: 92%
Infrastructure Reliability *(Total incidents that take chargers out of service)*	Garage: 2	Garage: 8

** Rounded to the nearest 100 miles*

*** Rounded to the nearest 5 metric tons*

2023 Factors Impacting Multiple KPIs

Performance across multiple battery electric bus KPIs declined in 2023. This was largely influenced by two factors:

1. On-route charger retirement; and
2. Numerous bus high voltage battery pack replacements.

Metro Transit removed on-route chargers from service in June 2023 due to ongoing reliability and safety issues. After several months of investigation, these chargers were permanently retired. As Metro Transit service changes are only implemented quarterly, many battery electric buses did not have sufficient range capacity to complete their scheduled vehicle task until schedules were reduced to reflect a garage-only charging strategy in December 2023. During this period, many battery electric buses needed to be swapped in order to complete their route resulting in increased roadcalls and fewer battery electric bus miles driven. If a battery electric bus was not available, service was provided with a diesel bus to ensure overall service reliability to customers.

In 2023, a significant number of battery electric bus high voltage battery pack replacements were needed. Although battery pack replacement was completed by the manufacturer under warranty, these replacements led to extended out-of-service times reducing the number of battery electric bus miles driven and decreasing battery electric bus availability and reliability.

In 2021, battery electric buses were out of service from March to November while plug-in chargers at the Heywood Garage were replaced under warranty. Therefore, 2021 data referenced throughout this report reflects data for the approximately 90 days the battery electric buses were in service.

Fleet Mileage

What is Being Measured?

- The total number of miles driven by battery electric buses each year.

How is it Being Measured?

- Total odometer miles for the battery electric buses.

Why is it Important?

- As Metro Transit makes progress towards transitioning its fleet to zero emission buses, including battery electric buses, the total number of fleet miles driven by zero emission buses will increase. Comparing annual vehicle mileage for battery electric buses using the **Fleet Mileage** metric will help depict how they perform in our service environment.

2023 Performance

In 2023, the battery electric bus fleet drove a total of approximately 117,400 miles (Table 3). The percentage of scheduled battery electric bus miles successfully driven by a battery electric bus declined significantly in 2023 compared to prior years (Figure 2). This decline was largely driven by two factors: (1) on-route charger retirement and (2) the need for numerous bus high voltage battery pack replacements. Overall, the average Metro Transit battery electric bus drove 75% fewer miles than its diesel counterpart (Figure 3).

Table 3: Total Annual C Line Miles Driven by Propulsion Type (2019-2023)

	2019	2020	2021	2022	2023
Annual C Line BEB Miles*	66,400	162,700	37,800	175,300	117,400
Annual C Line Diesel Miles*	312,600	466,700	625,200	476,900	561,800

** Values rounded to nearest 100*

Figure 2: Percent of BEB Miles Driven vs. Scheduled (2019-2023)

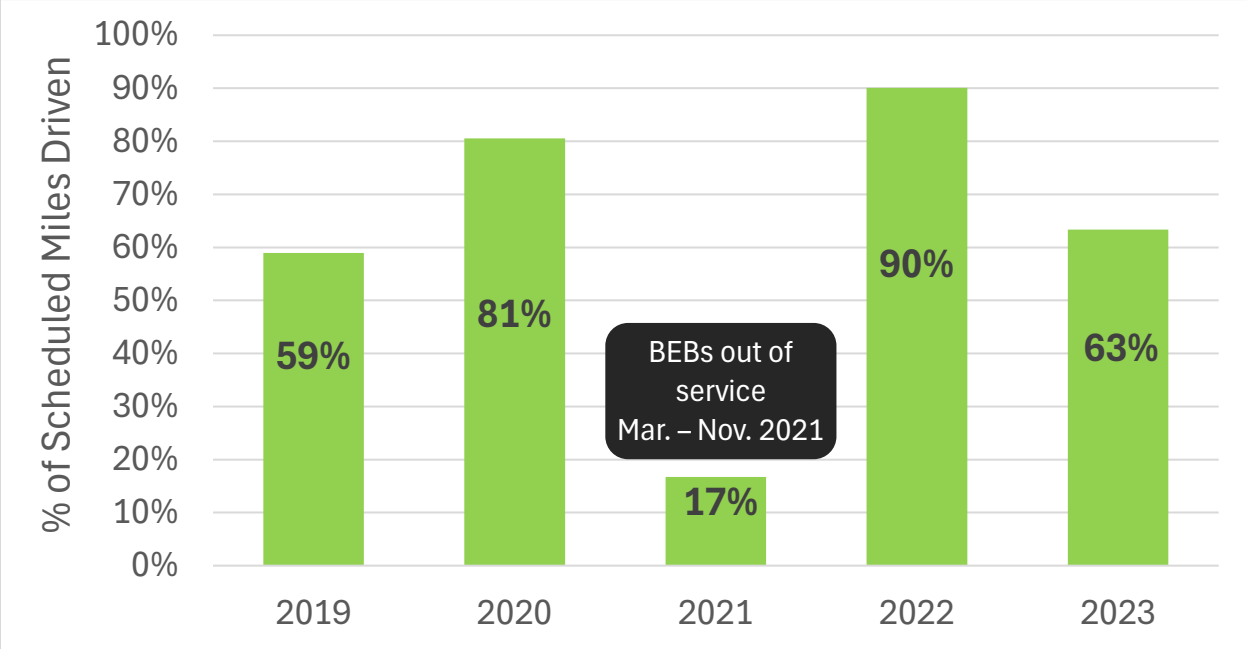
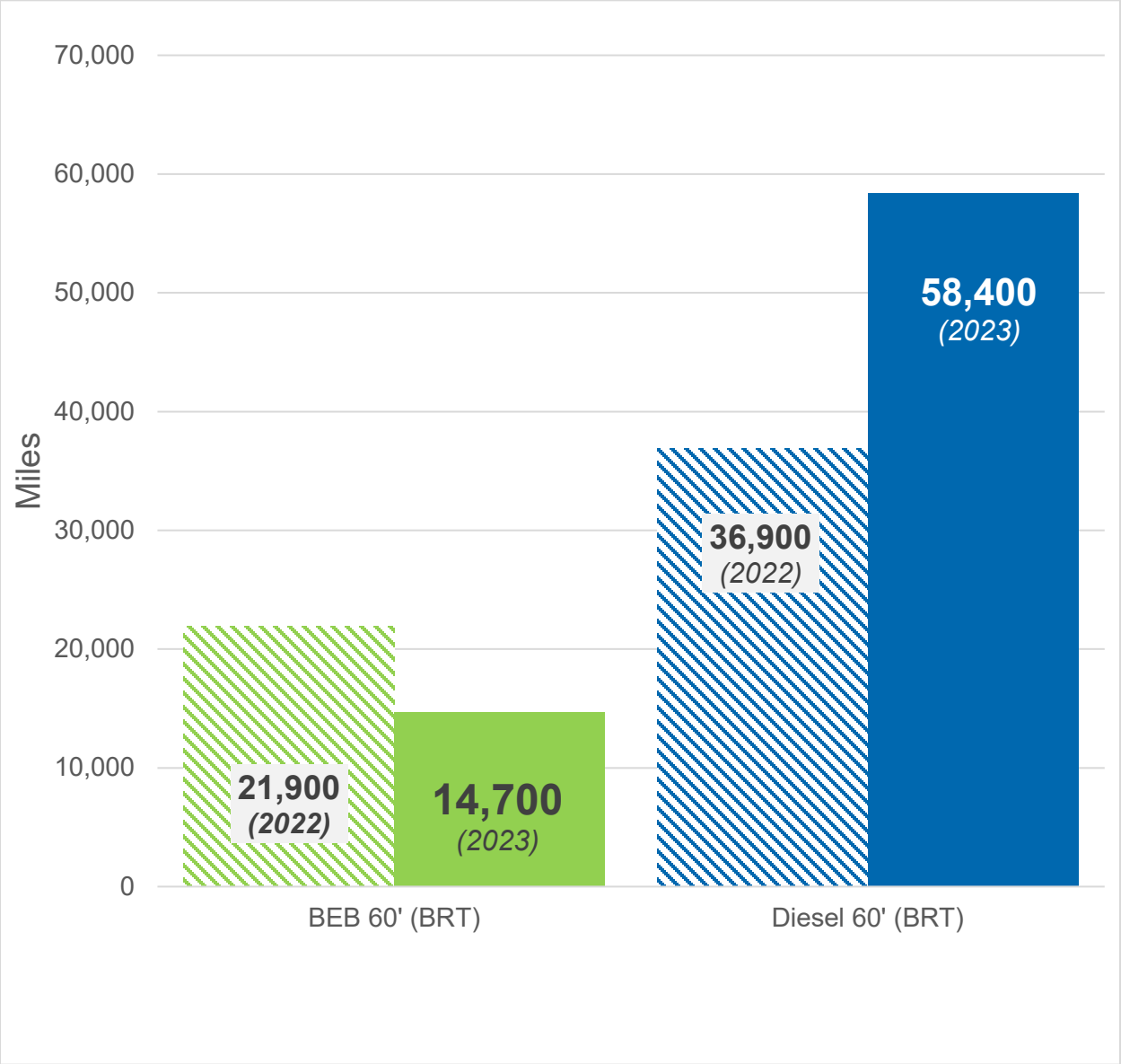


Figure 3: Miles per Bus by Propulsion Type



Bus Availability

What is Being Measured?

- The percent of battery electric buses available for use in service.

How is it Being Measured?

- The total number of days each bus is available for use in service divided by the total number of planned service days.

Why is it Important?

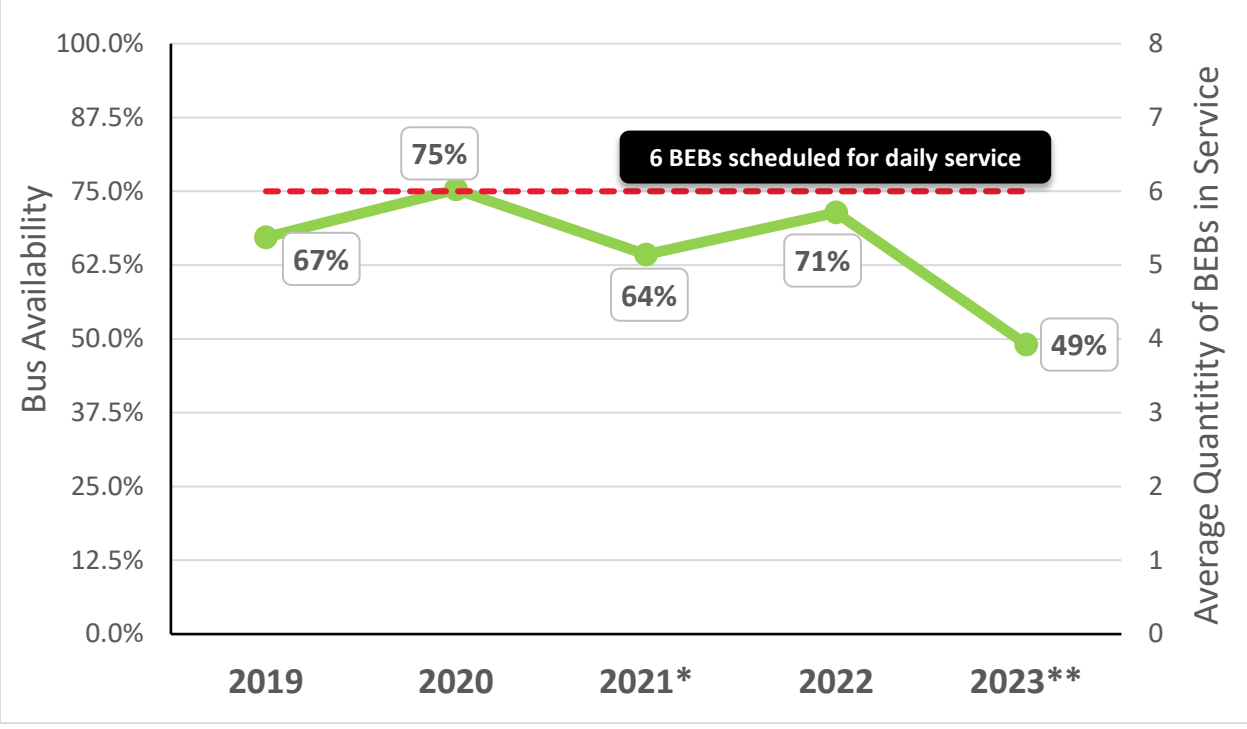
- The **Bus Availability** metric quantifies bus readiness and helps Metro Transit assess product availability to consistently provide reliable service.

2023 Performance

Battery electric bus availability declined in 2023 (Figure 4). This decline was largely influenced by the need to replace numerous battery packs which led to extended time out of service. (Figure 4).

As of 2023, Metro Transit owns eight battery electric buses. On a typical day, six electric buses are planned for use while the remaining two buses are spares to allow for non-revenue needs such as maintenance and training. In 2023, an average of only four battery electric buses were available per day. As a result, use of the diesel spare buses was required to ensure reliable service to customers.

Figure 4: Average Annual BEB Availability (2019-2023)



** 2021 metrics measured for the 90 days BEBs were used in revenue service*

*** 2023 metrics impacted by battery pack failures*

Bus Reliability

What is Being Measured?

- The mean (average) distance between chargeable road calls. Chargeable roadcalls are defined as instances when a bus requires unplanned maintenance attention while in service.

How is it Being Measured?

- The number of miles traveled divided by the number of chargeable roadcalls.

Why is it Important?

- The **Bus Reliability** metric will help Metro Transit evaluate how often a bus breaks down while in service to assess the impact battery electric buses have on service reliability and customer experience.

2023 Performance

Battery electric bus reliability declined in 2023, driven by the significant number of battery pack replacements and reduced battery electric bus fleet mileage. In 2023, the mean distance between chargeable roadcalls for the battery electric bus fleet was approximately 2,670 miles compared to approximately 7,700 miles for comparable 60' diesel BRT buses (Table 4).

Figure 5: BEB Annual Mean Distance Between Chargeable Roadcalls (2019-2023)

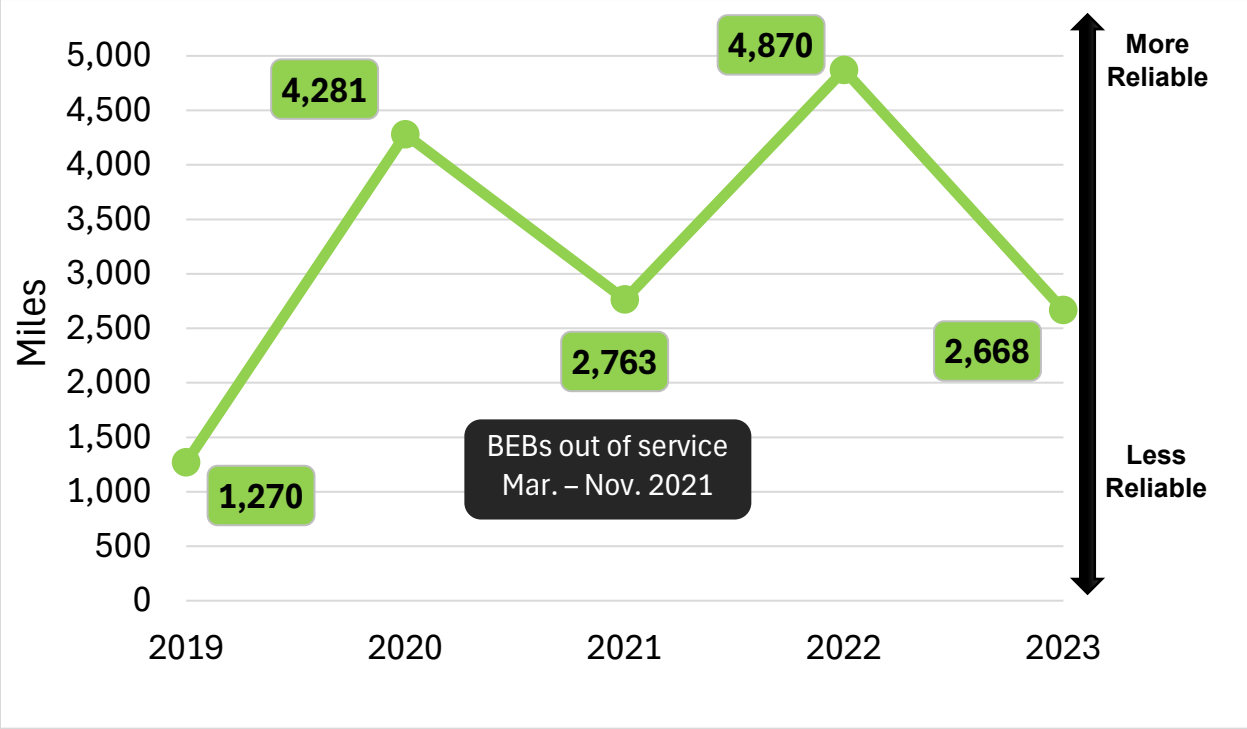


Table 4: Mean Distance Between Chargeable Roadcalls by Propulsion Type (2019-2023)

Mean Distance Between Chargeable Roadcalls	2019	2020	2021*	2022	2023
60' BEB BRT Buses	1,270	4,281	2,763	4,870	2,668
60' Diesel BRT Buses	8,247	8,656	5,201	8,862	7,700

** 2021 BEB metrics measured for the 90 days BEBs were used in revenue service*

Environmental Impact

What is Being Measured?

- Greenhouse gas (GHG) emission reductions compared to a baseline diesel fleet.

How is it Being Measured?

- Well-to-Wheel GHG reductions calculated using the Argonne National Laboratory's 2023 Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) model.[2] Well-to-wheel GHG estimates include the GHGs produced during fuel production and delivery (Well-To-Pump) in addition to GHGs produced during vehicle operation (Pump-To-Wheel).

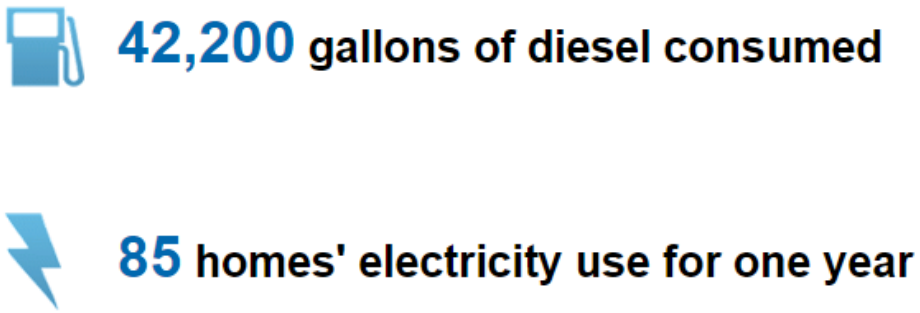
Why is it Important?

- The **Environmental Impact** metric quantifies the impact transitioning towards zero-emission buses has on reducing transit vehicle emissions and demonstrates the community benefits that battery electric buses deliver to the region.

2023 Performance

In 2023, battery electric bus deployments reduced Metro Transit's well-to-wheel GHG emissions by approximately 60 metric tons of CO_2 equivalent, resulting in a cumulative reduction of approximately 430 metric tons of CO_2 equivalent from June 2019 through 2023 (Figure 6).[3]

Figure 6: Well-to-Wheel GHG Emission Reduction Equivalencies (June 2019-December 2023)



[2] Historically, Argonne National Laboratory's AFLEET model has been updated every 2-3 years to add additional features and reflect updated vehicle emissions factors. The 2023 Annual Report uses the most recent 2023 AFLEET model and MROW eGRID 2022 Table 2 resource mixes.
[3] Source: *EPA Greenhouse Gas Equivalencies Calculator.* Accessed February 2024.

Equity and Environmental Justice

What is Being Measured?

- The percent of battery electric bus deployments on “High Priority” EEJ service blocks as defined in Section 8.3.2 of Metro Transit’s Zero-Emission Bus Transition Plan (February 2022). High priority service blocks have the greatest portion of bus mileage in High Priority (pink) EEJ Areas (Figure 7). EEJ priority areas were identified based on community input and ranking of seven different factors from the Metropolitan Council’s *Equity Considerations for Place-Based Advocacy and Decisions* dataset. Community input coalesced around cancer risk (a proxy for air quality), population density, and the percent of census tract population that identified as Black, Indigenous, and People of Color (BIPOC) as the top three factors when calculating census tract equity tiers.

How is it Being Measured?

- The number of battery electric bus deployments on “High Priority” EEJ service blocks divided by the total number of battery electric bus deployments.

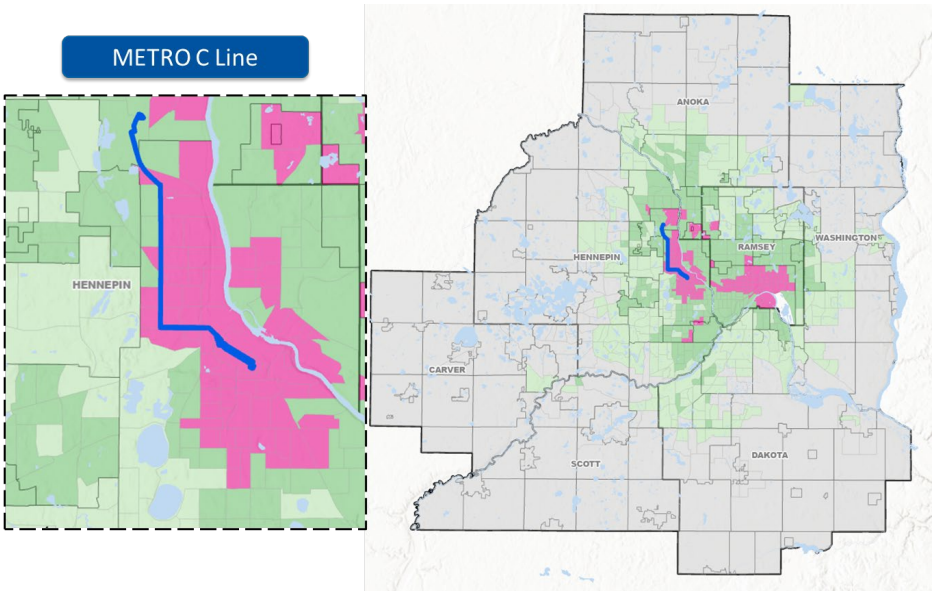
Why is it Important?

- The **Equity and Environmental Justice** metric will help Metro Transit understand the impact battery electric bus deployment prioritization is having in the community based on environmental, racial, and socioeconomic considerations.

2023 Performance

As of 2023, Metro Transit’s battery electric bus pilot program includes one route, the METRO C Line. This route was selected to be the first route in the region to pilot electric bus service in part, due to an emphasis on targeting the investment in a heavily utilized transit corridor serving historically underinvested communities with historically higher rates of asthma in downtown Minneapolis, North Minneapolis, and Brooklyn Center. As a result of this prioritization, in 2023, 100% of battery electric bus deployments were on “High Priority” EEJ blocks.

Figure 7: Equity and Environmental Justice Priority Areas and 2023 BEB Deployments



Energy Cost/Mile

What is Being Measured?

- Energy cost a bus uses to travel one mile inclusive of propulsion energy (diesel or electricity) and diesel fuel for bus auxiliary heat.[4]

How is it Being Measured?

- The total energy cost by vehicle group divided by the total miles traveled by that group.

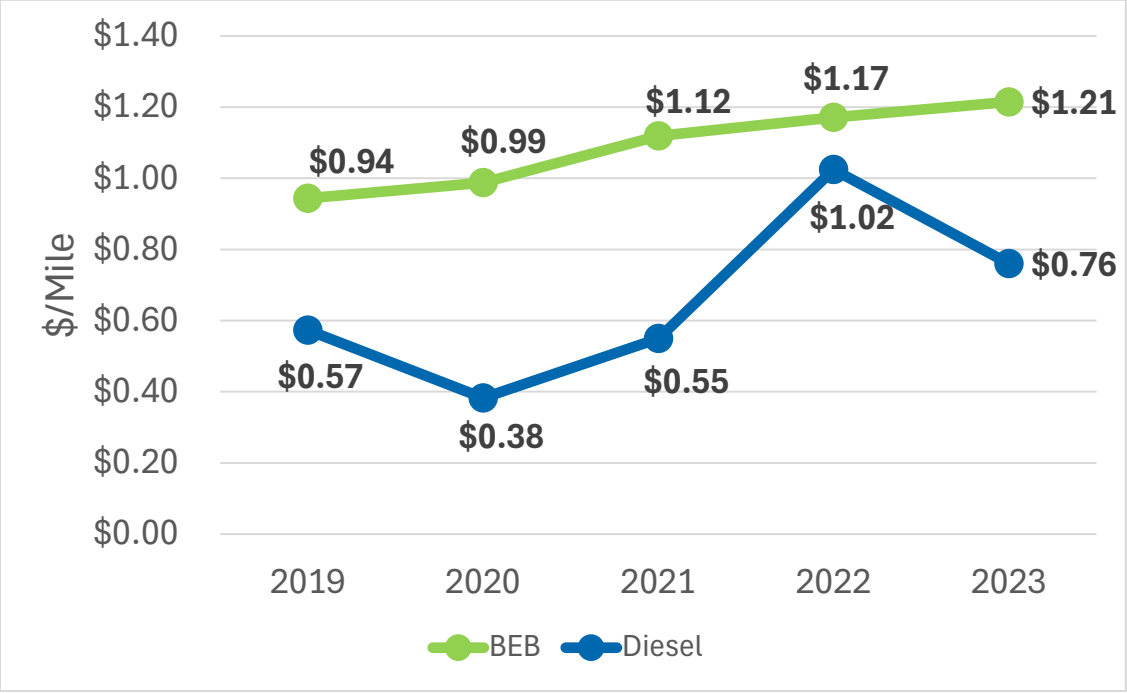
Why is it Important?

- The **Energy Cost/Mile** metric will help Metro Transit understand the ongoing energy costs and necessary budget to operate battery electric buses.

2023 Performance

In 2023, energy costs for battery electric buses were approximately $1.21 per mile. Compared to diesel, which can be a volatile commodity, electricity costs per unit volume are more stable in part due to multi-year utility rate structures. Despite this relative stability of electricity per unit volume, battery electric bus energy costs per mile in Metro Transit's experience are more expensive than diesel buses and have continued to increase in recent years (Figure 8). Refer to Section 12.2.1.5 of Metro Transit's Zero-Emission Bus Transition Plan (February 2022) for further discussion of electricity costs.

Figure 8: Average Annual Energy Cost per Mile by Propulsion Type (2019-2023)



[4] Note: All Metro Transit buses regardless of propulsion type include auxiliary diesel heaters for passenger comfort.

Infrastructure Availability

What is Being Measured?

- Percent of chargers available to charge a bus for revenue service.

How is it Being Measured?

- Total number of days each charger is available to support deploying buses in revenue service divided by the total number of planned service days.

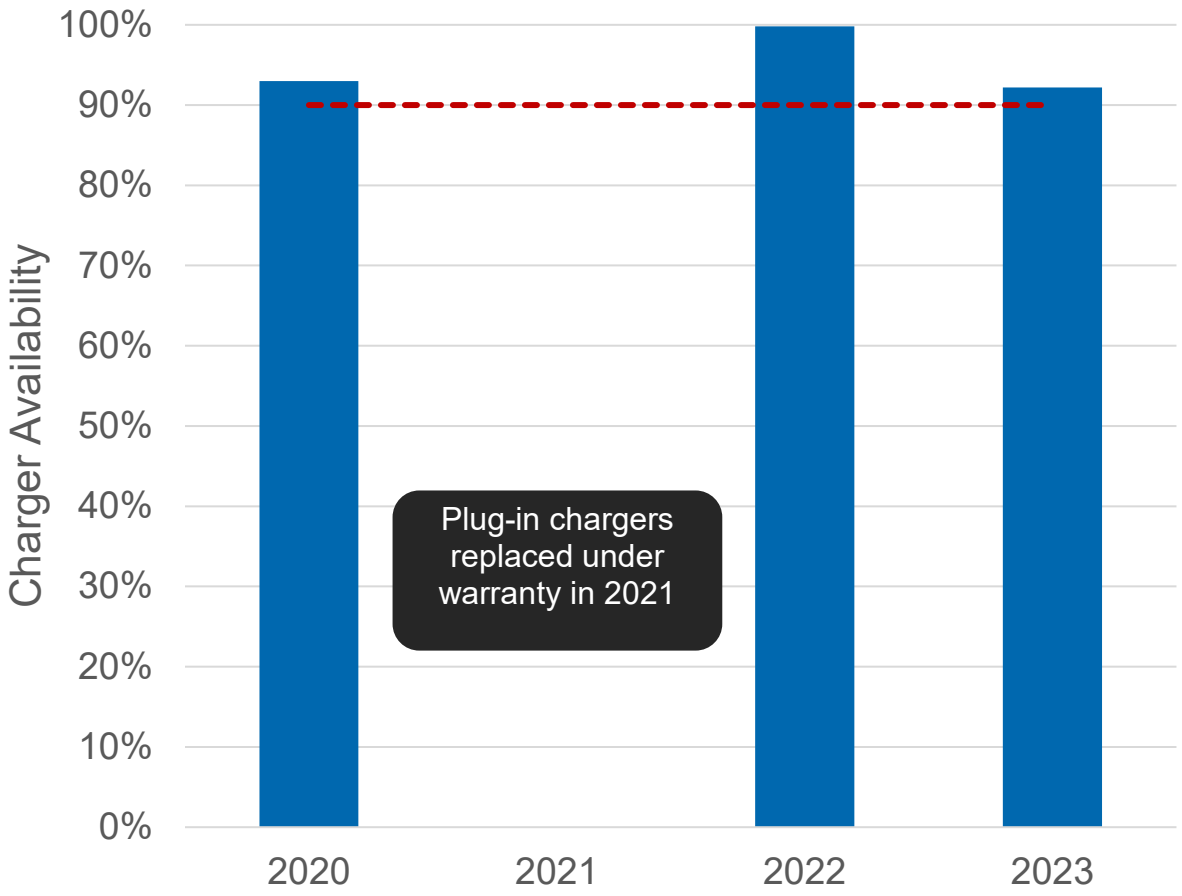
Why is it Important?

- Historically fuel pump availability was not a concern, however early charger deployments have had lower availability. The **Infrastructure Availability** metric will help Metro Transit assess technology ability to consistently provide reliable service.

2023 Performance

In 2023, plug-in charger availability met operational needs. Since the replacement of first-generation equipment under warranty in 2021, average annual garage (plug-in) charger availability has exceeded 90 percent.

Figure 9: Average Annual Plug-in Charger Availability (2020 - 2023)



Note: Metrics not reported for 2019 while commissioning was ongoing

Infrastructure Reliability

What is Being Measured?

- The quantity of incidents that take a charger out of service.

How is it Being Measured?

- Number of incidents that take a charger out of service.

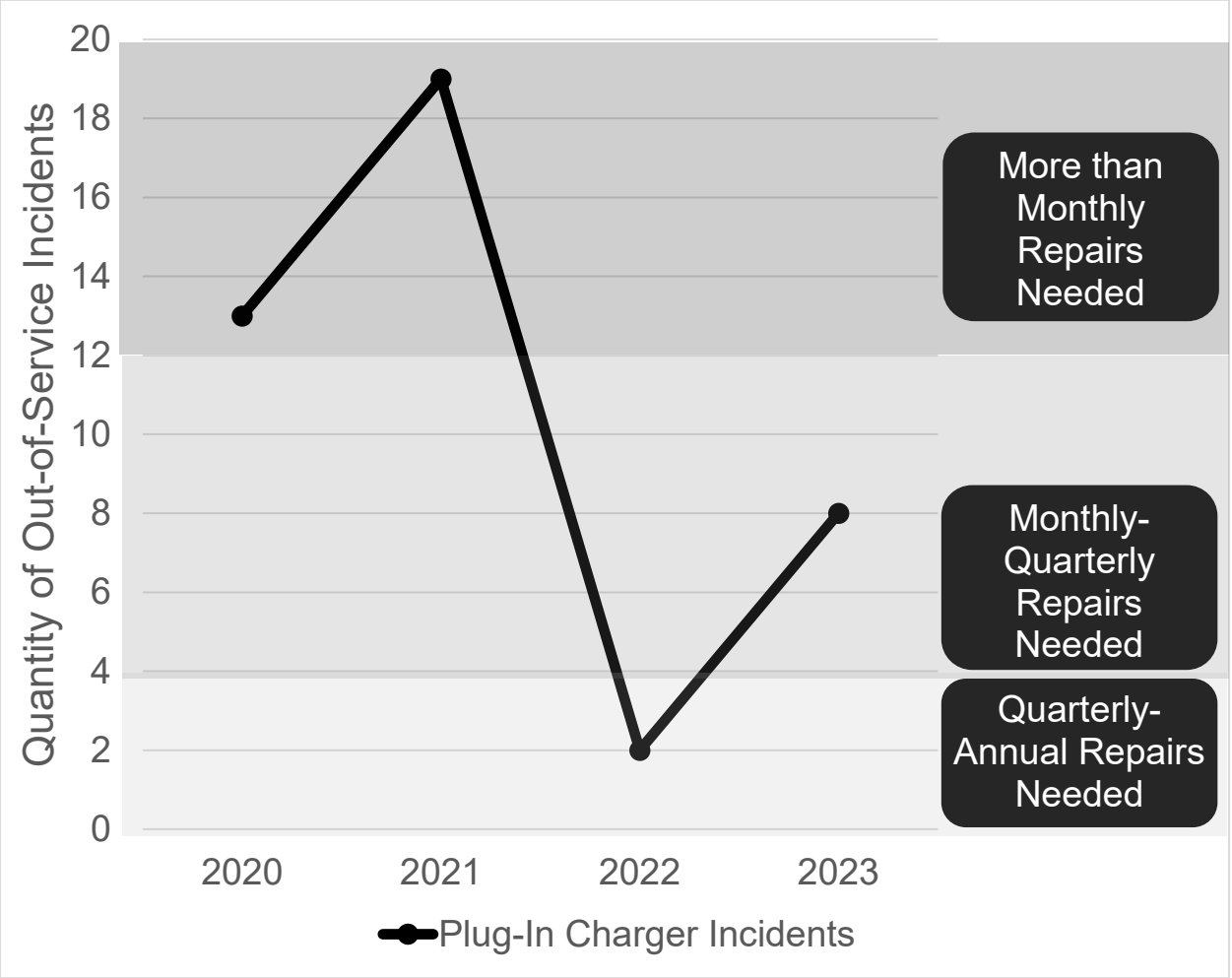
Why is it Important?

- The **Infrastructure Reliability** metric will help Metro Transit understand how often chargers must be temporarily removed from service for unplanned maintenance. This will help Metro Transit assess technology ability to consistently provide reliable service.

2023 Performance

In 2023, there were a total of eight out-of-service incidents across the eight garage (plug-in) chargers (Figure 10).

Figure 10: Annual Out-of-Service Incident Frequency (2020-2022)



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Conclusion (2023 Performance)

Annual KPI performance for calendar year 2023 is summarized in Table 5 compared to calendar year 2022. Key takeaways from 2023 include:

- Fleet KPIs (mileage, bus availability, bus reliability) declined from 2022 to 2023 largely due to an increased need to replace failed battery packs under warranty and retiring the on route chargers at BCTC
- Energy cost per mile for battery electric buses remains higher than diesel buses.
- Plug-in chargers are working as planned following replacement under warranty in 2021.
- 100% of 2023 battery electric bus deployments were on "High Priority" EEJ blocks.

Table 5: 2023 Annual KPI Summary

KPI	BEB 2022	BEB 2023*
Fleet Mileage*	175,300	117,400
Bus Availability *(% of BEBs Available for Use in Revenue Service)*	71%	49%
Bus Reliability *(Mean Distance Between Chargeable Road Calls)*	4,870	2,668
Environmental Impact** *(GHG [CO_2e] Reduction in Metric Tons)*	145	60
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Infrastructure Reliability *(Total incidents that take chargers out of service)*	Garage: 2	Garage: 8

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