Beloit Transit System Zero-Emission Transition Plan

November 2023

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List of Acronyms and Abbreviations

ASE	Automotive Service Excellence
BEB	battery electric bus
BJE	Beloit Janesville Express
BTS	Beloit Transit System
CMU	concrete masonry unit
FCEB	fuel cell electric bus
FTA	Federal Transit Administration
GHG	greenhouse gas
IIJA	Infrastructure Investment and Jobs Act
kW	kilowatt(s)
kWh	kilowatt-hour(s)
NRV	non-revenue vehicle
OEM	original equipment manufacturer
Plan	Zero-Emission Transition Plan
PPE	personal protective equipment
SAE	Society of Automotive Engineers
SLATS	Stateline Area Transportation Study
SOC	state of charge
v	volt(s)
ZEB	zero-emission bus

Executive Summary

The transportation sector is a significant driver of greenhouse gas (GHG) emissions in Wisconsin. Public transit plays an important role in reducing GHG emissions by reducing vehicle miles traveled by the general population. Transitioning the vehicle fleet of transit agencies to electric vehicles further reduces GHG emissions, improving local air quality and public health. The Zero-Emission Transition Plan (the Plan) is the Beloit Transit System's (BTS) plan to guide the agency as it strives to reach the City of Beloit's goals to reduce dependence on fossil fuels.

The Plan begins with an overview of its context and purpose that identifies relevant policies, initiatives, and studies (see "Transition Plan Context and Purpose"). The Plan then provides an overview of the various technologies and associated considerations for each vehicle type (see "Overview of Electric Bus Technology"), including the battery and charging infrastructure for each vehicle type.

In the next section ("Electrification Analysis and Evaluation"), the Plan evaluates existing facilities and their relationship to the technology transition. This evaluation provides an in-depth description of the service and fleet, including the current fleet composition, early transition opportunities, and a facility analysis.

The Plan also addresses resource availability, both current and future, to meet the costs associated with the vehicle fleet transition and its implementation (see "Resource Availability"). Resources including power from utility providers, funding availability, and the agency's workforce, are described in this section. The utility coordination discussion outlines the partnership between BTS and the utility provider, Alliant Energy. BTS plans to maintain open communication and work with the utility company to provide sufficient lead time to ensure continuous service availability when deploying its electric fleet. The workforce section examines the impact of the transition on the workforce and identifies strategies to avoid displacing existing workers. These strategies include hands-on training with the agency's new hybrid electric-diesel bus to understand the basics and the electric drive motors and be prepared for further training on electric buses.

After summarizing the conclusions (see "Conclusions"), the Plan identifies the next steps for BTS to begin the transition to a zero-emission fleet (see "Next Steps"). The Plan's responsiveness to the six elements required for a Federal Transit Administration (FTA)-compliant Zero Emission Fleet Transition Plan can be found at the following headings and pages:

1. Demonstrate a long-term fleet management plan (see "Fleet Transition Projection," page 15)
2. Availability of current and future resources to meet costs for the transition and implementation (see "Funding Availability," page 24)
3. Policy and legislation impacting relevant technologies (see "Existing Policies, Initiatives, and Studies," page 2)
4. Evaluation of existing and future facilities (see "Facility Analysis" page 15)
5. Partnership of the applicant with the utility or alternative fuel provider (see "Coordination Error" page 22)
6. Impact of the transition on the applicant's current workforce (see "Workforce Development and Training," page 25)

1. Transition Plan Context and Purpose

Reducing transportation-related emissions helps not only to improve local air quality but also to reduce greenhouse gas (GHG) pollution, which contributes to negative global impacts. Beloit Transit System (BTS) is committed to reducing the environmental impacts of its transit operations by evaluating low- and no-emission vehicles and implementing a Zero Emission Fleet Transition Plan.

Beloit Transit System and Facilities

Beloit Transit System, a division of the City of Beloit, WI, provides fixed-route bus service primarily within the City of Beloit in the Wisconsin portion of the Stateline Area Transportation Study (SLATS) Metropolitan Planning Area, with some connections to neighboring communities, including the Town of Beloit, WI, and City of South Beloit, IL. BTS directly operates six local routes and jointly operates an intercity route with the Janesville Transit System, the Beloit Janesville Express (BJE), which connects Beloit, Janesville, and points in between on weekdays. BTS currently contracts with Rock County Transit to provide complementary paratransit service. Figure 1 illustrates BTS's service area.

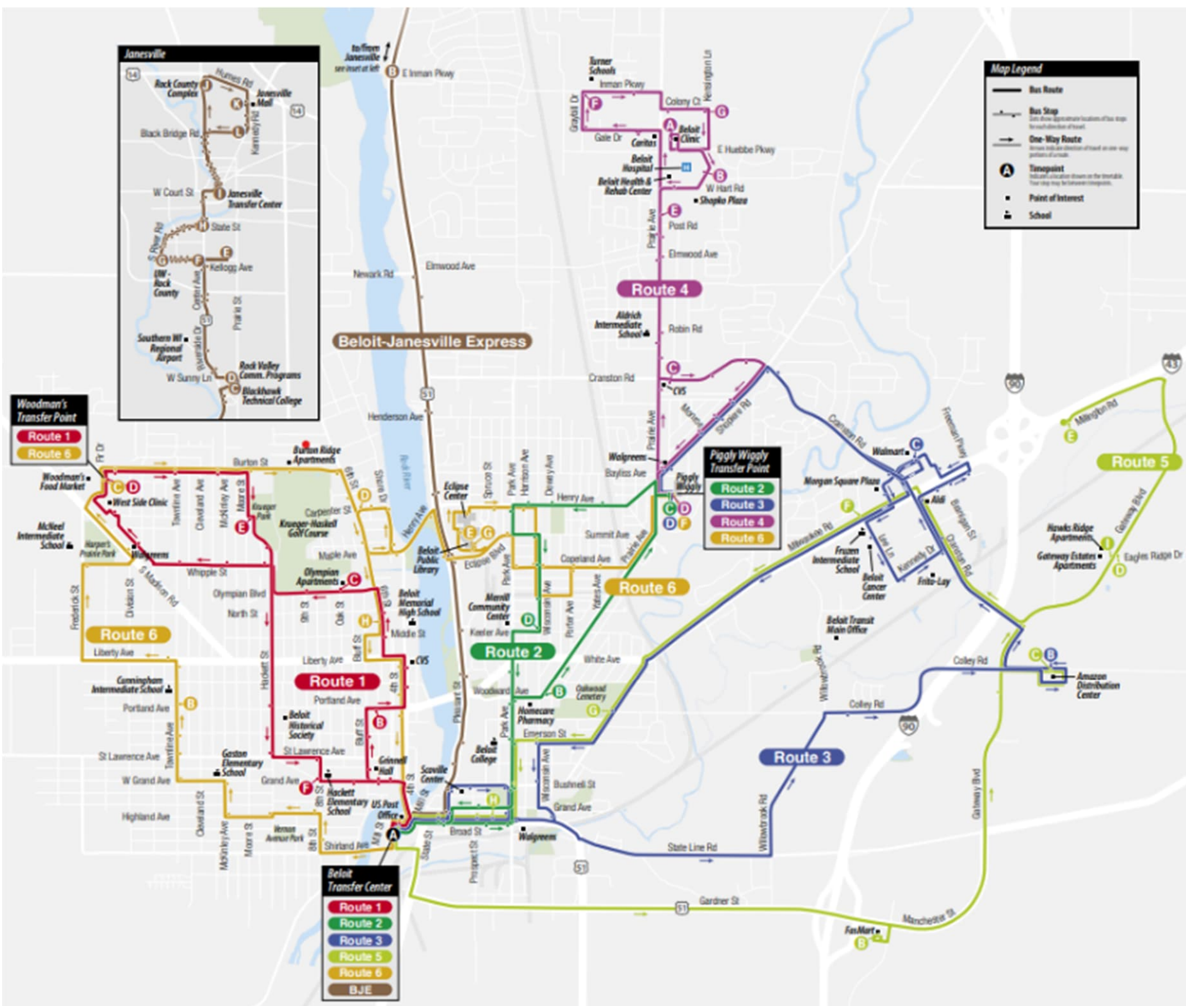

Figure 1: BTS System Map

BTS operates 10 35-foot diesel buses on its fixed-route service. The buses are housed at the BTS Administration Building, located on Willowbrook Road in a modern industrial park. This facility houses the operations, administrative, maintenance, and bus storage functions of the system and all in-person customer service. All BTS routes serve the Beloit Transfer Center, which has 10 bus bays, public restrooms, an indoor waiting area, a driver break room, and a customer service room.

Environmental Impacts of Transit

Transit has an important role to play when it comes to reducing a region's overall GHG emissions. Any time a passenger chooses to ride transit rather than drive their own vehicle, overall vehicle mileage traveled is reduced, along with net emissions. These net benefits can be further improved by reducing the emissions from transit vehicle operations.

Trend Toward Zero-Emission Buses

Transit agencies across the country and internationally are implementing strategies to reduce emissions from their fleets by integrating more low- and no-emissions technologies. Zero-emission bus (ZEB) adoption in the United States is anticipated to accelerate due to increased funding availability to support ZEB purchases and increased adoption of emissions-reducing policies by local governments and municipalities. As of September 2022, 5,480 ZEBs are on the road, awarded, or on order, which is a 66 percent growth rate since 2021.[1] Led by California, the West Coast, including Oregon and Washington, accounts for 41 percent of all ZEBs nationwide. However, nearly every state (except West Virginia and the Dakotas) has at least one ZEB on the road or on order; including Wisconsin, which has 60.

Existing Policies, Initiatives, and Studies

Nationally and locally, reducing emissions has been of increasing concern as research continues to demonstrate the wide range of environmental and health benefits associated with such reductions. This section discusses policy and legislation with implications on BTS's zero-emission transition.

Infrastructure Investment and Jobs Act

Signed into law by President Biden on November 15, 2021, the Infrastructure Investment and Jobs Act (IIJA), also known as the "Bipartisan Infrastructure Law," invests "$89.9 billion in guaranteed funding for public transit over the next 5 years—the largest federal investment in public transit history.[2] As part of these transit investments, the IIJA includes provisions to support and increase investment in zero-emission vehicles through grant programs, studies, fleet funding, and other measures.[3] In particular, the IIJA includes provisions to continue the grants for the Buses and Bus Facilities program with increased funding levels compared to that of previous authorizations. The IIJA also includes funding appropriation for the Low-No Grant program at around $1.1 billion annually from 2022 through 2026. (The Low-No Grant program is a program within the Federal Transit Administration's [FTA] Buses and Bus Facilities program.) This discretionary grant program requires agencies to have a zero-emission fleet transition plan. The program also requires that 5 percent of Low-No Grants related to zero-emission vehicles

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[1] CALSTART, *Zeroing in on ZEBs* (February 2023).
[2] The White House, *Fact Sheet: The Bipartisan Infrastructure Deal* (November 6, 2021).
[3] Alternative Fuels Data Center, *Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act of 2021).* Accessed June 2023.

and related infrastructure must be used for workforce development activities, unless the applicant certifies that less is needed to carry out their zero-emission fleet transition plan. However, it should be noted that federal transit funding focuses on capital needs, not the costs associated with the operation and maintenance of ZEBs or other transit services.[4]

City of Beloit Proclamation to Reduce Greenhouse Gases

In March 2021, Beloit's City Council signed a proclamation to support state, federal, and international efforts to reduce GHG emissions, with a goal of carbon neutrality by 2040. The city has reinforced this commitment by recently introducing its first hybrid diesel-electric bus into its fleet.

City Sustainability Committee

The City of Beloit formed an internal Sustainability Committee in 2019 with the purpose of evaluating strategies to promote sustainable practices, including strategies to reduce carbon emissions. As a Green Tier Legacy Community, Beloit is using best practices and associated metrics provided by the Wisconsin Department of Natural Resources to identify priorities and track progress on sustainability initiatives, with energy and emissions reductions and transportation system improvements as the primary goals. BTS is an active member on the Sustainability Committee and has participated in completion of all Green Tier reporting.

Based on BTS's history of operations and encouragement from local policymakers, there are no policies or legislation that will hinder the implementation of this Plan.

[4] Federal Transit Administration, *Fact Sheet: Buses and Bus Facilities Program* (last updated December 9, 2021).

2. Overview of Electric Bus Technology

Currently, three zero-emission bus technologies are commercially available: electric trolleybuses, fuel cell electric buses (FCEBs), and battery electric buses (BEBs).

Although electric trolleybuses (see Figure 2) have been in use for nearly a century, only five transit agencies across the country currently operate this type of ZEB as a part of their regular service offerings.[5] Power to these buses is provided via two trolley poles connecting the top rear of the bus to overhead catenary wires. Due to trolleybuses' limitations—including limited flexibility for off-wire operation, the extensive costs associated with building and maintaining a network of overhead wires, and the significant visual impacts of these wires—BTS does not intend to pursue the implementation of electric trolleybuses.

Figure 2: Trolleybus in operation

Source: SFMTA, Flying Flyers—Muni Trolley Buses Then and Now (May 3, 2018).

Conversely, FCEBs—buses that use an on-board electrochemical hydrogen fuel cell for propulsion—are growing in prevalence across the United States, with adoption of these buses increasing by 61% since 2021.[6] Due to the significant upstream carbon emissions associated with creating and trucking hydrogen, the high cost of FCEBs, and the current lack of an identified source of hydrogen supply, BTS does not currently plan to implement FCEBs in the short term.

BEBs use onboard battery packs for bus propulsion and power rather than conventional fuels such as diesel or compressed natural gas. BEBs are charged at garages or on route during operation. Transit agencies located in colder climates typically include an auxiliary diesel heater on their BEBs for supplemental heat to increase bus range. As of September 2022, approximately 95 percent of the full-size (30+ feet in length) transit ZEBs on the road or on order in the United States are BEBs. Due to the challenges associated with FCEBs outlined above and the comparatively lower capital costs and increased industry experience associated

[5] Federal Transit Administration, *The National Transit Database (NTD)* (last updated November 2, 2022).

[6] CALSTART, *Zeroing in on ZEBs* (February 2023).

with BEBs, BTS plans to focus its zero-emission transition toward BEBs. As such, the following sections of this transition plan focus on the analysis and evaluation of BEB technologies.

BEB Vehicle Considerations

The batteries onboard a BEB are used to provide both the energy required to drive the bus and the energy necessary to operate all vehicle auxiliary functions, including heating and cooling of the passenger cabin. The amount of energy provided by the battery is described by its energy capacity measured in kilowatt-hours (kWh). Unlike conventional diesel buses, which typically have 100+ gallon fuel tanks that allow a bus to travel more than 300 miles before refueling, BEBs typically have a reliable range of 150 miles or less on a single charge.[7] A BEB's range is a function of two primary characteristics: (1) battery capacity and (2) energy usage.

Larger **battery capacity** translates to increased energy (fuel) storage and thus increased range. As of Spring 2022, BEB manufacturers offer onboard BEB batteries with capacities that typically range from approximately 215 to 686 kWh.[8,9] Expanding on these capacities, Proterra began offering a 40-foot BEB in 2023 that can be equipped with up to 738 kWh of onboard energy.[10] These advertised capacities, also referred to as nameplate or nominal battery capacities, indicate the capacity of a new battery pack. Unfortunately, however not all the nominal battery capacity can be used for BEB operation. Instead, batteries wear down and become less efficient over time as they are constantly charged and discharged. Furthermore, charging a BEB to full capacity or charging it from a zero state of charge (SOC) increases the rate at which the batteries degrade, as this process puts additional strain on the physical and chemical components of the battery. Thus, many manufacturers carve out an unusable portion of the battery to preserve the longevity of the hardware. An additional consideration for the unusable portion is that at a low enough SOC, the battery will not be able to produce enough power to move the vehicle. In addition, just as operators avoid driving a conventional bus until the fuel tank is empty, a portion of a BEB's battery capacity is typically preserved for operational flexibility. By preserving this capacity, transit agencies are able to ensure that BEBs have sufficient range to return to the garage in the event of an unforeseen delay or other unexpected event that requires a BEB to remain in service longer than originally planned. These factors translate to usable battery capacities of between approximately 145 kWh and 465 kWh.

The amount of **energy usage** by the bus (kWh/mile) also impacts BEB range. When the energy used to heat and cool the bus cabin is the same energy that would be used for the propulsion of the bus, bus range can be substantially reduced in cold weather, as increased energy must be devoted to maintaining a comfortable temperature in the passenger cabin. The speed at which a BEB operates also influences energy usage and therefore BEB range. Typically, slower speeds are a result of either busy or congested environments. In busy environments, buses often experience greater energy usage related to bus doors being open more often and for longer periods of time. When the doors are open, heating and cooling the bus cabin are more difficult,

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[7] National Academies of Sciences, Engineering, and Medicine, *Guidebook for Deploying Zero-Emission Transit Buses* (Washington, DC: The National Academies Press). https://doi.org/10.17226/25842.
[8] National Renewable Energy Laboratory, *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses* (April 2021).
[9] GILLIG, *GILLIG's Next-Generation Battery to Provide 32 Percent Increase in Onboard Energy* (GILLIG LLC, November 8, 2021).
[10] Proterra, *Proterra Introduces ZX5 Electric Bus With 738 Kilowatt Hours of Energy* (GlobeNewswire, April 14, 2022).

as extra energy is drawn from the battery. In addition, when buses are stuck in congested environments, they spend increased time idling and accelerating from rest, thereby requiring greater energy usage. Efficient operation of the vehicle through gentle accelerations and decelerations can reduce energy usage by requiring not only less energy to accelerate from rest but also to maximize the bus's ability to regenerate energy. When the bus is rolling forward, BEBs are capable of recapturing some of that energy and improving overall energy usage. From this combination of factors, energy usage on the same bus can vary widely within a single transit agency's operation, and therefore lead to different functional ranges.

Charging Infrastructure

In the North American BEB industry, there are currently three primary types of BEB chargers: (1) plug-in chargers; (2) overhead conductive chargers with inverted overhead pantograph dispensers; and (3) in-ground wireless inductive chargers (Figure 3). Plug-in chargers are typically used at garages and in bus service/maintenance bays, whereas overhead and inductive chargers can be used for either garage or on-route (opportunity) charging. BEB charging infrastructure typically includes transformers, switchgear, chargers (charger "bases/cabinets" where the majority of charging equipment is housed, including AC–DC rectifiers, charge controls, and communication) and dispensers (e.g., pantographs or plugs).

Plug-In	Overhead Conductive	Wireless Inductive

Source: Photo by Kevin Clark, The Herald (October 25, 2021).	Source: TriMet, March 2021	Source: Link Transit & eVehicle Technology

Figure 3: BEB Charging Infrastructure

Plug-in chargers can be either an "all-in-one" unit, with a dispensing plug-in cord attached directly to the charger, or a charging cabinet that connects to remote plug-in dispensers (Figure 4).

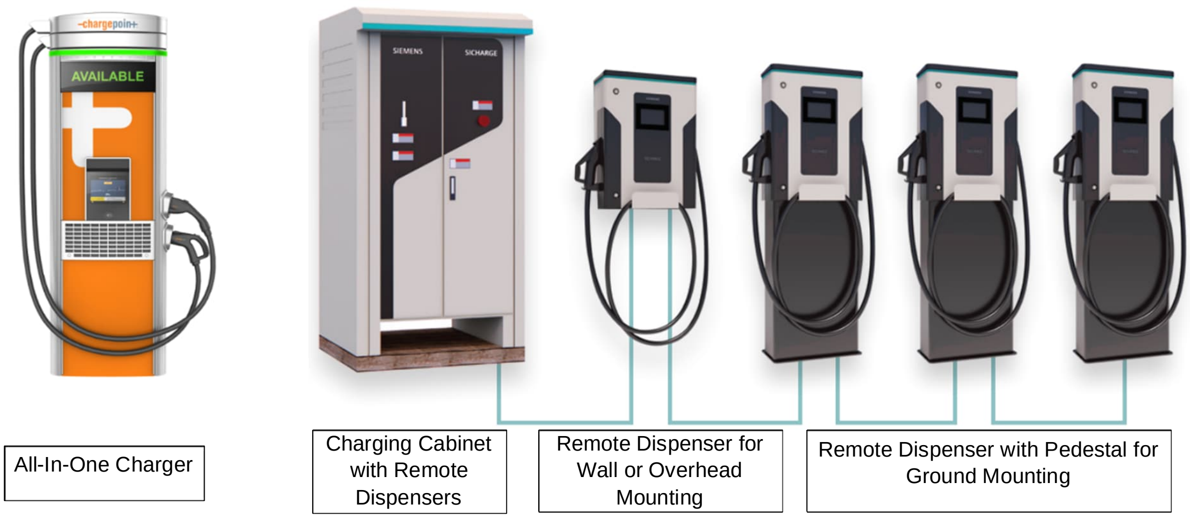

Figure 4: Plug-In Charger Detail

The smaller size of a remote dispenser allows for multiple vehicles to be charged away from the large charging cabinet which is practical when powering multiple large vehicles. Typically, an all-in-one charger has one or two cords while a charging cabinet can energize between one to four remote dispensers, allowing for scheduled charging of multiple buses. Charge power for plug-in chargers ranges from 50 to 180 kilowatts (kW). Due to this relatively low power, plug-in chargers typically take several hours to fully charge a bus and are therefore often used primarily for overnight charging. A factor to be considered with shared charging (one charging cabinet energizing multiple dispensers) is that depending on the charger manufacturer and model, the nameplate rating of the charger (180 kW, for example) might only output a maximum of 60 kW if, for example, the one charger cabinet is energizing three dispensers (this situation is expressed as a 1:3 charging ratio).

There is currently no industry standard for shared charging configuration, so any shared plug-in charging assumes performance operations, such as “ability to provide 180 kW to any dispenser at a time,” is recommended to balance the planned incoming charging equipment with the anticipated charging operational time. BEBs by default have charging ports located in similar locations to conventional internal combustion engine fuel ports: that is curb side, rear quarter of bus. Buses can be specified to have plug-in ports on both sides of the vehicle or only one at the center rear to the bus to increase flexibility in parking positions especially at ground-mounted charger islands and curbs. Per unit capital costs for plug-in chargers are lower compared with other types of charging infrastructure. The J1772 standard, published by the Society of Automotive Engineers (SAE), allows for interoperability of plug-in chargers with different types of buses from multiple manufacturers, analogous to the standardized pump size for gasoline vehicles across manufactures, which allows you to fill your gas tank at any gas station. Note that retrofitting ground-mounted charger cabinets (2 feet to 3 feet 6 inches in depth) adjacent to parked buses in existing dense bus parking arrangements can lead to blocking of staff circulation or create a bus-to-charger impact danger.

On large retrofit deployments at existing dense, close-parked bus lanes that are 12 feet wide or less, it is not uncommon to have to eliminate some bus parking spaces to allow for ground-mounted chargers. Overhead suspended dispenser plug-in cords mounted over parked buses energized by charging cabinets located remotely away from bus parking can be used where ground-mounted plug-in cord equipment is impractical or not desired. Overhead plug-in cords over buses, if not left always dangling and protected by bollards or other structures, do require some means to retract and extend the cord. Currently, the charging equipment original equipment manufacturers (OEMs) do not offer a remote overhead reel or retraction system and rely on third-party vendors or site-specific custom solutions, from the simple, suspended rope tagline connected to a manual-pull charging cord to powered retraction systems using reels or winches.

Overhead conductive chargers typically use an inverted extending arm pantograph or piston-mounted charging bars that lower down from the charger to connect to the roof-mounted charge rails on the bus. Two examples of these inverted overhead chargers are shown on Figure 5.

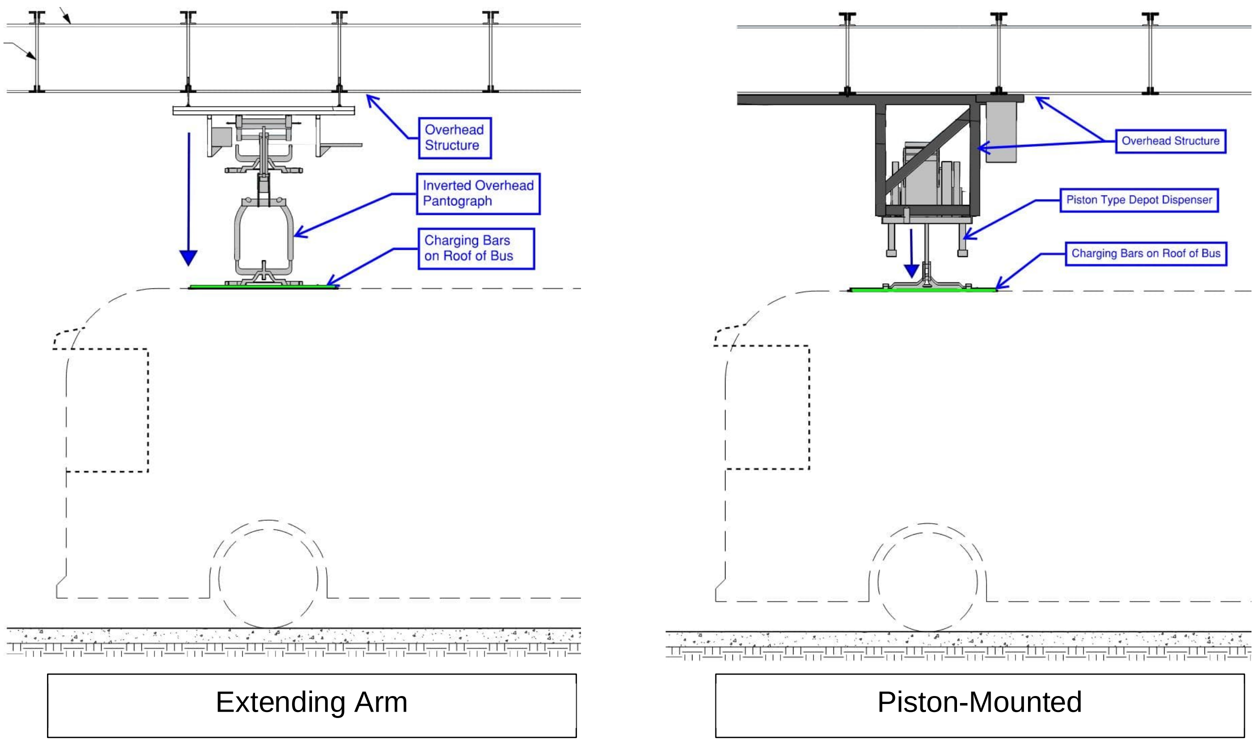

Figure 5: Example Schematics of Inverted Overhead Conductive Chargers

With a non-inverted overhead pantograph system, pantographs mounted to the bus extend up to connect to an energized charge point mounted to an overhead structure; however, this type of pantograph is rarely used in the U.S. market due to the added weight of the pantograph to the bus and the single source proprietary overhead connector. As such, we will be referring to the inverted pantograph system when discussing overhead conductive chargers.

Charge power for overhead conductive chargers ranges from 150 to 600 kW.[11]

The lower-capacity units are typically used at depot bus parking similar to where plug-in chargers would be used but with the benefit of not requiring ground space. Higher-capacity units (300+ kW) are used at shared charging positions at depots or at on-route charging locations. Overhead conductive chargers can be flexibly used to “top-up” a bus’s charge for 5 to 20 minutes at higher power or for longer durations at lower power. Overhead conductive chargers historically rely on a smaller ratio of chargers to buses due to their higher power output, which reduces the footprint for the charging equipment. However, it also means that a malfunction of a charging station may have a larger impact on service if the charger is not available.

OEM-proprietary overhead conductor chargers (i.e., chargers that use proprietary conductor contact configurations and non-SAE standard charge communication and charge control protocols) also exist. Proterra’s horizontal-articulating charger mast uses a semi-autonomous bus-to-charger alignment paired with a 500 kW charger (an example of a proprietary overhead conductive charger). However, most manufacturers of both BEBs and chargers have moved to producing SAE 3105/1712-compliant chargers that are interoperable with different combinations of buses and chargers and thus improve flexibility for the operating agencies.

A number of charging OEMs producing SAE 3105 /1712-compliant overhead conductive chargers now offer charger cabinets that can energize multiple overhead conductor chargers and even support a mix of connected dispensers (i.e., plug-in cords and overhead conductors connected to the same cabinet). Overhead conductive charging can be operationally challenging, as proper alignment between a bus and pantograph is critical in achieving proper charging. Similar to the standard established for plug-in chargers, the J3105 standard for overhead conductive chargers allows transit agencies to operate different models of buses from multiple vehicle manufacturers with the same overhead conductive charger. Compared to plug-in chargers, overhead conductive chargers have higher capital and construction costs.

Inductive chargers utilize a wireless power pad as the charging dispenser embedded in the garage floor or roadway surface in addition to a power receiver installed under the bus. An aboveground charging cabinet similar to a plug-in or overhead conductor cabinet is still needed to convert AC to DC power and energize the charging pad dispenser. Like plug-in and overhead conductor chargers, the charging cabinet ranges from 50 to 350+ kW. Some inductive chargers are capable of energizing multiple wireless charging pad dispensers in 1:2 and 1:3+ ratios.

Inductive chargers eliminate concerns for overhead clearances, as they are built into the floor of a garage or roadway. However, there may be significant costs and operational disruptions to install, repair, or replace the charger and wireless pad since it is embedded in the floor of the garage or roadway. Retrofitting multiple induction pads and their associated aboveground chargers in existing garages would require significant trenching and cutting of the floor slabs.

Inductive charging can be operationally challenging, as proper alignment between a bus and an inductive charger is critical in achieving proper charging. Inductive charging is still considered to be in its infancy, as only a small number of North American agencies have implemented inductive chargers either as a charge in parking place at a depot or as an off-site opportunity

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[11] National Academies of Sciences, Engineering, and Medicine, *Guidebook for Deploying Zero-Emission Transit Buses* (Washington, DC: The National Academies Press). https://doi.org/10.17226/25842.

charger. Currently, there is no national standard for inductive charging. As a result, each bus manufacturer can approach this charging strategy differently, meaning that different charging equipment may not work for different types of buses or even different bus models from the same manufacturer. These complexities are analogous to how some smartphone charging ports are not compatible with smartphones from different manufacturers or how smartphone companies can change the charging port between phone versions.

3. Electrification Analysis and Evaluation

Service and Fleet Analysis

This section of the Plan analyzes BTS's bus fleet and service to identify the estimated number of revenue round trips each route could take before needing to return to the garage to charge. This analysis looks at three scenarios: current technology BEBs, moderate technology improvement, and significant technology improvement. These scenarios refer to the battery capacities on BEBs and how their improvement would improve the range of the vehicles.

Current Fleet Composition

As discussed earlier in the Plan, BTS's operating fleet consists of ten 35-foot diesel buses and one home garage to provide service along seven fixed-routes. BTS recently received a grant to purchase its first hybrid diesel-electric bus, which will replace one of its older diesel vehicles. In addition, four buses are nearly at the end of their useful lives in 2023, two more in 2026, and the remainder eligible for replacement after 2031.

Service Analysis Assumptions

BTS bus routes operate Monday through Friday, with the earliest routes starting around 5:10 a.m. and the last bus returning to garage by 6:45 p.m. Table 1 shows the mileage for each route.

Table 1: BTS Mileage by Route

	Deadhead Miles (From Garage)	Deadhead Miles (To Garage)	Deadhead Miles (Total)	Revenue Miles (Per Round Trip)	Round Trips per Weekday
Route 1	3.3	3.3	6.6	7.3	25
Route 2	3.3	2.1	5.4	6.3	25
Route 3	3.3	0.9	4.2	16.5	12
Route 4	4.1	3.1	7.2	6.8	23
Route 5	3.3	0.9	4.2	12.9	4
Route 6	3.3	3.4	6.7	15.0	4
Beloit/Janesville Express (BJE)	3.3	3.3	6.6	45.5	6

Source: BTS route mileage and published schedules.

As previously discussed in this document, battery/energy capacity and energy usage are the primary drivers influencing BEB range and consequently the viability for existing bus service to be served by BEBs. The following section defines the assumptions for each factor used in assessing BEB service viability. Battery capacity and energy usage assumptions are then summarized in Table 2.

Battery/Energy Capacity Impacts on BEB Range

To calculate and model a battery's energy capacity, three factors must be considered:
(1) battery degradation; (2) battery life; and (3) operational flexibility. Each are discussed in the following sections:

Battery Degradation

Batteries become less efficient and wear down over time as they are constantly charged and discharged. For example, as smartphone and laptop users are aware, as these devices grow older, they require more frequent charging as a "full charge" no longer provides power for as long as when the device was new. Based on manufacturer warranties, it is estimated that a BEB's battery capacity degrades by approximately 2 percent per year, which equals a capacity loss of approximately 12 percent after 6 years (bus mid-life, and up to about 27 percent after 12 years (bus end-life).

Battery Life Capacity Reservations

Beyond general battery degradation, charging a BEB to full capacity or charging it from a zero SOC increases battery degradation rates, as additional strain is placed on the battery's physical and chemical components. All battery manufacturers recommend reserving a portion of the battery's capacity to preserve battery life to prevent a more rapid degradation of battery capacity than the annual 2 percent described above. The portion of a battery's capacity that is protected and unavailable for use varies by manufacturer and can range from between 5 percent to approximately 35 percent of the battery's capacity.[12]

Operational Flexibility Capacity Reservations

Just as operators avoid driving a conventional vehicle until the fuel tank is empty, a portion of a BEB's battery capacity is typically preserved for operational flexibility.[12] By preserving this capacity, transit agencies can increase the likelihood that BEBs will have sufficient range to return to the garage in the event of unseen delays or other unexpected events that might require a BEB to remain in service longer than originally planned.

Usable Battery Capacity Calculation Summary

Overall, BTS's BEB service planning is based on a battery's usable, rather than nominal, capacity at bus mid-life to account for battery degradation and capacity reservations. Based on an approximately 2 percent annual battery capacity degradation and the reservation of 10 percent battery capacity for battery life and 10 percent for operational flexibility, the usable battery capacity at bus mid-life (6 years) is calculated as 70 percent of the nominal (advertised) battery capacity.

Energy Usage Impacts on BEB Range

Along with battery capacity, the amount of energy consumed by the bus (kWh/mile) also impacts BEB range. When the energy used to heat/cool a bus's passenger cabin is the same energy that would be used for the propulsion of the bus, bus range can be substantially reduced in cold weather, as increased energy must be devoted to maintaining a comfortable passenger cabin temperature.

Beloit, WI, typically experiences 5 months of the year when average low temperatures are below freezing, which can be detrimental to a BEB's range because much energy will be required to heat the interior.[13] Therefore, even though many transit agencies across the country can largely plan BEB service assuming relatively warm average ambient temperatures, BTS must plan BEB service around worst-case range estimates based on winter temperatures to

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[12] National Renewable Energy Laboratory, *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses* (April 2021).
[13] U.S. Climate Data, Climate Beloit–Wisconsin and Weather Averages Beloit (2022).

ensure reliable service can be maintained year-round. Drawing on the experience of other cold weather agencies operating diesel-heated buses, this BTS transition plan utilizes the same worst-case energy efficiency of 2.9 kWh/mi.

Summary of BEB Service Analysis Assumptions

Table 2 summarizes the battery capacity and energy usage assumptions and criteria outlined above and used to assess the suitability of BTS's service routes for BEB operation. In recognition of the speed at which BEB technology is advancing (battery capacities have increased by more than eightfold from 2014[14] to 2023[15]), three service analysis scenarios have been considered based on differing BEB technology assumptions, as quantified by the buses' nominal battery capacity. The three scenarios are: current technology (588 kWh); moderate technology improvement (738 kWh); and significant technology improvement (880 kWh). The current technology capacity was selected to align with the battery capacities commonly available in the current BEB market, the moderate technology capacity aligns with recently deployed improvements from Proterra,[15] and significant technology improvement is comparable with the trajectory of recent battery capacity improvement in the industry, as expected to be available in the near future.

Table 2: Assumptions for Fixed-Route BEB Service Analysis

Item	Current Technology	Moderate Technology Improvement	Significant Technology Improvement
Battery size–nominal capacity	588 kWh	738 kWh	880 kWh
Battery size–usable capacity *	412 kWh	517 kWh	616 kWh
Average kWh per mile**	2.1	2.1	2.1
Average range in miles	196	246	293
Worst-case kWh per mile**	2.9	2.9	2.9
Worst-case (winter in Beloit) range in miles	142	178	212

Note: All analyses assume 35-foot garage-charged BEBs using an auxiliary diesel heater.

* Usable battery capacity is defined as the bus mid-life battery capacity calculated as 70% of nominal battery capacity. This definition assumes a 2 percent annual battery capacity degradation and a total of 20% capacity reserved for a combination of battery health and operational flexibility.

** Average and worst-case energy efficiency (kWh per mile) were calculated using assumptions and modeling efforts based on an area with similar operating and weather characteristics to Beloit, WI.

Fixed-Route BEB Service Analysis Results

Using the criteria presented in Table 2, each of BTS's bus routes can be analyzed to assess BEB suitability. For each of the three technology scenarios, the number of round trips that a bus can take before it should return to the garage for charging has been determined by using the following equation and then rounding down for a conservative estimate:

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[14] National Renewable Energy Laboratory, *Foothill Transit Battery Electric Bus Demonstration Results* (January 2016).

[15] Inside EVs, Proterra Introduces 738 kWh Battery Packs for ZX5 Buses (April 18, 2022).

$$\# \; of \; Round \; Trips = \frac{(Scenario's \; Mile \; Range) - (Deadhead \; Miles)}{(Revenue \; Miles \; per \; Round \; Trip)}$$

As the length of buses operated on any given route is subject to change in the future, this service analysis is applied to all routes regardless of the bus length currently operating. BEB service viability analysis results are likely to fluctuate as BTS's route characteristics are modified. To establish a baseline and to illustrate how this methodology can be used to inform BEB transition policies and prioritize BEB deployment, the analysis results of BTS service are summarized in Table 3.

This table displays the number of existing round trips per route compared with the number of revenue round trips viable under each technology scenario before the BEB needs to return to the garage for charging; this is shown under the Average and Worst-Case energy assumptions for each of the three battery technology scenarios for each of BTS's existing fixed routes.

Table 3: Number of Revenue Round Trips Viable for Each of BTS's Existing Fixed-Routes for 35-Foot BEBs

Route		Current Technology (588 kWh)		Moderate Technology Improvement (738 kWh)		Significant Technology Improvement (880 kWh)	
Assumption	**Existing Round Trips**	**Average**	**Worst-Case**	**Average**	**Worst-Case**	**Average**	**Worst-Case**
Route 1	25	25	18	32	23	39	28
Route 2	25	30	21	38	27	45	32
Route 3	12	11	8	14	10	17	12
Route 4	23	27	19	35	25	42	30
Route 5	4	14	10	18	13	22	16
Route 6	12	12	9	15	11	19	13
BJE	6	4	2	5	3	6	4

As shown, Routes 1, 2, 4, 5, and 6 could be replaced 1:1 with 35-foot BEBs with current battery technology for average days but would struggle in the worst-case scenario. Route 3 could be served when using moderate technology improvements for the average scenario but would need significant improvements for the worst-case scenario. Under significant technology improvements, Routes 1 through 6 could all be served by BEBs with a 1:1 replacement.

The BJE is a long round trip and could not be replaced 1:1. To make the BJE feasible with BEBs, strategies to extend the vehicles' range would be necessary to achieve full zero-emission transition. Such strategies could include rescheduling blocks based on the range limitations of the BEBs, but this strategy would require additional vehicles and operators to complete the same amount of vehicle miles as well as other operational adjustments. An alternative strategy is on-route (opportunity) charging, which can extend the range of the vehicles by utilizing layovers to quickly charge the vehicles but is also associated with expensive equipment and increased charging costs due to its high power demand during peak power periods. To help control these costs, BTS could potentially partner with Janesville Transit System to install this equipment at either agency's transit center and share the costs as they share the route's operation should that agency choose to transition to BEBs.

Because BTS has newer buses that will not be eligible for replacement for over a decade, the BJE should be the last route to transition to a BEB, when the technology can handle the demands of such a long route.

Fleet Transition Projection

At present, BTS does not have any electric buses and will be applying for one hybrid diesel electric bus with the Fiscal Year 2023 Low or No Emission Vehicle Program to supplement the hybrid diesel-electric vehicle it is set to receive in 2023. This introduction into battery electric propulsion will serve as an "on-ramp" to fully transition the fleet to zero-emission vehicles.

One of the requirements of an FTA transition plan is to demonstrate how the agency will reach a 100 percent zero-emission fleet. Figure 6 shows BTS's anticipated fleet transition through 2035, when all buses are anticipated to be electric (made possible based on the application that BTS is pursuing this year [hybrid vehicles]). It is worth noting that this figure shows one scenario, and it is possible that the plan implementation could be moved earlier or delayed into the future. A key factor affecting the timing will be whether hybrid buses are purchased instead of BEBs. With most of its buses able to be replaced on a 1:1 basis with depot charging, the agency would need to prepare its garage for charging infrastructure to begin the transition.

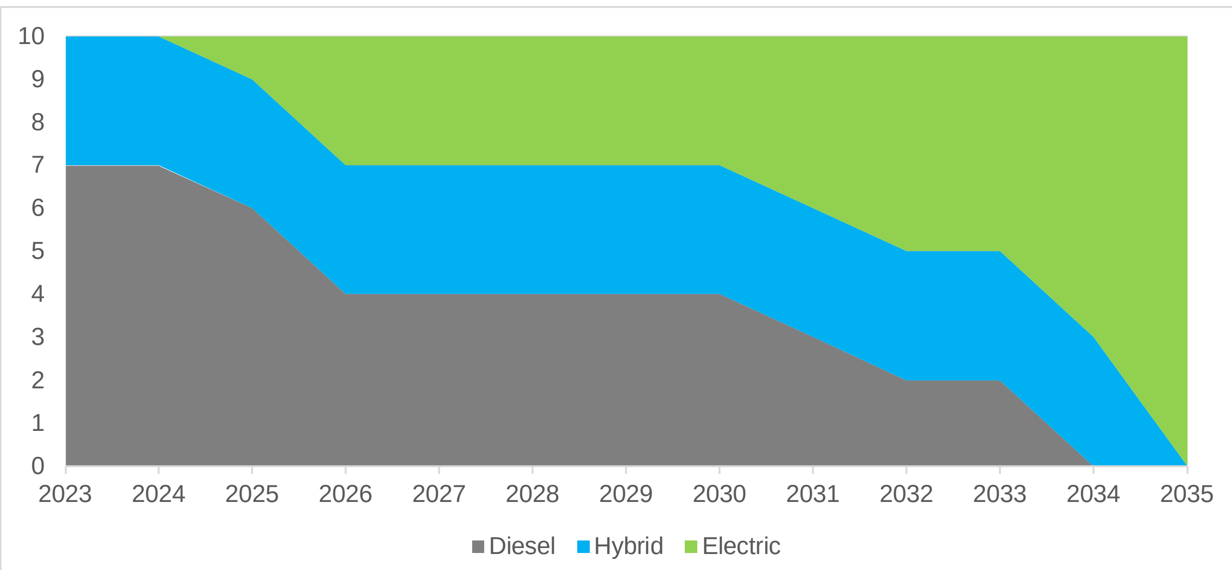

Figure 6: Fleet Composition Projection with Procurement Schedule

Facility Analysis

This section analyzes the suitability of BTS's facility to support a transition to BEBs. BTS operates and maintains its transit fleet from the agency owned BTS Administration Building (BTS Garage), located at 1225 Willowbrook Road, Beloit, WI 53511. The BTS Garage was reviewed for existing configuration, current operational on-site vehicle flow, bus parking configuration, and existing electrical service entrance location and size. BTS's goal of eventual replacement of existing diesel and hybrid diesel-electric buses with BEBs is anticipated to be implemented as the existing and near-term incoming buses are replaced. In preparation for this transition, existing operational bus site flow and bus parking configurations must be identified and reviewed as compatible with the selected BEB charging technology. As introduced in "

Overview of Electric Bus Technology," above, there are multiple BEB charging options/equipment configurations and the future charging technology should be compatible with the existing facility, and the current on-site bus daily and nightly service circulation.

BTS Garage

The BTS Garage is a standalone purpose-built transit operations and maintenance facility. It houses BTS Administrative, operations, bus maintenance, and nightly service spaces. The buses are parked inside a covered garage (Figure 7). The fuel and wash areas are enclosed and attached and adjacent to the bus parking. There is capacity to park 16 35-foot to 40-foot transit buses in the existing bus parking area. With the current bus fleet of 10 diesel and incoming diesel hybrid buses, the extra parking spaces currently house BTS non-revenue vehicles (NRVs), Beloit Police specialty vehicles, and facility maintenance equipment, materials, and vehicles (Figure 8). The garage has the capability to store up to 12 demand response, cutaway vehicles in this extra space if this ancillary equipment is removed. The bus parking building is concrete block / concrete masonry unit (CMU) walls, and open web steel-bar roof joists support a corrugated metal deck roof, which is a shallow-sloped roof with a high point at the mid-span of the parking enclosure. The maintenance bays are separated from the operations / administration office and the bus parking areas by CMU walls. There are three maintenance bays, including a pit bay.

Figure 7: Existing Enclosed Bus Parking

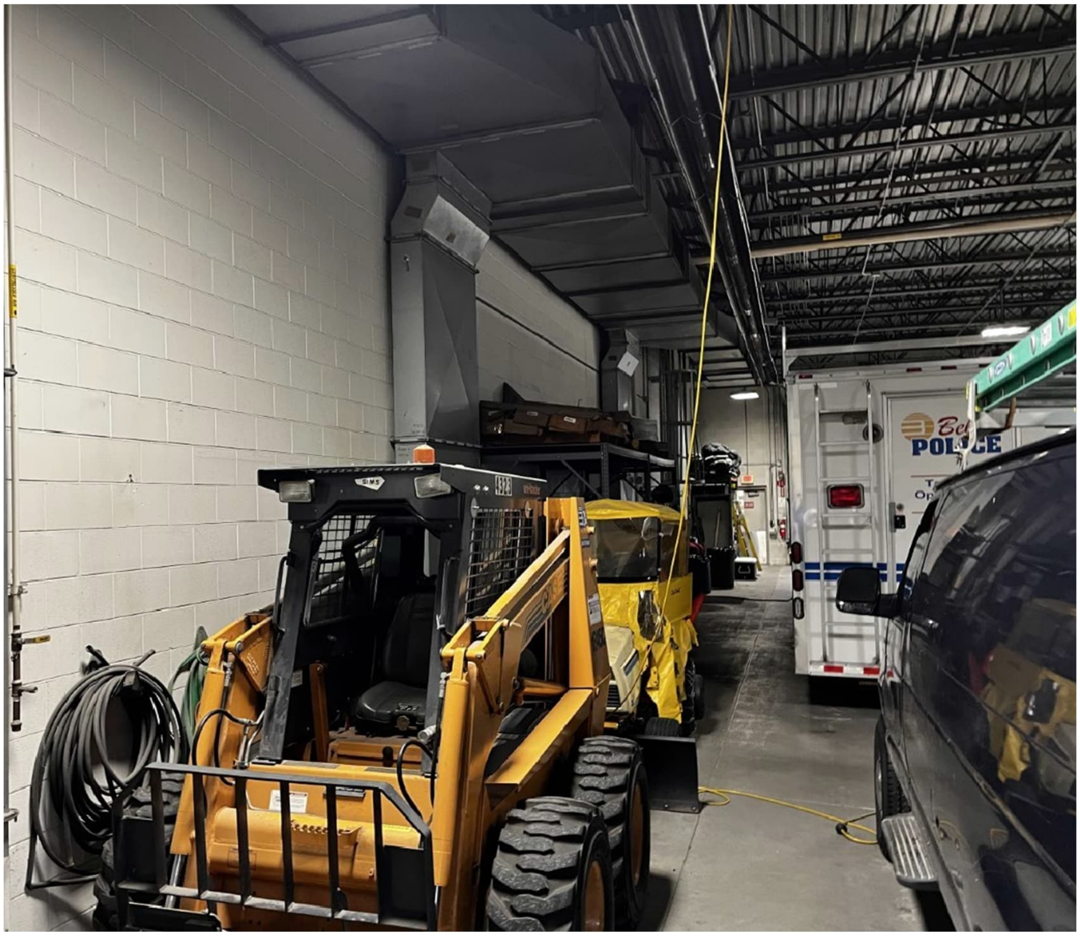

Figure 8: NRV, Police & Materials in Parking Area

Existing Bus Circulation

At the end of the daily shift for the p.m. pull-in, buses enter the BTS Garage site from Willowbrook Road and enter the fuel bay at the southern end of the BTS Garage building. After refueling, the bus operators then enter the enclosed bus wash bay adjacent to the fuel bay. After the exterior wash is completed, the bus operators leave the enclosed bus wash bay and circulate back outside along the eastern edge of the site. The bus operators then make a 180 degree turn to enter the designated position within the bus parking area. The buses are parked in pull through parking tracks two buses deep, where they are ready for the a.m. pull-out. Daily fare collection and interior bus cleaning occurs during this nightly service and parking cycle. In the morning, the buses pull out through the west overhead doors and exit to Willowbrook Road to begin daily transit service. Figure 9 displays the bus circulation as it occurs at the BTS Garage.

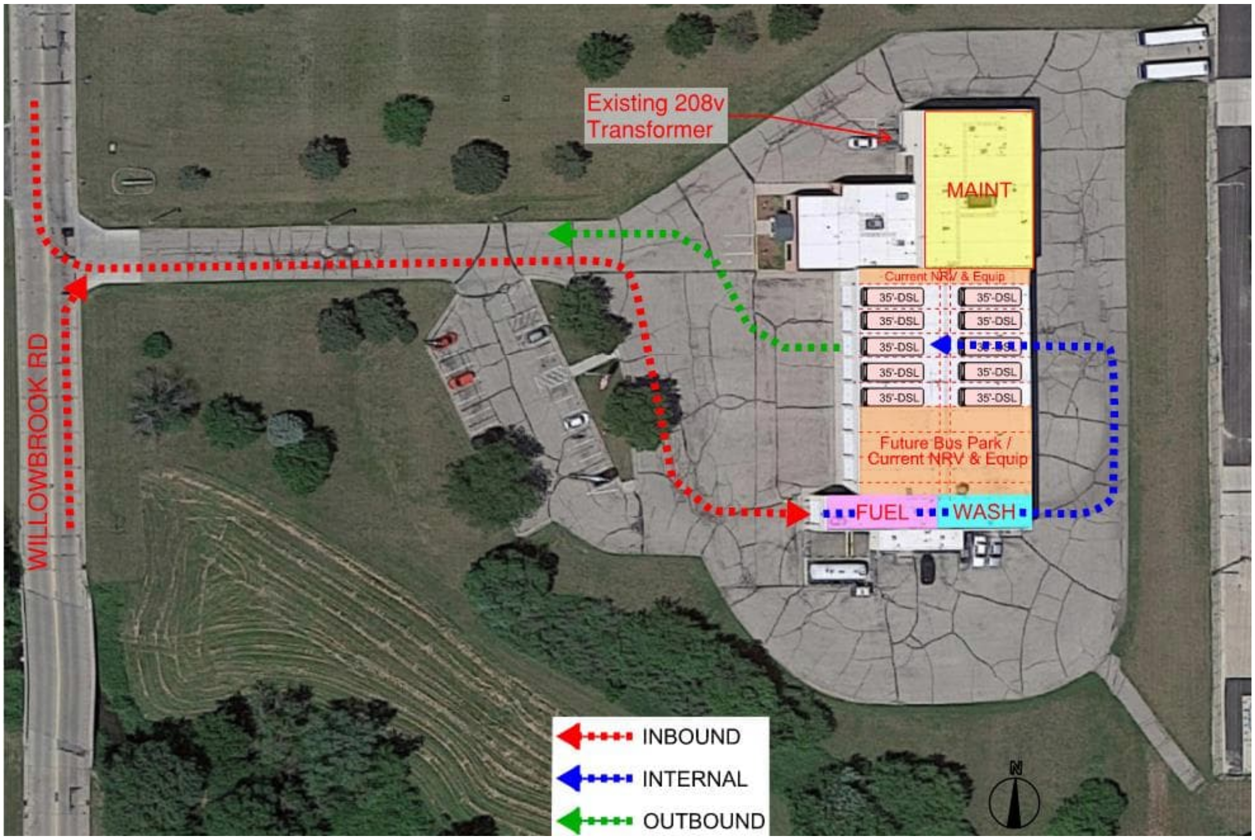

Figure 9: Existing BTS Garage Site and Bus Circulation Plan

Bus Charger Opportunities

The enclosed bus parking area, within the BTS Garage, has adequate distance from the top of the bus roof to the underside of the garage roof structure to accommodate both overhead conductive chargers or a drop-down reel or retracted plug-in cord. The bus parking track widths are nominally 14 feet wide and would physically fit a remote ground-mounted, plug-in dispenser. It is recommended to avoid placing charging equipment and dispensers in the path of travel of the buses unless an overhead dispenser (pantograph or plug-in cord) is not viable. Since the BTS Garage is compatible with two types of overhead charging dispensers, this type of charging is recommended, as it would significantly reduce the risk of buses damaging charging dispensers. As shown on Figure 10, the potential BEB parking plan allows BTS to keep the exact site and vehicle flow that is utilized now with either a drop-down plug-in cord or an overhead pantograph.

It is recommended that BTS pursue extending arm, overhead pantograph dispensers at the garage. We like the extending arm dispenser because it is more common, which means it should be more cost effective to purchase and maintain than the piston type, and the garage's height can accommodate it. Because this equipment is mounted to the roof of the building and connects to the top of the bus, there are less opportunities for accidental contact from someone passing by the charging vehicle as opposed to the drop down, plug-in dispensers. Accidental contact of these plugs-ins can damage the equipment, disconnect the plug-in which stops the charging sequence, or potentially injures the passerby should they fall from the contact.

However, the overhead pantographs are more expensive than a drop down charger and the BTS may decide to mitigate some of these risks in exchange for a lower project price.

A new 480-volt (v), three-phase transformer and new 480 v, three phase switchboard would be needed to energize a Level 3 charger in the 60 kW to180 kW range. There is ample room in on-site grass areas to locate a new utility transformer. Because of the available space on-site, there are multiple viable options to install charging service and equipment. The approach shown on Figure is for new feeder lines to be installed from a new utility-provided transformer that would likely be trenched or bored across the existing circulation pavement. Feeders would rise up the vertical wall of the BTS Garage and either enter in and run in the plenum space / below roof decking or, as shown, run across the roof then drop down to top-feed a new 480 v, three-phase switchboard. The new switchboard would have capacity to energize one to eight+, 150 kW nominal chargers. Each charger cabinet would be used to energize two dispensers each. Space can be consolidated by either placing the charger cabinets on a new raised mezzanine or along the outside of the building envelope.

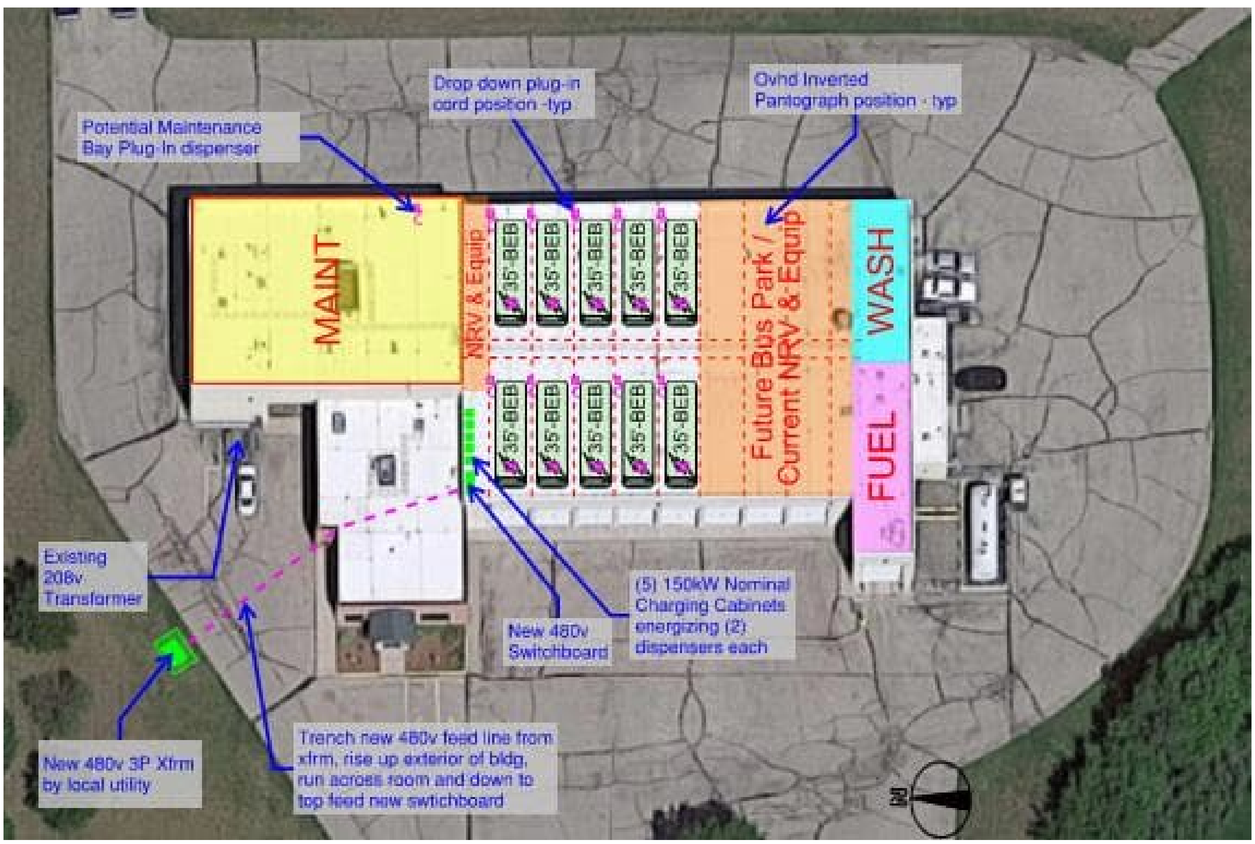

Figure 10: BEB Concept Master Plan

Due to the disruptive nature of construction at a transit facility, it is recommended that any facility modifications required for a full fleet transition, such as running conduit, laying concrete pads, upgrading switchboards, provisioning space for future chargers, etc., be designed and implemented during the initial deployment of the BEBs. This approach will allow the agency to quickly and easily add future BEBs and chargers to the fleet without having to modify the garage multiple times.

Due to the potential for cold weather and snow, there is benefit to locating the charger cabinets inside the garage. Additional space saving could be achieved if a higher charger-to-dispenser ratio, such as 1:3 or 1:4, is used, therefore requiring fewer cabinets. The charger cabinets can energize either plug-in or pantograph dispensers, and there is adequate vertical space for either. Given that the bus parking area is fully enclosed, the location of the bus charging port (front of the bus for the pantograph and rear of the bus for the plug-in) would not be an issue as either charging setup could be accommodated. It is recommended that any DC charging and communication wiring from charger to dispenser be done in cable tray / wireway systems in lieu of being enclosed in conduit. Such an approach would allow easier reconfiguration of dispensers, if needed, and would also better accommodate the replacement or upgrading of the charging equipment multiple times in the remaining life of the BTS Garage.

Limited charging is needed in the maintenance bays, as buses will typically complete their long-term charging in a parking position in lieu of taking up a maintenance bay. If desired and achievable during detail design of the chargers, a remote charging plug-in cord dispenser can be added to the maintenance facility. One drop down plug between the two non-pit bays could supply both bays with charging power. Alternatively, a portable charger with 50 kW nominal capacity is available but would require a 480 v plug and only 208v power is currently available in the shop. BTS is currently installing overhead, fall protection systems which is an important safety consideration when servicing vehicles like BEBs with roof mounted equipment. The amount of equipment on the roof of a BEBs is why overhead pantograph charging is not recommended for use in maintenance bays.

Wireless inductive chargers could be retrofitted into the existing BTS garage. This would require trenching of the existing slab and structural slab patching, or this could be installed in a raised surface. While a surface mounted version eliminates the need to trench and repair the slab, the raised cable trays and pads would present potential tripping hazards at the floor level that would not be present if the overhead dispensers were utilized. Please refer to the “inductive chargers” discussion in Section 2, on page 9, for additional considerations of this technology.

Beloit Transfer Center

The Beloit Transfer Center serves as the main transfer hub for all BTS service (Figure 11) and is a potential location to install opportunity charging if the agency desires to take advantage of this technology. The existing passenger loading/unloading berths are compatible with either mast-supported inverted pantographs (due to adequate clear space above berths) or wireless induction charging. It is recommended to consider usage of inverted pantograph charging if opportunity charging is added to the Beloit Transfer Center. Although compatible space-wise (with room to install the aboveground power modules), high capacity (over 22 kW) wireless charging currently does not have an SAE standard that allows for a mix of charger OEMs. This new wireless charging standard is in the process of being developed and would be a recommended technology for opportunity charging once available with a higher charger capacity. Because this location is at the end of the lines, the routes’ recovery time can be utilized to provide a quick charge to each vehicle’s batteries and extend its range. The layout of the bus berths is conducive to installing overhead charging equipment; however, the agency would need to coordinate with the utility company to determine power availability in the area and the infrastructure updates that would be needed.

Figure 11: BTS Bus at the Beloit Transfer Center

4. Utility Coordination

Utility rates for electric fleets users are usually far more complex than for residential or small users. Electricity will eventually replace diesel as the primary energy cost, so understanding how it is priced can help cut costs. Unlike diesel, electricity usually has the time of day and peak use components. This means applying operating strategies to defer charging until cheaper off-peak periods or to minimize peak demand can dramatically cut costs.

Energy, Demand, and Fixed Charges

Large utility tariffs usually have three major components and a variety of smaller riders or variables:

- The first is energy, (kWh) (power over time); this is the method for charging consumers for energy used.
- The second is demand (kW), which is the peak instantaneous power used, usually over a month. Alliant Energy automatically assigns any agency using 75kw or higher to tariff plan that includes demand charges.
- Third, there is a fixed monthly rate for the connection. The fixed-rate is usually quite a small amount and covers the administrative overhead of reading the meter and invoicing.

Additional smaller fees or adjustments are also applied, but demand and energy are the cost driver so we will explore these in a little more detail.

Energy Charges (kWh)

Energy charges are levied by your electrical provider, Alliant Energy, per kWh and are the component of the bill people are familiar with paying privately at home. Alliant utilizes time-of-use pricing periods which charges different rates for different times of day and season:

- High rate: (Summer = Jun. Jul. Aug.) 11 a.m. to 7 p.m.
- High rate: (Winter = Dec. Jan. Feb.) 5 p.m. to 9 p.m.
- Low rate: 11 p.m. to 6 a.m. weeknights
- Low rate: All hours on weekends and holidays
- Regular rate: All other hours

Our plan for BTS defers charging to late at night (after 10:00 PM) when the costs are typically lower and allow considerable savings. Reducing the total daily amount of energy required by the fleet only occurs by improving the overall efficiency of the chargers, vehicles, and operations. A reduction in daily energy costs can be achieved through charging at smarter times for an equal amount of energy.

Demand Charges (kW)

Demand charges are based on the highest power in kW (kiloWatts) drawn at any time over a given period. The maximum power is measured and averaged over a 15-minute window by the utility meter. The demand charge is then set to that maximum for the full billing period, even if it only occurs once. To prevent its large power customers from taxing the grid during times of peak use, Alliant only applies these charges during “On-Peak Demand” which is currently 10:00AM-10:00PM. These incentives it energy users to only “demand” high power during the “Off-Peak Demand” times. These charges can often be the biggest part of a user’s utility bill, often doubling or tripling the energy charges themselves. Fortunately, BTS will be able to fully charge their buses during the “Off Peak Demand” and avoid many of these expensive demand charges.

Utility Rate Considerations

BTS has traditionally not had to concern itself with demand charges on its utility bills due to its low energy demand. However, with the introduction of this technology, it will need to be moved to a tariff for high energy users which includes demand charges. Between the building's energy demands and the demand of just one BEB charger, Alliant Energy has just one tariff option: Cp-1. There may be an opportunity to install a standalone electric service for the chargers only, which would allow the rest of the facility to enjoy the lower rates on its current tariff, but this would involve installing separate transformers and switchgears. We recommend this opportunity be explored as part of the infrastructure design process.

Considering the financial consequences of charging a bus at the wrong time, BTS should have a charge management system in place that will limit the amount of kW the charger will utilize depending on several factors, but most importantly during on-peak demand times. Almost all chargers come with their own charge management system, but there are third party systems that may be more beneficial and are worth exploring.

Utility tariffs change biannually, so it is crucially important to keep in touch with your Alliant client representative throughout the process of purchasing and operating a BEB to ensure you understand how these changes would affect your electric bill.

Coordination With the Utility

Alliant Energy has been engaged and prepared to assist BTS with the transition of its buses to zero-emission technology. The utility confirmed that there is enough power in the area to accommodate the agency's future power needs over the length of time it will take to transition the fleet; however, the transformer is undersized for charging battery electric buses and would need to be upgraded before any initial BEB deployment. Alliant Energy staff were confident that they could supply the necessary equipment in a similar time frame to that required to order, build, and deliver a BEB to the agency.

BTS will work closely with Alliant to coordinate future energy needs as its zero emission fleet grows to ensure power is available to operate its electric fleet.

5. Resource Availability

Funding Availability

BEBs and their associated infrastructure would require additional funding beyond that which is usually available for transit vehicle acquisition due to the additional costs associated with the technology and the facility changes. The table below outlines cost estimates for the BEB, charging infrastructure, and design work.

Project	Estimate Metrics	Cost Estimate	Source
35’ Gillig BEB	Base vehicle cost	$1,039,708	State of Washington Transit Bus Contract
Infrastructure Design	Infrastructure planning and design	$200K per project	Engineer’s estimate
Power upgrade projects	Design, construction & equipment	Variable ($200K–$400K) per project depending on capacity added	Engineer’s estimate; includes 20% contingency.
Charging installation projects	Charging equipment & installation	$132K per 150 kW charger $72K per pantograph dispenser	Quotes and estimates, include 20% contingency.

Figure 12: Estimated Project Costs

Some of the programs that could provide such funding are described below.

2023 Low-No Grant

At present, BTS is working on a Low-No Grant application for one hybrid electric-diesel GILLIG bus. As it continues the transition to a zero-emission fleet, BTS will likely use this annual grant program as the primary funding source for both the vehicles and the infrastructure needed to reach its goals.

Buses and Bus Facilities Competitive Program

The Grants for Buses and Bus Facilities Competitive Program makes federal resources available to agencies like BTS to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities, including technological changes or innovations to modify low- or no-emission vehicles or facilities. Funding is provided through formula allocations and competitive grants.

RAISE Grant

The Rebuilding American Infrastructure with Sustainability and Equity (RAISE) discretionary grant program helps project sponsors at the state and local levels, complete critical freight and passenger transportation infrastructure projects. The eligibility requirements of RAISE allow project sponsors to obtain funding for projects that are harder to support through other U.S. DOT grant programs, however, many agencies have been successful in utilizing this program to advance their zero emission fleet programs.

Urbanized Area Formula Grants

BTS receives an annual allocation of formulaic grant funds from the FTA known as 5307 funds for transit capital and operating assistance and transportation-related planning. Helping the agency transition to zero-emission vehicles is an eligible expense under this grant.

State and Local Funds

Almost all federal grants require non-federal, matching resources to receive funding. BTS has historically depended on local bonding and/or assistance from the State of Wisconsin to provide this matching resource, and BTS is anticipated to do so for this program.

Workforce Development and Training

BTS currently maintains its buses with two experienced diesel mechanics, one of which leads the maintenance department, both of whom began their careers with the City of Beloit at the Department of Public Works. Both mechanics have Automotive Service Excellence (ASE) A6 certifications, which demonstrates proficiency with automotive electrical/electronic systems. Their understanding of bus electric systems will continue to mature with the agency's delivery of its first hybrid electric-diesel bus. With its delivery, both mechanics will receive high-voltage safety instruction; training from the electric drive system's manufacturer, BAE Systems; and training from the bus manufacturer, GILLIG LLC. These long-term employees will receive comprehensive training to ensure that they are prepared to work with low-emission technologies.

BTS will take the same approach to training mechanics as part of future BEB purchases; BTS will ensure that their mechanics complete the extensive training needed to ensure that they are able to transition to maintaining zero-emission vehicles. Their understanding of hybrid electric vehicles will make this transition easier. This training will become part of the standard training protocol for future hires.

BTS will utilize future BEB OEMs to train bus operators on the differences between a diesel-powered vehicle and a BEB, including any driving changes needed to ensure that the battery is utilized efficiently, and the safety considerations needed to safely operate BEBs. If BTS choses to utilize plug-in charging for its vehicles, operators would also receive safety training on this equipment. These changes will be folded into the organization's training program to ensure that all new operators are sufficiently educated for safe operation of BEBs.

Safety is of paramount importance. To support the safe operation and maintenance of BEBs, BTS plans to purchase the additional personal protective equipment (PPE), tools, and equipment that the mechanics will need based on OEM recommendations. BTS will also provide training to local first responders to help mitigate risks in case of a safety event affecting a BEB in the future.

BTS will communicate with its frontline workers to determine if they need additional training as they attain experience with the equipment. By empowering the current workforce to maintain this new equipment, BTS plans to keep its existing staff; BTS does not expect to displace any of its employees because it is transitioning to zero-emission buses.

6. Conclusion

BTS is well positioned to begin incorporating battery electric buses into its fleet. Most of the vehicle daily runs could be accomplished with existing BEB technology and with overnight vehicle charging. The BTS Garage has the space to accommodate BEB charging equipment, and the maintenance staff are receiving training on electric drive systems with their new hybrid diesel-electric bus, which is expected to be delivered in 2023. Aside from some building upgrades, BTS is ready to begin adding BEBs to its fleet.

Next Steps

The next steps identified to move BTS's fleet transition forward include the following:

1. Determine the amount of power that is needed at the BTS Administration Building to charge a fleet of BEBs. The agency can model the amount of power that will be needed in the future and work with the utility company and a engineering design team to ensure that the proper upgrades are made to its infrastructure.
2. Provide the necessary updates to the building's electric systems.
3. Coordinate with the utility company to upgrade its transformer.
4. Prepare a procurement/contract for BEB vehicles.

Updates to the Transition Plan

This transition plan is reflective of zero-emission technology as it exists today. The technology is rapidly evolving and, with the increased acceptance of these vehicles into large fleets, will likely improve its performance. It would be beneficial for BTS to review and, if necessary, update this plan every 3 to 5 years, much like a long-range strategic plan. Such a process would help ensure that BTS is maximizing the benefits of new technology and the efficiencies it will likely bring.