Metro Transit

Zero-Emission Bus Annual Report
2022

October 2023

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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 2022, 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, and
- (2) Siemens on-route overhead conductive chargers (300 kW) located at BCTC.

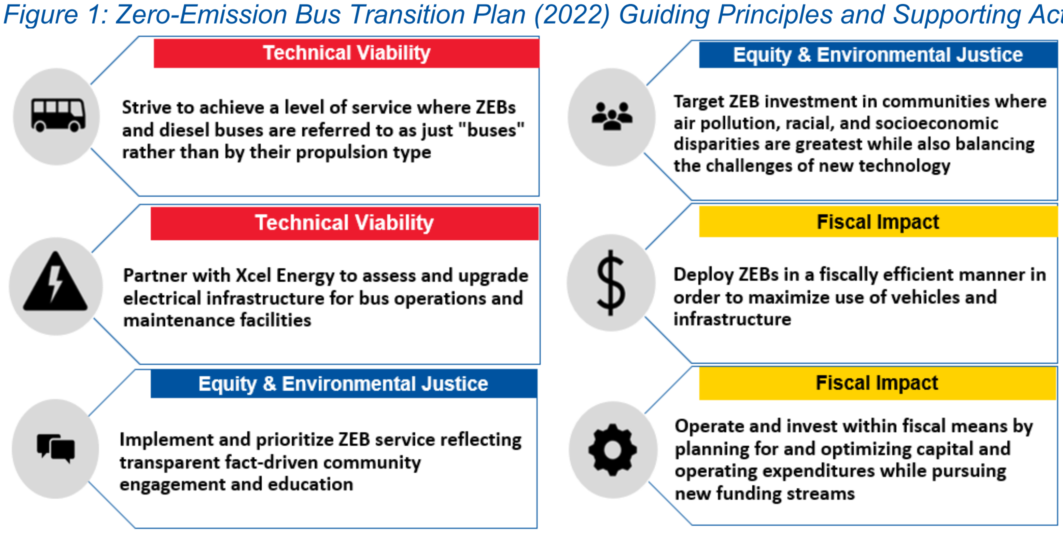
Zero-Emission Bus Transition Plan

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 five years (Minn. Stat. 473.3927). 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 2023) 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.

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 2022 Annual Report documents the performance of Metro Transit's Zero-Emission program from launch in 2019 through calendar year 2022. As of 2022, all of Metro Transit's ZEB's are battery electric buses (BEBs). A summary of the 2022 KPIs is presented in Table 2 followed by a more detailed summary of each indicator. Note that battery electric buses were out of service from March to November 2021 while plug-in chargers at the Heywood Garage were replaced under warranty.

Table 1: Zero-Emission Bus Transition Plan (2022) 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: 2022 Annual KPI Summary

KPI	BEB 2021*	BEB 2022**
Fleet Mileage***	37,800	175,300
Bus Availability *(% of BEBs Available for Use in Revenue Service)*	64%	71%
Bus Reliability *(Mean Distance Between Chargeable Road Calls)*	2,763	4,870
Environmental Impact**** *(GHG [CO_2e] Reduction in Metric Tons)*	10	145
Equity and Environmental Justice (EEJ) *(Percent of BEB Deployments on "High Priority" EEJ Blocks)*	100%	100%
Energy Cost/Mile	$1.12 *($0.55 for diesel bus)*	$1.17 *($1.02 for diesel bus)*
Infrastructure Availability *(Avg. Full Days Available to Charge a Bus for Use in Revenue Service)*	Garage: 22% On-Route: 87%	Garage: 99.8% On-Route: 96%
Infrastructure Reliability *(Total incidents that take chargers out of service)*	Garage: 19 On-Route: 10	Garage: 2 On-Route: 21

** In calendar year 2021, BEBs were out-of-service March - November*

*** **Green** cells or text indicate an improvement or consistent performance since 2021 while **orange** cells or text represent a decline.*

**** Rounded to the nearest 100 miles*

***** Rounded to the nearest 5 metric tons*

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.

2022 Performance

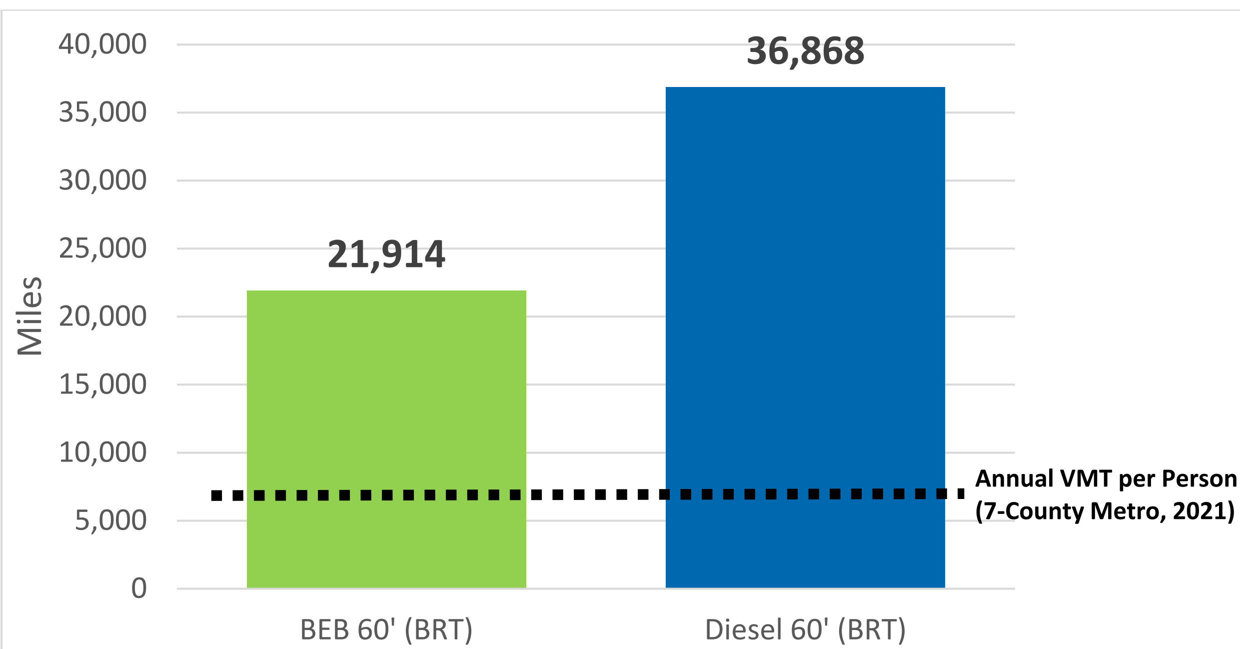
In 2022, the battery electric bus fleet drove a total of approximately 175,300 miles (Table 3). Due in large part to battery electric bus range constraints, however, the average Metro Transit battery electric bus drove 41% fewer miles than its diesel counterpart (Figure 2). Therefore, although the total mileage driven by battery electric buses is increasing, the productivity of a battery electric bus has been less than a comparable diesel bus.

Table 3: Total Annual C Line Miles Driven by Propulsion Type (2019-2022)

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

** Values rounded to nearest 100*

Figure 2: Miles per Bus by Propulsion Type (2022)



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.

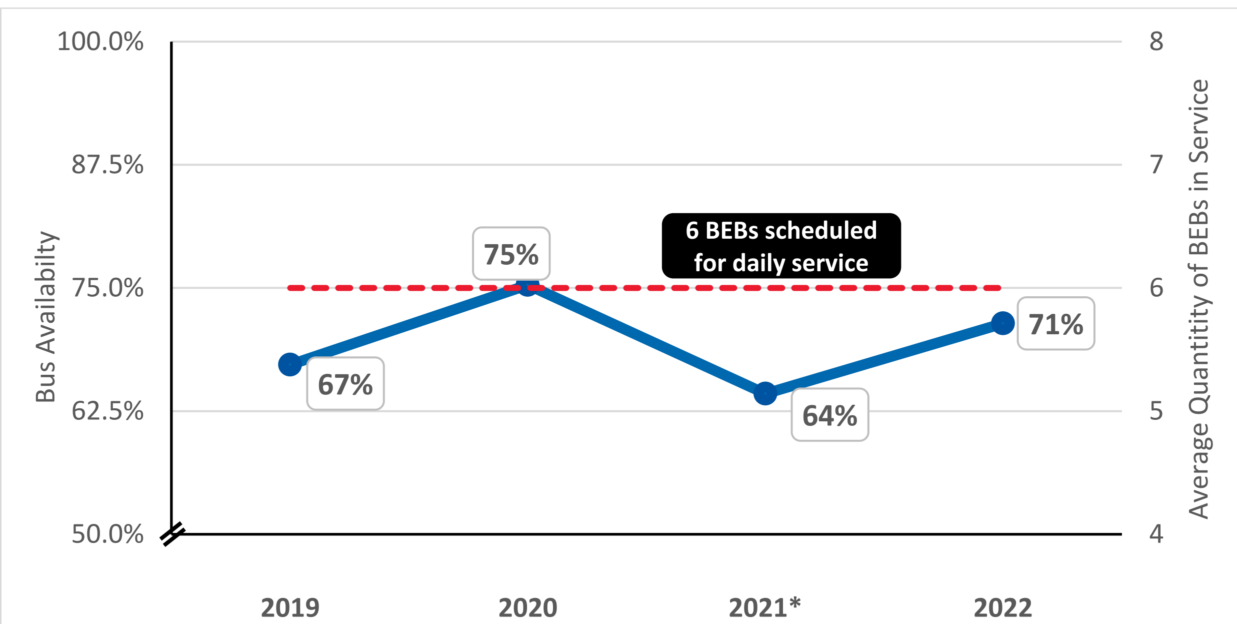
Why is it Important?

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

2022 Performance

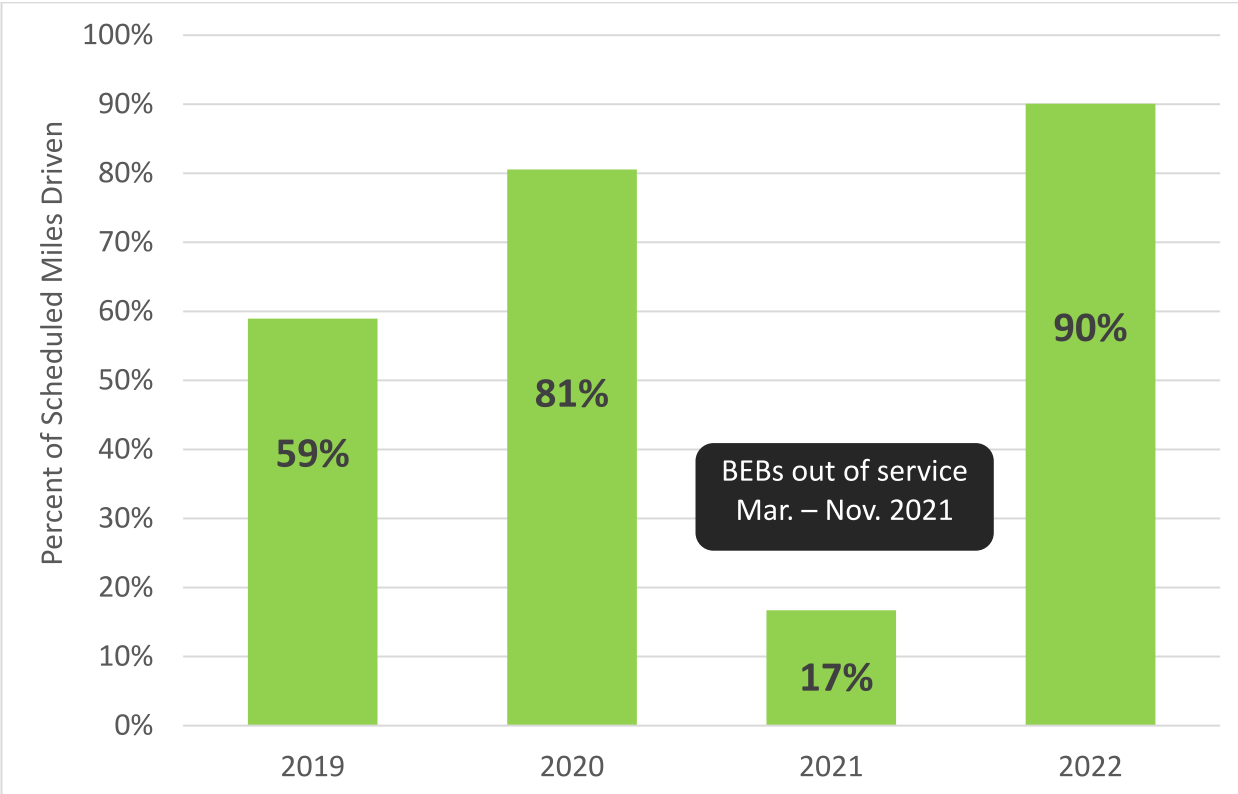
In 2022, annual battery electric bus availability was approximately 71 percent. As of 2022, Metro Transit owns eight battery electric buses. Six buses are scheduled for daily service. The remaining two buses are spares to allow for non-revenue needs such as maintenance and training. Historically, diesel bus availability has not been tracked as their availability to make revenue service has not been a concern. Battery electric bus availability is closely monitored as the annual availabilty has averaged at or below the six bus (75%) service delivery schedule (Figure 3). Except for 2021, when battery electric buses were out of service for most of the year, the percentage of scheduled battery electric bus miles that were successfully driven by a battery electric bus has steadily increased, reaching 90 percent of scheduled miles in 2022 (Figure 4).

Figure 3: Average Annual BEB Availability (2019-2022)



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

Figure 4: Percent of BEB Miles Driven vs. Scheduled (2019-2022)



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.

2022 Performance

In 2022, the mean distance between chargeable roadcalls for the battery electric bus fleet was approximately 4,870 miles. Except for 2021, when battery electric buses were out of service for most of the year, battery electric bus reliability has steadily increased, increasing by nearly four times from 2019 to 2022.

Figure 5: BEB Annual Mean Distance Between Chargeable Roadcalls (2019-2022)

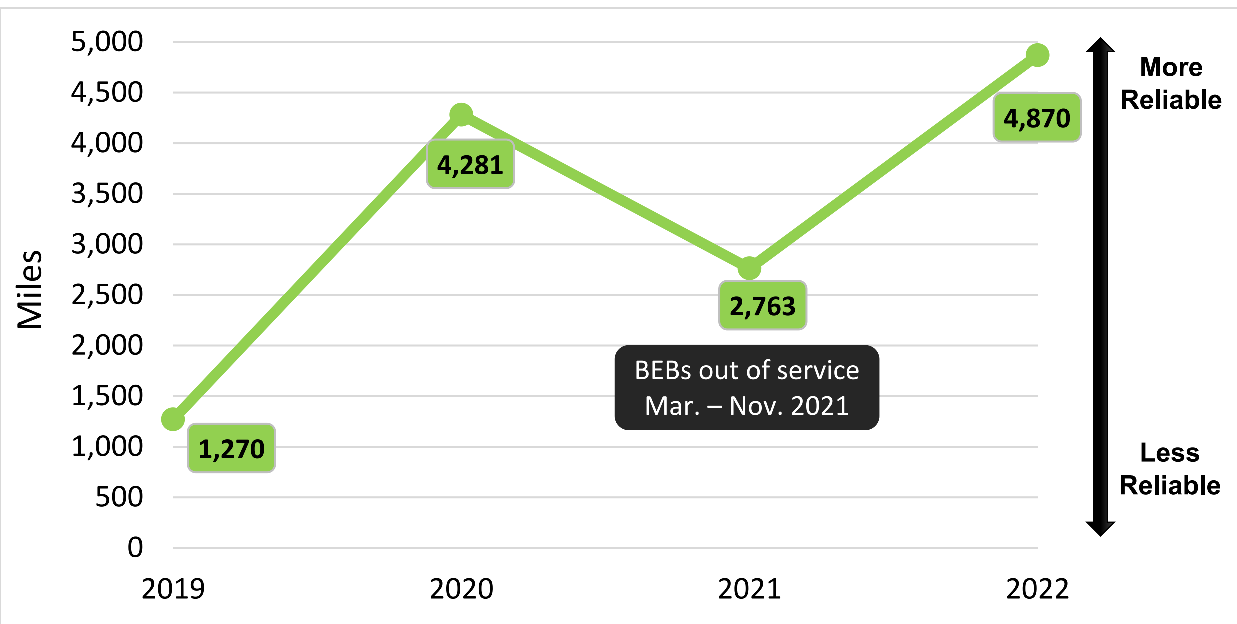


Table 4: Mean Distance Between Chargeable Roadcalls by Propulsion Type (2019-2022)

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

** 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 2020 Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) model.[1] 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).

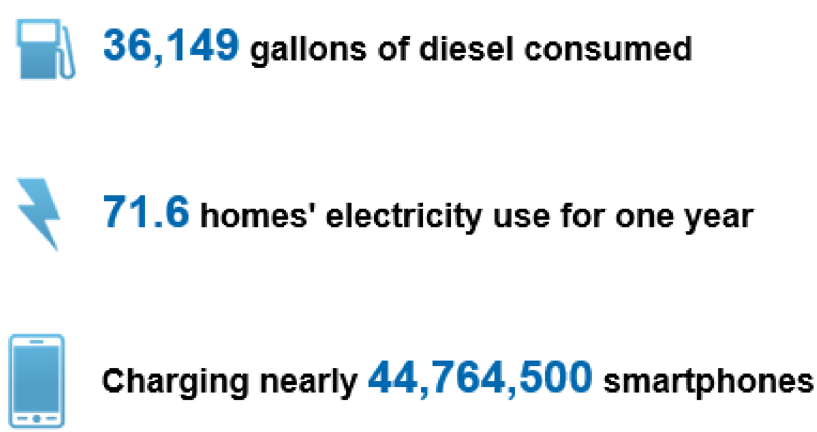
Why is it Important?

- 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.

2022 Performance

In 2022, battery electric bus deployments reduced Metro Transit's well-to-wheel GHG emissions by approximately 145 metric tons of CO_2 equivalent, resulting in a cumulative reduction of approximately 370 metric tons of CO_2 equivalent from June 2019 through 2022 (Figure 6).[2]

Figure 6: Well-to-Wheel GHG Emission Reduction Equivalencies (June 2019-December 2022)



[1] 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 2022 Annual Report uses the 2020 AFLEET model.

[2] Source: *EPA Greenhouse Gas Equivalencies Calculator*

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 raking 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.

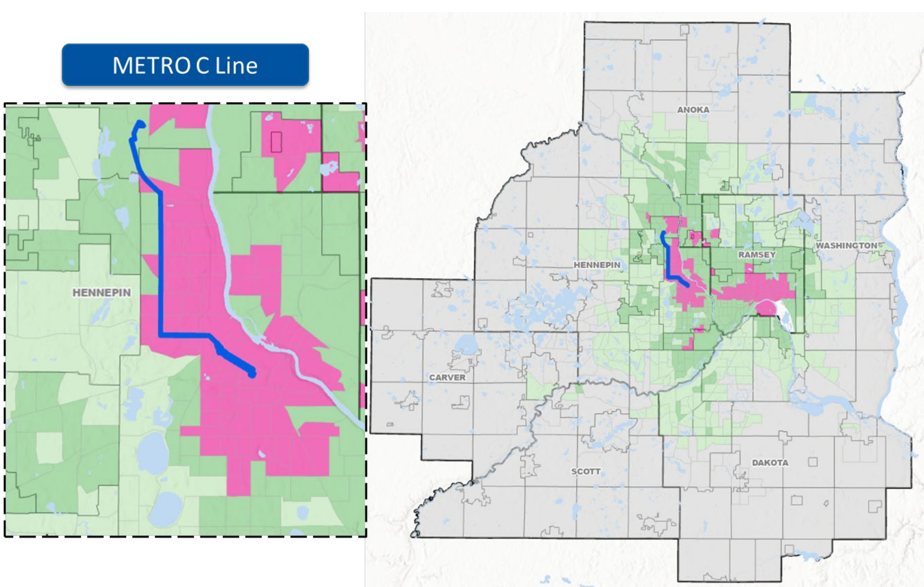
Why is it Important?

- 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.

2022 Performance

As of 2022, 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 2022, 100% of battery electric bus deployments were on "High Priority" EEJ blocks.

Figure 7: Equity and Environmental Justice Priority Areas and 2022 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.

How is it Being Measured?

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

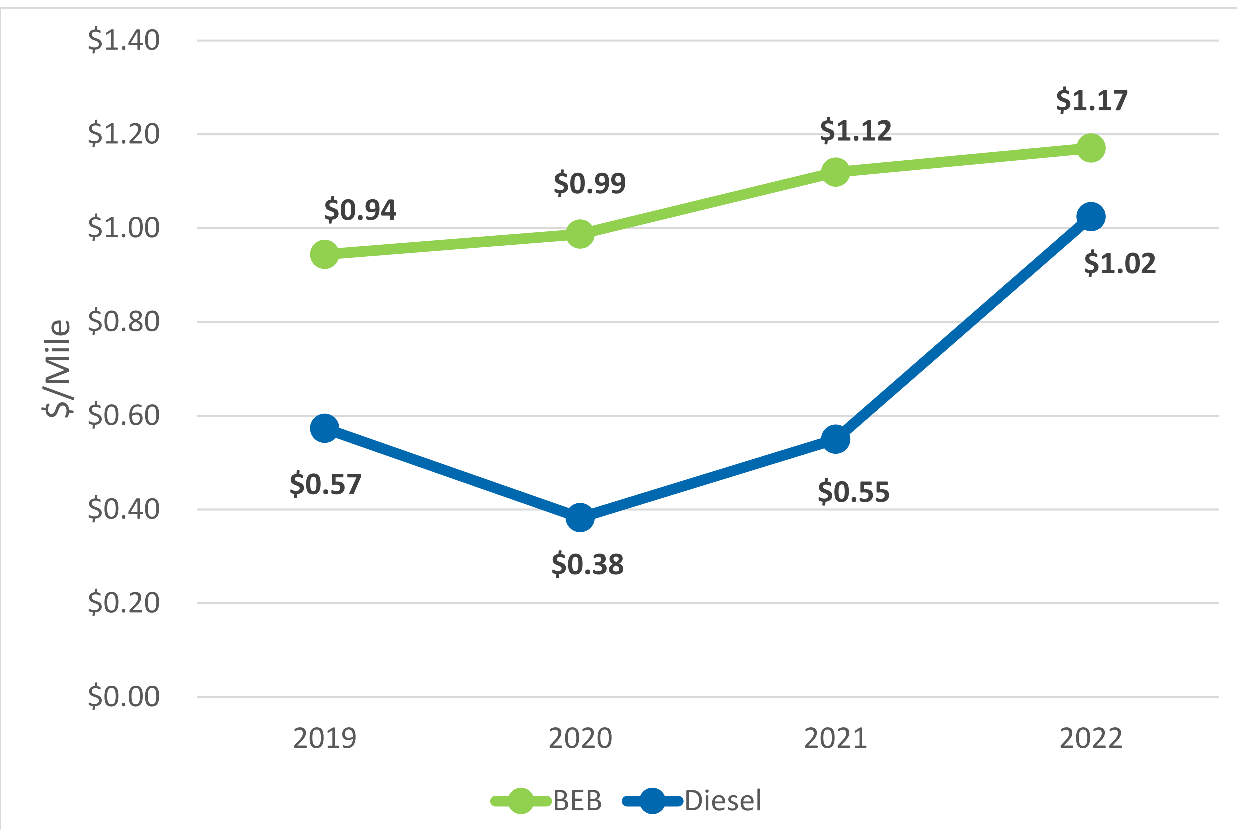
Why is it Important?

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

2022 Performance

In 2022, energy costs for battery electric buses were approximately $1.17 per mile. Compared to diesel, which is a volatile commodity, electricity costs per unit volume are more stable in part due to multi-year utility rate structures. Despite this stability of electricity per unit volume, battery electric bus energy costs per mile in Metro Transit's experience are more expensive than diesel buses (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 (2019-2022)



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.

2022 Performance

In 2022, all charger locations achieved an average availability greater than 95 percent, reflecting steady charger availability improvement as Metro Transit's continues to learn and tackle early adopter challenges (Table 5). Notably, following the replacement of the plug-in chargers under warranty in 2021, plug-in chargers exceeded 99 percent availability in 2022. Except for 2021, plug-in chargers have had a higher annual availability than on-route chargers.

Table 5: Annual Infrastructure Availability by Charger Type (2020-2022)

Plug-In: Heywood Garage

2020	2021	2022
93%	22%*	99.8%

On-Route: BCTC

2020	2021	2022
62%	87%†	96%

Note: Metrics not reported for 2019 while commissioning was ongoing

** 2021 Plug-In charger availability reflects the full calendar year (365 days) as plug-in charger availability resulted in the BEBs being out-of-service for most of the year*

† 2021 On-Route charger availability reflects data from 1/1/21 – 3/2/21 when BEBs were in-service

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.

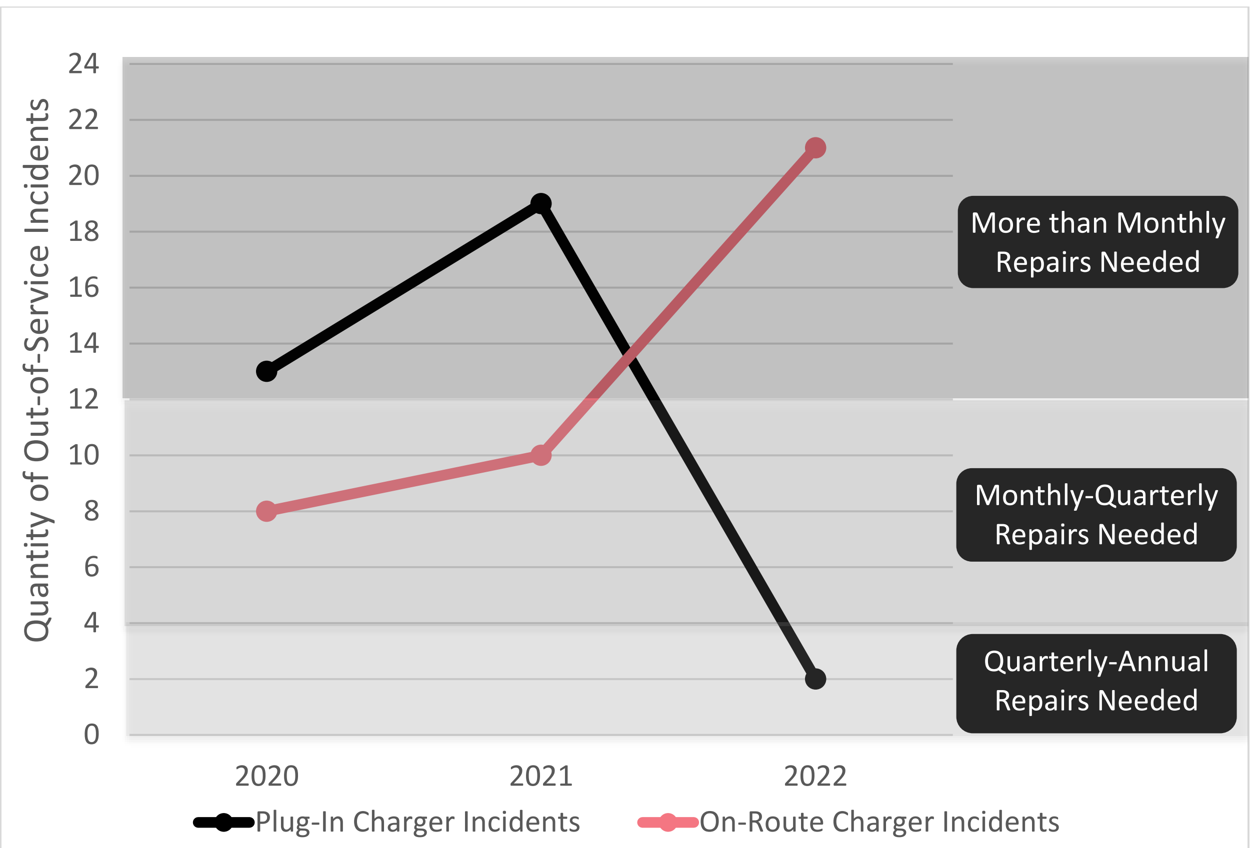
Why is it Important?

- 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.

2022 Performance

In 2022, there were only two out-of-service incidents across the eight plug-in chargers compared to 21 out-of-service incidents across the two on-route chargers (Figure 9). Out-of-service incidents are decreasing for garage (plug-in) chargers representing improved reliability and increasing for on-route chargers representing worsening reliability.

Figure 9: Annual Out-of-Service Incident Frequency by Charger Type (2020-2022)



Note: Metrics not reported for 2019 while commissioning was ongoing. 2021 On-Route charger reliability reflects data from 1/1/21-3/2/21 when BEBs were in service.

Conclusion (2022 Performance)

Annual KPI performance for calendar year 2022 is summarized in Table 6 compared to calendar year 2021. Key takeaways from 2022 include:

- Despite historic issues, battery electric bus performance is improving in 2022
- 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
- On-route chargers continue to present challenges
- 100% of 2022 battery electric bus deployments were on “High Priority” EEJ blocks

Table 6: 2022 Annual KPI Summary

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