Minnesota Valley Transit Authority

Phase 1 Zero-Emission Bus Transition Plan

May 2022

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Prepared by MVTA in collaboration with AECOM.

1 Executive Summary

MVTA's Zero-Emission Bus (ZEB) Transit Plan describes the analysis that will be used to guide and inform our transition toward ZEBs in alignment with our pledge to "…effectively and continuously move toward more sustainable operations." This Plan introduces the importance of and trend towards zero-emission buses, key technology differences between conventional internal combustion engine buses and battery electric buses (BEBs),and addresses the availability of current and future resources necessary for transitioning towards a zero-emission fleet. In addition, our Transition Plan also assesses the suitability of MVTA's bus fleet, service, and facilities to support a transition towards ZEBs. This Plan is a living document that will be regularly revisited, refined, and updated as ZEB technology improves.

Zero Emission Bus Technology Overview

The transportation sector is a major greenhouse gas (GHG) emitter both in Minnesota and nationwide. To mitigate the impacts of climate change, and to move toward more sustainable operations in alignment with local and regional sustainability policies, MVTA is pursuing the integration of and transition towards ZEBs. Three ZEB technologies are currently commercially available including: electric trolleybuses, hydrogen fuel cell electric buses (FCEBs), and battery electric buses (BEBs). While electric trolleybuses 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.[1] Out of the more than 3,500 full-size transit ZEBs either on the road or on order in the United States as of September 2021, more than 95% are BEBs while only two states, California and Ohio, have adopted a total of more than 10 FCEBs. Due to the high cost of FCEBs, current lack of hydrogen fueling stations in Minnesota, and expanded industry resources and experience with BEBs compared with the other two ZEB technologies, MVTA has selected BEBs as our short-term ZEB technology for implementation and deployment.

Fixed Route Service Suitability for BEB Deployment and Operation

BEB technology is a rapidly advancing field. For example, battery capacities, and thus BEB range, is anticipated to increase by more than eightfold between 2014[2] to 2023.[3] In recognition of the rapid pace of BEB innovation, the suitability of our fixed route bus service to support BEB deployment and operation was modeled against three future BEB technology scenarios: current technology, moderate improvement, and significant improvement. Modeling results showed that a majority of our bus service could be provided by directly replacing current diesel buses with BEBs in each of the three scenarios. In the *Current Technology* scenario, based on a BEB's worst-case (Minnesota winter) range on a single garage-charge, approximately 56% of our bus blocks, representing over a third of our annual revenue hours and miles, could be served with a direct 1:1 BEB replacement of existing diesel buses. In the *Significant Technology Improvement* scenario these shares increased to nearly 90% of bus blocks representing approximately 80% of revenue miles and hours. To operate BEBs on the remaining portion of our service that was not technically viable under any of the

[1] Source: The National Transit Database (NTD)
[2] Source: Foothill Transit Battery Electric Bus Demonstration Results, NREL, 2016
[3] Source: Proterra Introduces ZX5 Electric Bus With 738 Kilowatt Hours of Energy, Proterra, April 14, 2022

three technology scenarios would require more pronounced technology improvements, replacing diesel buses at a greater than 1:1 ratio, or other service alterations.

Opportunities and Needs for Facility Electrification

MVTA's fleet of more than 170 buses is stored in two garages: the Eagan Bus Garage (EBG) and Burnsville Bus Garage (BBG). To support BEB operation, both facilities would require the construction and installation of charger and other supporting infrastructure as well as other electrical modifications and upgrades. Based on an assessment of the existing operational and spatial constraints at each garage, EBG has been selected as the initial garage to receive electrical upgrades and house BEBs. Currently BBG is undergoing a three-phase expansion and modernization project. As part of this project, a variety of energy efficiency and sustainability improvements are planned including electrification initiatives designed to lay the foundation for BEB operations in the medium- to long-term future at this facility.

In addition to our two garages, MVTA also owns six Park and Ride/Transit Center facilities of the land on which these facilities are located. Although MVTA does not plan to pursue on-route opportunity charging in the short-term, a preliminary assessment of these facilities indicated that none of the six facilities were critically flawed as all have sufficient space to install overhead charging infrastructure in the future.

Enhanced and Expanded Workforce Development and Training

Operating and maintaining a BEB differs in many ways from traditional procedures associated with conventional internal combustion engine buses. To ensure the safe and efficient operation and maintenance of BEBs, MVTA plans to build upon and expand the skills of its existing workforce. ZEB training and workforce development strategies include utilizing hands-on BEB training and technical expertise from BEB and supporting infrastructure on-site vendor technicians, purchasing and training staff on the proper usage of high voltage personal protective equipment (PPE), and providing training to local first responders to help mitigate potential safety risks. MVTA will communicate with and empower frontline workers, through its contractor Schmitty and Sons, to learn what additional training is needed as experience with ZEB equipment is developed.

Funding Availability to Support a Transition Toward ZEBs

BEBs and their associated infrastructure 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. To remain fiscally sustainable while transitioning towards ZEBs, it is anticipated that MVTA will need to pursue additional funding streams in addition to capitalizing upon existing funding sources that may be expanded in the near future due to recent federal legislation. One such opportunity for potential capital funding includes the Federal Transit Administration's (FTA) Low or No Emission (Low-No) discretionary Grant. As a result of the federal Infrastructure Investment and Jobs Act (IIJA) being signed into law, $1.1 billion will be annually appropriated to the Low-No program in federal fiscal years 2022-2026. Presently, MVTA is working to develop a Low-No Grant application for five 588 kWh long-range 40-foot Gillig BEBs, along with the supporting infrastructure for one lane at EBG to support these five vehicles. Should this grant be awarded, MVTA will be taking an important step towards its zero-emission future. As MVTA gains experience with emerging zero-emission technologies and the operation of BEBs, we will continue to collaborate with our partners including Xcel Energy to continue to assess and identify strategies to mitigate ongoing BEB operation and maintenance costs.

Collectively, the context, results, and future considerations presented in this ZEB Transition Plan establish a framework from which MVTA plans to transition towards more sustainable operations. As ZEB technology improves, this living document will be regularly refined and updated to align with industry best practices as well as local and regional sustainability policies and initiatives all while continuing to "…connect customers to desired destinations."

2 Transition Plan Context and Purpose

This section outlines the purpose and motivation for the Minnesota Valley Transit Authority's (MVTA) Zero-Emission Bus Transition Plan and places the Transition Plan in a broader political and environmental context. Specifically, this section highlights the impact the transportation sector has on the environment in Minnesota, the nationwide trend towards zero-emission buses, and existing policies and initiatives with zero-emissions implications.

2.1 MVTA Bus System and Facilities

The Minnesota Valley Transit Authority (MVTA) is the second largest public transit agency in Minnesota based on ridership, providing transportation throughout seven suburbs south of Minneapolis and Saint Paul in some of the largest and fastest-growing communities in the state. MVTA operates within Dakota and Scott counties and extends substantial service beyond these borders into adjacent regions. MVTA provides flexible transit service through a variety of programs including flex routes as well as local, commute, and reverse commute, and on-demand service. In 2019, prior to the COVID-19 pandemic, MVTA provided over 2.5 million rides with an average weekday ridership of more than 9,200.[4] As the major transit provider for Minnesota's southern metro area, MVTA is committed to serving our communities well while pledging to effectively and continuously move toward more sustainable operations.

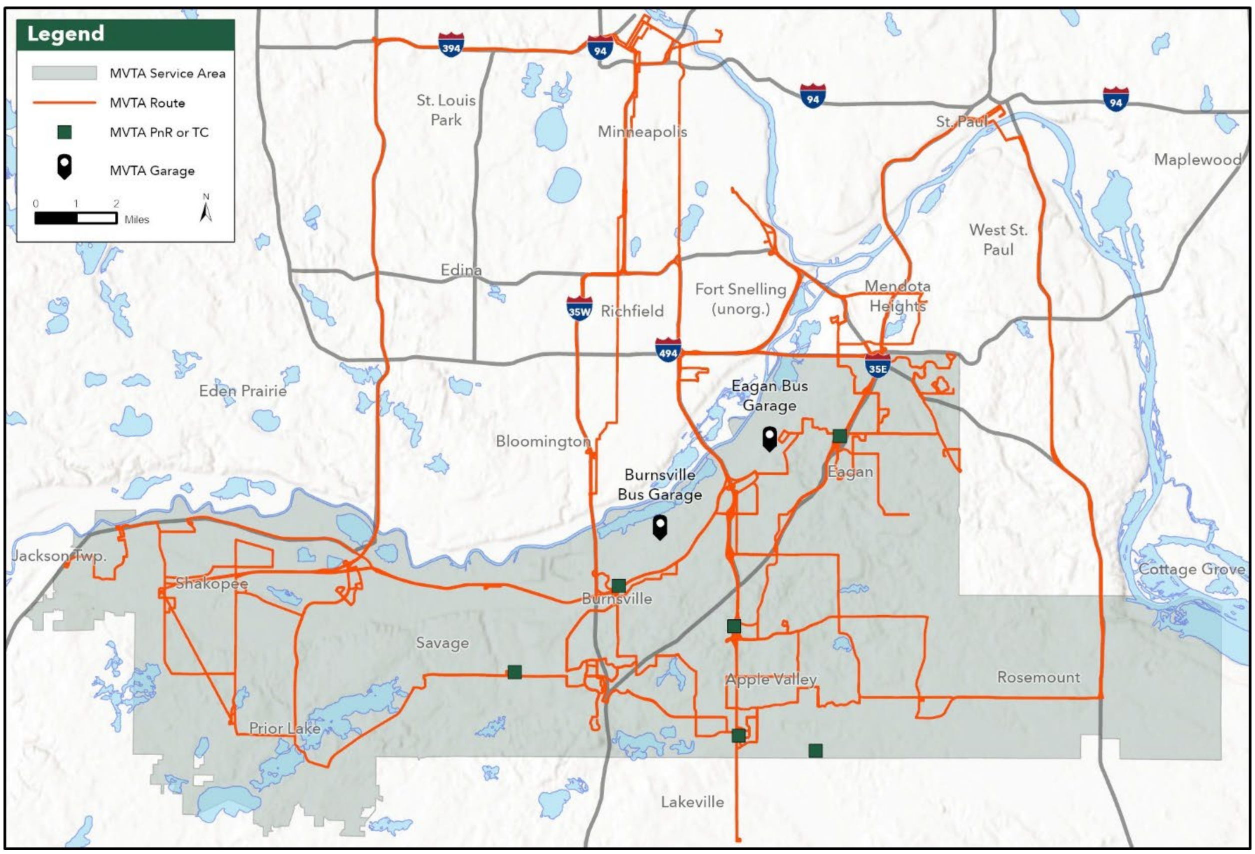
MVTA's bus fleet is composed of 172 buses operated and maintained by Schmitty and Sons. Most of MVTA's buses are either 40-feet in length (54% of total fleet) or are 45-foot coach buses (31%). In addition to these two primary bus types, MVTA also deploys six 35-foot buses as well as 20 cutaway vehicles 26-feet in length or less. MVTA bus service is provided and maintained by Schmitty and Sons. Together, these buses currently operate on a total of 25 routes distributed across a nearly 140 square mile service area (Figure 1).[4,5] Prior to the COVID-19 pandemic, MVTA operated service on 32 routes. MVTA buses are housed and operated from two garages: Eagan Bus Garage (EBG) located at 3600 Blackhawk Road, Eagan MN, 55122 and the Burnsville Bus Garage (BBG) 11550 Rupp Drive, Burnsville, MN 55337. In addition, MVTA has either land or facility ownership of six Park and Ride or Transit Center facilities across the region (Table 1, Figure 1).

[4] Source: *Minnesota Valley Transit Authority 2019 Annual Agency Profile*, National Transit Database
[5] Source: *2018-2022 Minnesota Valley Transit Authority Strategic Plan*, MVTA, March 2018.

Table 1: Park and Ride and Transit Center Facilities With Associated MVTA Ownership[6]

Facility	Location	Land Owner	Facility Owner
Apple Valley Transit Station	15450 Cedar Avenue S Apple Valley MN, 55124	Apple Valley Development Authority	MVTA
Burnsville Transit Station	100 Highway 13 East, Burnsville MN, 55337	MVTA	MVTA
Eagan Transit Station	3470 Pilot Knob Rd Eagan MN, 55123	MVTA	MVTA
Palomino Hills Park & Ride	12760 Pennock Ave Apple Valley MN, 55124	MVTA	
Savage Park & Ride	14121 Huntington Avenue Savage MN, 55378	MVTA	
157th Street Station	15865 Pilot Knob Rd Apple Valley MN, 55124	MVTA	MVTA

Figure 1: MVTA Service Area and Bus System



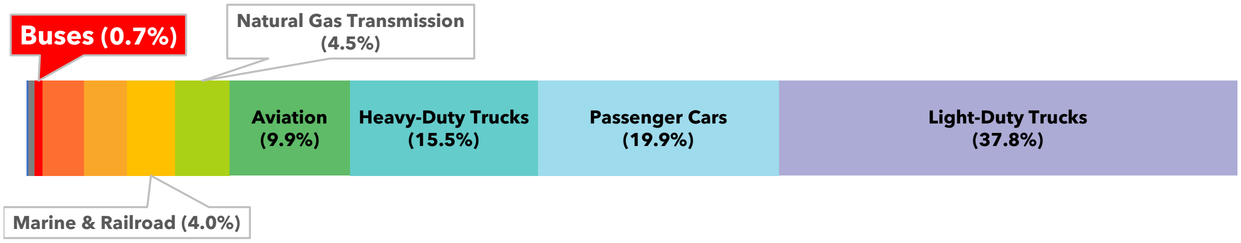
2.2 Transportation and the Environment

The transportation sector is a major greenhouse gas (GHG) emitter in Minnesota. According to 2018 data from the Minnesota Pollution Control Agency (MPCA), the transportation sector is

[6] Source: Park & Rides and Transit Centers, Metropolitan Council, 2022.

the largest source of greenhouse gases in Minnesota accounting for about one quarter of all statewide GHG emissions.[7] The majority (73 percent) of transportation-related GHG emissions in Minnesota come from light-duty trucks and SUVs, passenger vehicles, and heavy-duty trucks while approximately 0.7 percent of these statewide emissions are emitted by buses.

Figure 2: Minnesota Transportation Sector GHG Emissions by Source



Although bus emissions represent a proportionately small share of the total transportation GHG emissions across the state, MVTA is committed to exploring opportunities for zero-emissions replacement and expansion vehicles and charging systems to "provide services within our region that use more sustainable energy sources that benefit our environment."[5,8]

2.3 Trend Towards Zero-Emission Buses

Over the past decade, transit agencies across the country have begun to integrate zero-emission buses (ZEBs) into their fleets. ZEB adoption and the pace at which transit agencies transition towards ZEB fleets is anticipated to grow in the coming years due in part to increased funding sources to support ZEB investments. For example, as of September 2021 in the United States, the count of full-size ZEBs on the road or on order has grown to more than 3,533 buses, a 27% growth since 2020.[9] Although nearly half (49%) of these ZEBs are located in California, every state, with the exception of New Hampshire, North and South Dakota, and West Virginia, has at least one ZEB on the road or on order as of September 2021.[9]

2.4 Existing Policies, Initiatives, & Studies

This section provides a review of policy and legislation with zero-emission implications. These policies include an overview of MVTA Sustainability Initiatives, the federal Infrastructure Investment and Jobs Act (IIJA), and local county and municipal sustainability initiatives.

2.4.1 MVTA Sustainability Initiatives

As a major transit provider for Minnesota's southern metro area, MVTA is "committed to serving our communities well while pledging to effectively and continuously move toward more sustainable operations." In alignment with this vision and the framework of the American Public Transportation Association (APTA) Sustainability Commitment, in April 2021, MVTA adopted sustainability as a "formalized policy objective."[10] As a signatory of APTA's Sustainability

[7] Source: *Climate change in Minnesota: Greenhouse gas emissions data*, Minnesota Pollution Control Agency, 2018
[8] Source: *First Electric School Bus in State to Serve Local Students*, MVTA News Archives, July 10, 2017.
[9] Source: *Zeroing in on ZEBs*, CALSTART, December 2021.
[10] Source: *2021 Board Meeting Packets*, MVTA, April 28, 2021

Commitment, MVTA has designated our intent to fulfill the core principles of the Sustainability Commitment including:

- Making sustainability part of MVTA's strategic objectives;
- Identifying a sustainability champion within MVTA coupled with the proper human and/or financial resources and mandates;
- Establishing an outreach program (awareness-raising and education) on sustainability for all MVTA staff; and
- Establishing a base-line measurement for MVTA of eight indicators including criteria air pollutants, GHG emissions (and savings), and energy use.[11]

In addition to recently becoming a signatory of APTA's Sustainability Commitment, MVTA has also signed on to the Federal Transit Administration's (FTA) Sustainable Transit for a Healthy Planet Challenge.[12]

2.4.2 Infrastructure Investment and Jobs Act (IIJA)

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 five years—the largest Federal investment in public transit history."[13] 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.[14] 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 Emissions or No Emission Vehicle Program (Low-No) at around 1.1 billion dollars annually from 2022 through 2026, which is a program within the Federal Transit Authority's (FTA's) Buses and Bus Facilities program. This discretionary grant program requires agencies to have a zero-emission fleet transition plan. It also requires that five percent of Low-No Grants related to zero-emission vehicles 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. It should be noted, however, that federal transit funding focuses on capital needs, not addressing the costs associated with operation and maintenance of ZEBs or other transit services. [15,16]

2.4.3 State/Local Policy and Legislation

In addition to conforming to federal legislation such as the IIJA, MVTA's ZEB Transition Plan aligns with and advances several statewide and local sustainability policies and initiatives

[11] Source: *APTA Sustainability Commitment*, APTA 2022
[12] Source: *Sustainable Transit for A Healthy Climate Challenge Participants*, FTA, April 12, 2022
[13] Source: *Fact Sheet: The Bipartisan Infrastructure Deal*, The White House, November 6, 2021
[14] Source: *Bipartisan Infrastructure Law (Infrastructure Investment and Jobs Act of 2021)*, Alternative Fuels Data Center, 2021
[15] Source: *Fact Sheet: Buses and Bus Facilities Program*, Federal Transit Administration, December 9, 2021
[16] Note: COVID-19 Relief laws Coronavirus Aid, Relief, and Economic Security (CARES) Act, Coronavirus Response and Relief Supplemental Appropriations Act (CRRSAA), and American Rescue Plan allowed federal funds to be used for operating and maintenance costs. However, funds provided for transit to large urban areas outside of COVID relief bills have been restricted to capital projects.

including the State of Minnesota Climate Action Framework, regional long-range plans, clean energy goals, and other county and municipal initiatives. Beyond these policies, this Transition Plan encompasses our first steps towards achieving state requirements to develop and maintain a zero-emission and electric transit vehicle transition plan. Moving forward, MVTA will continue to refine and build upon this Transition Plan in collaboration with the Metropolitan Council.

2.4.3.1 State of Minnesota Climate Action Framework

In December 2019, Governor Walz established a Climate Change Subcabinet and a Climate Change Advisory Council. To guide the work of the Climate Change Subcabinet, the State of Minnesota developed a Climate Action Framework in collaboration with staff from 15 agencies including the Metropolitan Council and the Department of Transportation.[17] In Spring 2022 a draft of this Framework was published with the final Framework expected for publication in Summer 2022.

Intended to spur action at state agencies and beyond, the Framework outlines a vision for how the state will "address and prepare for climate change" through six goals and a series of immediate near-term actions. The first of these goals is Clean Transportation which establishes a vision of Minnesota's transportation system as a system that is "sustainable and resilient to a changing climate and supports transportation options for all Minnesotans as well as technology to reduce pollution." To achieve this goal, the Framework outlines six priority actions including increasing transit service and incentivizing increased investment in a broad portfolio of cleaner fuels, electricity, and charging infrastructure with the aim of reducing greenhouse gases (GHG) in the transportation sector 30% by 2025 and 80% by 2050.[17]

2.4.3.2 MnDOT 2020 Sustainable Transportation Advisory Council (STAC) Recommendations

The goal of the STAC is to "help Minnesota transition to a low-carbon transportation system in a way that is consistent with statutory goals for energy and emissions reductions and maximizes benefits to Minnesota, while recognizing the importance of continued work towards improving safety, reducing inequities, and supporting economic development." In alignment with this goal, the STAC has developed several recommendations with the purpose of promoting and increasing the use of low-emission vehicles, increasing use of transit as a percentage of all statewide trips, and reducing the transportation sector's greenhouse gas emissions.[18]

2.4.3.3 Thrive MSP 2040

Adopted by the Metropolitan Council in May 2014, Thrive MSP 2040 is the region's comprehensive long-range plan. Thrive MSP 2040 sets the policy foundations for systems and policy plans, including the 2040 Transportation Policy Plan (TPP). The 2040 TPP describes how the transportation system will be developed and operated in a way that is consistent with the regional vision and goals described in Thrive MSP 2040. Thrive MSP 2040 lists five outcomes, including sustainability, that define its shared regional vision, aiming to provide leadership to support climate change mitigation, adaptation, and resilience. These outcomes include:

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[17] Source: *Minnesota's Climate Action Framework Draft*, State of Minnesota, 2022
[18] Source: *Sustainable Transportation Advisory Council Charter*, MnDOT, June 22, 2020

- Stewardship;
- Prosperity;
- Equity;
- Livability; and
- Sustainability.

2.4.3.4 Xcel Energy Clean Energy Transition

Xcel Energy, the primary electrical utility provider for both MVTA garages, was the first major US utility to signal it would move to 100 percent carbon-free electricity by 2050 when it announced its vision in December 2018.[19] Approved in February 2022, Xcel Energy's Upper Midwest Energy Plan will make significant strides towards this goal by reducing carbon emissions by 85% by 2030 compared to 2005 levels.[20,21]

2.4.3.5 County Sustainability Policies

In addition to statewide policies, both counties within MVTA's service area (Scott County and Dakota County) have developed policies and plans to increase sustainability and mitigate environmental impacts.

Dakota County

The majority of MVTA bus routes and both garages serve or are in Dakota County. As such, it is important to align this Transition Plan with County sustainability goals and policies. Guided by the Dakota County Board's Strategic goals and Public Engagement conducted throughout 2020, the County's 2040 Transportation Plan establishes twelve overarching principles including *Sustainability* and *Transportation Technology* that guide the Plan's policies and strategies. Based on public engagement, the 2040 Transportation Plan reflects community priority's such as investing in the creation of "viable, environmentally sustainable transportation options in Dakota County." [22] In support of the *Sustainability* goal, the Transportation Plan recommends implementing "Dakota County energy transportation strategies that address greenhouse gas emissions [to] support [a] transition to alternative or renewable energy" in addition to other environmentally sound practices.[22]

Scott County

Informed by public input from community engagement and visioning workshops, Scott County recently developed its 2040 Comprehensive Plan describing the "long-range, big picture description of [the county's] desired future."[23] The County Board's Guiding Principles for the plan included the mission to "advance safe, healthy, and livable communities through citizen-focused services" reflecting the values of "stewardship, partnership, leadership, commitment, customer service, and innovation."[23] Based on these principles and public feedback, the Plan's

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[19] Source: *Xcel Energy Commits to 100% Clean Energy by 2050*, State of Minnesota
[20] Source: *Clean Energy Transition Highlights*, Xcel Energy, 2022
[21] Source: *Upper Midwest Energy Plan*, Xcel Energy, 2022
[22] Source: *Dakota County 2040 Transportation Plan*, Dakota County, July 2021
[23] Source: *Scott County 2040 Comprehensive Plan Story Map*, Scott County, 2019

Vision for 2040 is that the County will have "respected and managed [its] natural…and environmental resources."[24]

2.4.3.6 Municipal Plans, Programs, and Initiatives

More locally, at the municipal-level, several of the suburbs within MVTA's service area have policies and/or legislation with sustainability and zero-emission implications.

Minnesota GreenStep Cities Program

Figure 3: MN GreenStep Cities

Six of the seven suburbs within MVTA's service area participate in Minnesota's GreenStep Cities program a "voluntary challenge, assistance, and recognition program to help cities achieve their sustainability and quality-of-life goals" led by the Minnesota Pollution Control Agency (MPCA).[25] Among other features, this program establishes and supports participating cities' efforts to achieve "cost-effective sustainable development best practices in five categories including: Buildings and Lighting, Transportation, Land Use, Environmental Management, and Economic and Community Development."[26] As of Spring 2022, three of suburbs within MVTA's service Area (Apple Valley, Burnsville, and Eagan) have achieved Step 5 recognition, currently the highest level of the program while Rosemount, Savage, and Shakopee have all achieved Step 2.[25]

2.4.3.7 Other Municipal Plans & Initiatives

In addition to participating in Minnesota's GreenStep Cities Program, several of the largest suburbs served by MVTA have taken steps to implement additional sustainability policies and legislation with ZEB implications. Select sustainability policies are summarized below for cities in which an MVTA bus garage is located.

City of Burnsville

Burnsville's Sustainability Guide Plan, updated in September 2020, "lays out the foundation for the City's continuing sustainability efforts over the coming decade."[27] The City's vision includes a commitment to "long-term sustainability through multiple projects" to "reduce community-wide GHG emissions 40% below 2005 levels by 2030 and 80% below 2005 levels by 2050."[27] To achieve this vision, the Plan outlines nearly three dozen goals including increasing public transit ridership and increasing "electric vehicle adoption to 10% of the citywide vehicle share by 2030."[27] One of the many strategies and actions to achieve these goals include establishing and promoting a "Burnsville's Greenest Fleets" award/promotional program recognizing the City's greenest commercial fleets.[27] Supplementing the Sustainability Guide Plan, the City of Burnsville is also engaging in a Climate Adaptation Plan to "improve the community's resilience and readiness for changing climate impacts."[28] MVTA's ZEB Transition Plan and continued

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[24] Source: Scott County 2040 Vision, Scott County, June 18, 2019
[25] Source: Minnesota GreenStep Cities, Minnesota Pollution Control Agency
[26] Source: Resolution of Support for the City of Eagan's Participation in the Minnesota GreenStep Cities Program, City of Eagan, August 17, 2010
[27] Source: City of Burnsville Sustainability Plan, City of Burnsville, September 2020
[28] Source: Sustainability Guide Plan Update–Community Survey, City of Burnsville, September 2, 2019

commitment to provide services within our region that use more sustainable energy sources will support these efforts of reducing GHG emissions and improving the climate change resilience and readiness within our service area communities.

City of Eagan

Eagan is committed to preserving, protecting, and investing in the natural environment.[29] In alignment with this commitment, the City's 2040 Comprehensive Plan and Transportation Plan establish a goal to ensure that the "Eagan transportation system is resilient, sustainable, and able to evolve with societal advancements and changes, safeguarding investments for many years to come."[30,31] To meet this goal, the City of Eagan identified two dozen strategies including mitigating "impacts to the natural environment and cultural resources when planning, constructing, and operating transportation systems" and "minimizing the effect of air quality impacts on the natural environments with proposed transportation improvements."[30,31]

3 Electric Bus Technology Overview

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

Figure 4: Trolleybus in Operation

Source: *Flying Flyers–Muni Trolley Buses Then and Now*, SFMTA, May 3, 2018

While electric trolleybuses 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.[32] 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, extensive costs associated with building and maintain a network of overhead wires, and the significant visual impacts of these wires, MVTA does not intend to pursue the implementation of electric trolleybuses.

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 nearly doubling between 2020 and 2021.[9] Despite this significant increase, the deployment of FCEBs remains limited to only 10 states and only California and Ohio have adopted more than 10 FCEBs in total as of September 2021.[9] Due to the significant upstream carbon emissions associated with creating and trucking hydrogen, the high cost of FCEBs, and the current lack of hydrogen fueling stations in Minnesota, MVTA does not currently plan to implement FCEBs in the short-term.

BEBs use onboard battery packs for bus propulsion and power rather than using conventional fuels such as diesel or compressed natural gas (CNG). BEBs are charged either at garages, or

[29] Source: *Green Eagan*, City of Eagan, 2019
[30] Source: *2040 Comprehensive Plan–Chapter 7*, City of Eagan,
[31] Source: *2040 Transportation Plan Update*, City of Eagan, 2018
[32] Source: *The National Transit Database (NTD)*

utilize "opportunity charging" during operation on-route or at key layover, park and ride, or transit center locations. 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 2021, approximately 95% 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 several challenges associated with FCEBs outlined above as well as comparatively lower capital costs and increased industry experience associated with BEBs, MVTA plans to focus on a zero-emission transition towards BEBs. As such, the following sections of this transition plan focus on an analysis and evaluation of BEB technologies.

3.1 BEB Vehicle Considerations

The batteries onboard a BEB are used to provide both the energy required to drive the bus as well as the energy necessary to operate all vehicle auxiliary functions including heating and cooling the passenger cabin. The amount of energy provided by the battery is described by its energy capacity measured in kilowatt-hours (kWh). Analogous to a fuel tank on a diesel bus, larger battery capacities translate to increased energy (fuel) storage, and thus, increased range. 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 in transit service of 150 miles or less on a single charge.[33] A BEBs 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 on-board BEB batteries with capacities typically ranging from approximately 215 kWh to 686 kWh.[34,35] Expanding on these capacities, Proterra has announced that starting in 2023, they will offer a 40-foot BEB that can be equipped with up to 738 kWh of onboard energy.[36] 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, and so many manufacturers carve out an unusable portion of the battery to preserve the longevity of the hardware. An additional consideration for the unusable region is that at low enough states of charge, the battery will not be able to produce enough power to move the vehicle. Additionally, 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 will have sufficient range to return to the garage in the event of an unforeseen delay or other unexpected event requiring

[33] Source: *Guidebook for Deploying Zero-Emission Transit Buses*, The National Academies Press, 2021
[34] Source: *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses*, National Renewable Energy Laboratory, April 2021
[35] Source: *GILLIG's next-generation battery to provide 32 percent increase in onboard energy*, Gillig, November 2021
[36] Source: *Proterra Introduces ZX5 Electric Bus With 738 Kilowatt Hours of Energy*, Proterra, April 14, 2022

a BEB to remain in service longer than originally planned. These factors translate to usable battery capacities 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 see greater energy usage, owing to bus doors being open more often and for longer periods of time. When the doors are open, heating and cooling the bus cabin is more difficult as extra energy needs to be drawn from the battery. Additionally, when buses are stuck in congested environments, they spend an increased time idling and accelerating from rest, thereby also requiring greater energy usage. Efficient operation of the vehicle through gentle accelerations and decelerations can reduce energy usage by not only requiring 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.

3.2 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 5). 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 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).

Figure 5: BEB Charging Infrastructure

Plug-In

Source: The Herald,
Kevin Clark, Oct. 2021

Overhead Conductive

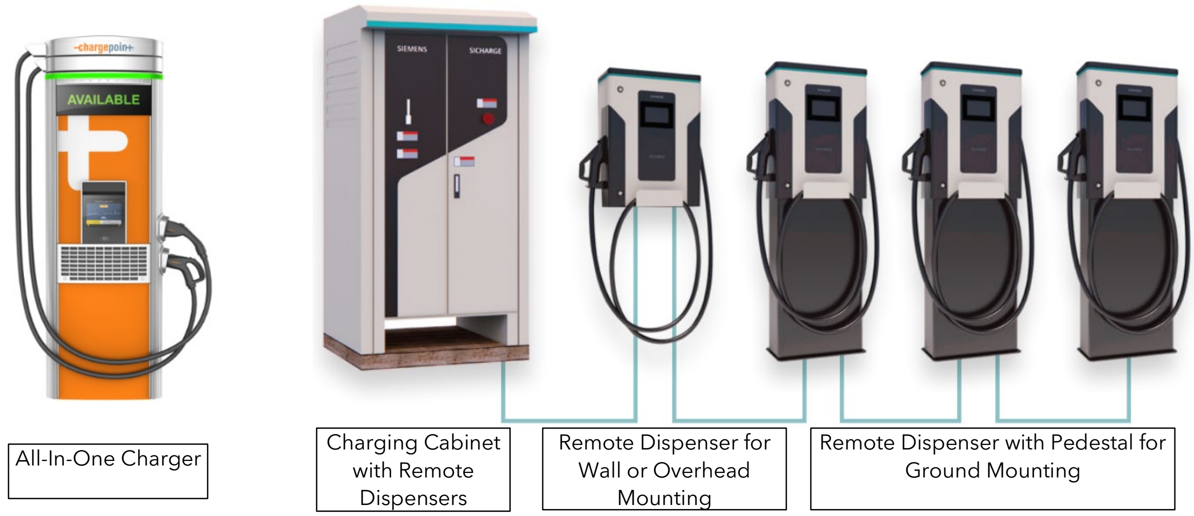
Source: TriMet, March 2021

Wireless Inductive

Source: Link Transit & eVehicle Technology

Plug-in chargers can be either an 'All-in-one' unit with dispensing plug-in cord attached directly to the charger cabinet or a charging cabinet connected to remote plug-in dispensers.

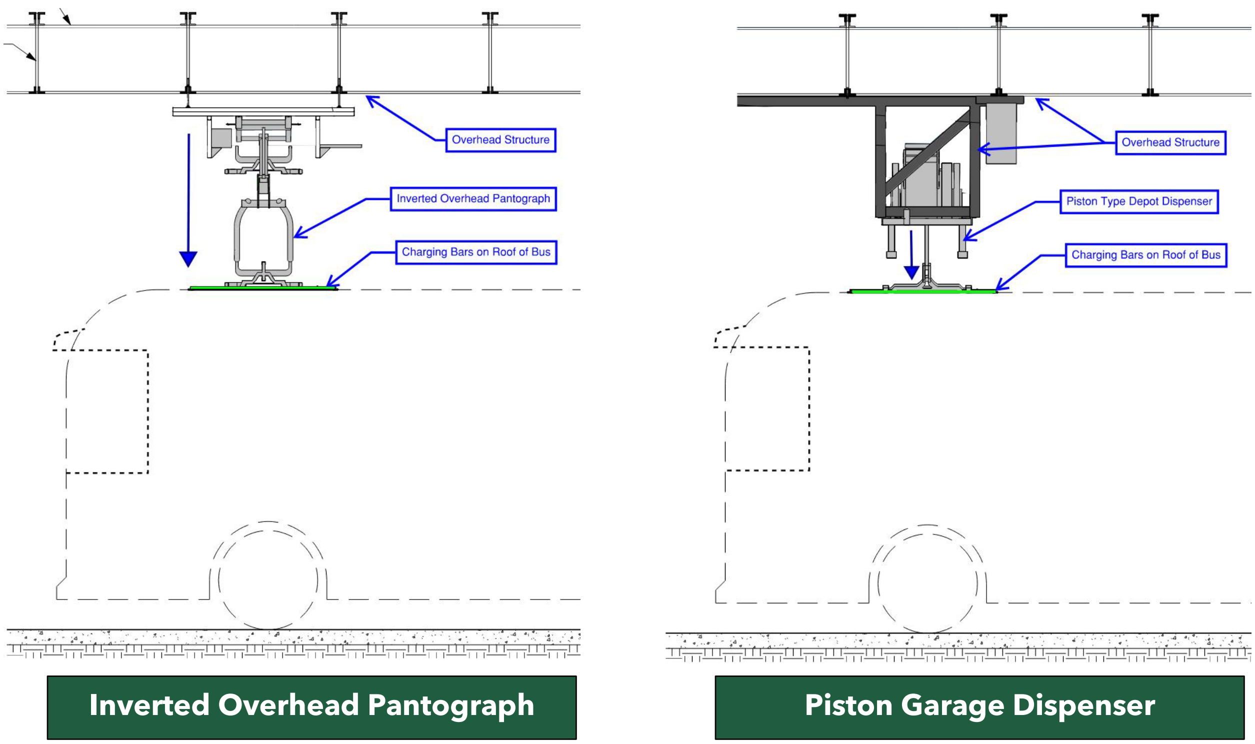
Figure 6: Plug-In Charger Detail



Typically, a plug-in all-in-one unit has one or two cords and a remote dispenser cabinet that can energize between one and four+ dispensers allowing for scheduled charging of multiple buses. Charge power for plug-in chargers ranges from 50 to 180 kW. Due to this relatively low power, plug-in chargers typically take several hours to fully charge a bus and are therefore often used 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 name plate rating of the charger (180kW for example) might only output a maximum of 60kW if the one charger cabinet is energizing three dispensers (expressed as a 1:3 charging ratio). There is no industry standard yet for shared charging configuration so any shared plug-in charging assumed performance operations, such as 'ability to provide 180kW 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 – 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 than for other types of charging infrastructure. The J1772 standard, published by the Society of Automotive Engineers, 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 (2ft to 3ft 6 inch) in depth adjacent to parked buses in existing dense bus parking arrangements can lead to blocking of staff circulation at or create a bus to charger impact danger. On large retrofit deployments at existing dense close parked bus lanes, 12ft 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 protected by bollard or other structure, do require some means to retract and extend down cord. Currently the charging equipment OEMs do not off a remote overhead reel or retraction system and rely on third party vendors or site-specific custom solution from the simple, suspended rope tagline connected to a manual pull charging cord, to powered retraction systems using reels or winches.

Overhead conductive dispenser typically use an extending arm pantograph dispenser or piston mounted charging bars dispenser that lowers down from where the dispenser are mounted to structure above to connect to the roof mounted charge rails on the bus. A remote charging cabinet is required to convert AC to DC current and send the DC power and communications / data from the cabinet to the overhead dispenser.

Figure 7: Example Schematics of Overhead Conductive Dispensers



There are also pantographs mounted to the bus that extend up to connect to an energized charge point mounted to overhead facility structure but this type of pantograph is rarely used in the US market due to the added weight of the pantograph to the bus, a single source proprietary overhead connector, and not being Buy America compliant. Charge power for overhead conductive chargers ranges from 150 to 600kW.[33] The lower capacity units are typically used at garage bus parking similar to where plug-in dispensers would be used but with the benefit of not requiring ground space. Higher capacity units, 300+ kW, are used at shared charging positions at garages or at on-route charging locations. Overhead conductive chargers, due to their ability to distribute more power than a plug-in cord, 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 that 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. A number of charging OEMs 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 floor of a garage or roadway surface in addition to a power receiver installed under the bus. An above ground 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 is available in ranges from 50-350+ kW. Some inductive chargers are capable of energizing multiple wireless charging pad dispenser 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 would be embedded in the floor of the garage or roadway. Retrofitting multiple induction pads and their above ground chargers in existing garages will require significant trenching and cutting of the floor slabs. Inductive charging can be operationally challenging as proper alignment between a bus and 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 charge in parking place at a garage or as an offsite opportunity charger. Currently, there is no national standard for inductive charging. As a result, each bus manufacturer could 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.

3.2.1 Short-Term Charging Strategy

In the short-term, MVTA has elected to pursue a garage-based charging strategy using either plug-in or overhead conductive chargers. MVTA has dismissed the use of inductive chargers due to the lack of a national standard for inductive charging, higher capital and construction costs, and relative infancy of the technology compared to overhead conductive and plug-in charging solutions. Opportunity charging strategies have also been dismissed in the short-term, due to outdoor maintenance challenges particularly during Minnesota winters, higher operational costs due to daytime electricity premiums, and lower maintenance cost effectiveness compared to garage charging where assets are consolidated in one or two locations rather than across the region. As charging technology evolves, MVTA will continually reassess the feasibility of these various charging strategies.

4 Electrification Analysis & Evaluation

4.1 Service/Fleet Analysis

This section analyzes MVTA's bus fleet and service to identify the share of existing bus blocks, platform hours and miles and revenue hours and miles that are technically viable for a one-to-one transition to BEBs with only garage charging. This analysis looks at three scenarios including: Current Technology BEBs, Moderate Technology Improvement, and Significant Technology Improvement.

4.1.1 Current Fleet Composition

As introduced in Section 2.1, MVTA's bus fleet is composed of buses of varying lengths operating from two home garages to provide a range of service types. As of Spring 2022 MVTA does not operate any ZEBs. Instead, MVTA's fleet includes a total of 172 vehicles comprised of:

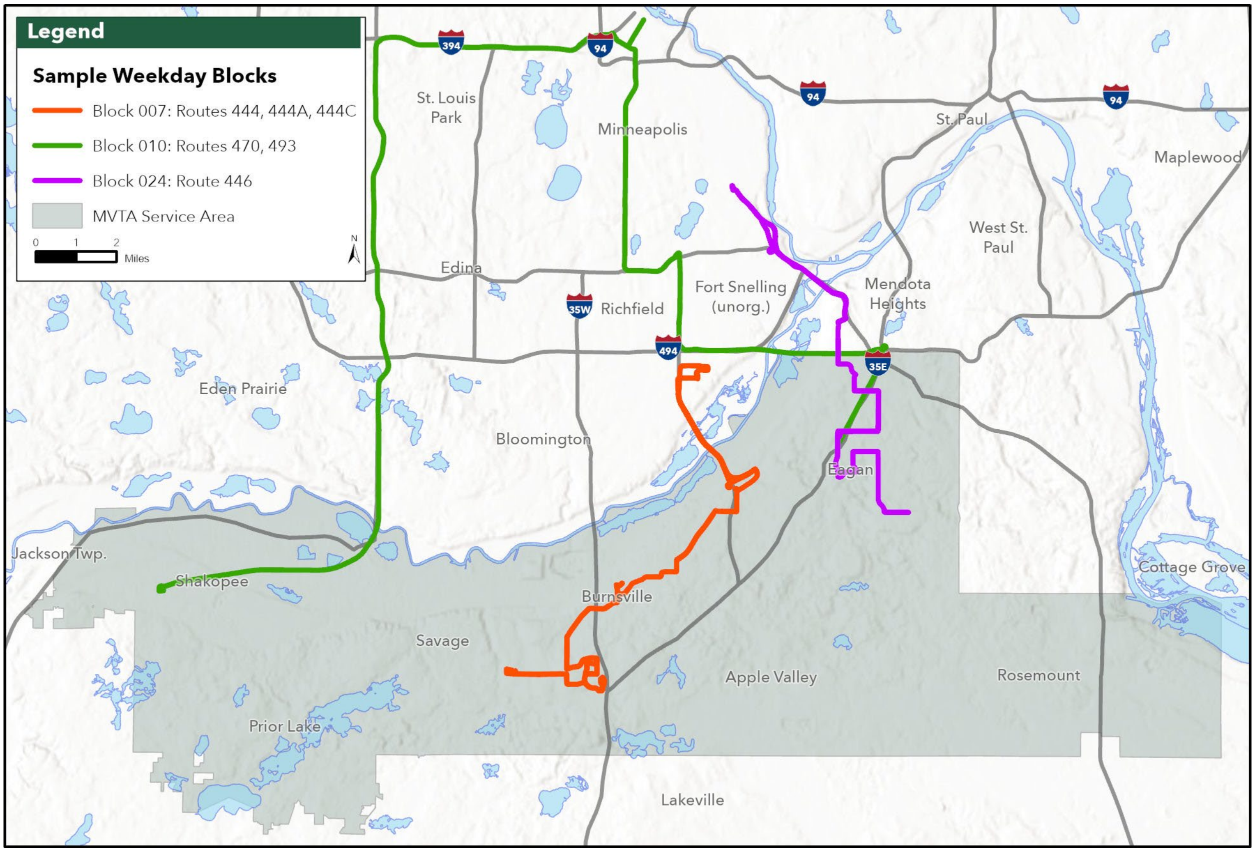
- (1) 17-foot gasoline van;
- (4) 23-foot gasoline cutaway vehicles;
- (8) 25-foot gasoline cutaway vehicles;
- (4) 25-foot diesel cutaway vehicles;
- (3) 26-foot gasoline cutaway vehicles;
- (6) 35-foot diesel buses;
- (93) 40-foot diesel buses; and
- (53) 45-foot diesel coach buses.

Historically, about 44% of MVTA's vehicles operate out of the Burnsville Bus Garage while the remainder operate out of the Eagan Bus Garage. Currently, however, all bus service is operated out of the Eagan Bus Garage while the Burnsville Bus Garage is being renovated. MVTA is actively pursuing funding opportunities to pursue adding BEBs to its bus fleet in alignment with our pledge to "…effectively and continuously move toward more sustainable operations."

4.1.2 MVTA Scheduling Practices

To maximize scheduling and operational efficiency, MVTA divides its many routes into blocks—a series of transit trips that are linked together and assigned to a single bus for operation. To illustrate this blocking concept Figure 8 depicts three example weekday blocks. As shown, blocks can either contain one route (i.e., Block 024), one route with multiple branches (i.e., Block 007), or multiple routes/branches (i.e., Block 010). Service blocks are reconfigured every quarter to maximize efficiency and tailor service to ridership and the available workforce even when service levels are relatively stable. To analyze the short-term viability to transition towards BEBs, this analysis uses service blocks rather than bus routes as service blocks represent the total work performed between the time a bus pulls out of a garage and the time it pulls back into the garage. Therefore, service blocks establish a minimum duration between BEB charging opportunities at a garage.

Figure 8: Overview Map of Three Example Service Blocks



4.1.3 Fixed Route ZEB Transition

As introduced in Section 3.1, based on the current state of BEB technology, a BEBs range on a full charge is significantly less than the range a traditional diesel or gasoline vehicle can travel on a single tank of fuel. As a result, for longer service blocks, BEBs cannot typically be used as a one-to-one replacement for existing diesel/gasoline powered vehicles. Instead, for particularly long blocks, multiple BEBs will likely be needed to deliver the same level of service provided by MVTA's current diesel buses. For example, Foothill Transit, a Greater Los Angeles transit provider, estimates that switching to BEBs would require the agency "to buy more buses to meet the service that we provider to our customers." Foothill Transit's Director of Maintenance and Vehicle Technology estimates that for their service profile, a replacement ratio of "about 1.5-to-1 between BEBs and CNG buses" would be needed to fully deliver their existing levels of bus service.[37]

Although longer blocks likely require either multiple BEBs to deliver the same service or significant BEB technology advancements, some service blocks may be technically viable for a one-to-one BEB replacement using current BEB technology. To determine whether a bus block

[37] Source: Q&A: Foothill Transit Team Discusses Sustainability Leadership, Federal Transportation Policy Opportunities, EESI, January 14, 2021

is technically viable for BEB service, block length is compared against the BEB's worst-case range. For any given block, if the BEB's worst-case range is greater than the block's total length, then the block is technically viable for a 1:1 replacement with BEB service. The following analysis estimates the percentage of MVTA's fixed route bus blocks that are feasible for a one-to-one BEB replacement in the short term given conservative range assumptions.

4.1.3.1 Service Analysis Assumptions

As introduced in Section 3.1, 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.

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 as much as 2.4 percent per year. [38] This is equal to a capacity loss of up to approximately 14 percent after six years (bus mid-life), and up to about 25 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 state of charge (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 2.4 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.[34]

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.[39] 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 would require a BEB to remain in service longer than originally planned.

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[38] Source: *Battery Electric Bus and Facilities Analysis Final Report*, Milwaukee County Transit System, January 2020
[39] Source: *Electrifying Transit: A Guidebook for Implementing Battery Electric Buses*, National Renewable Energy Laboratory, April 2021

Usable Battery Capacity Calculation Summary

Overall, MVTA's BEB service planning is based upon a battery's usable, rather than nominal, capacity at bus mid-life to account for battery degradation and capacity reservations. Based on an approximately 2.4 percent annual battery capacity degradation as well as 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. Based on 30-year average temperatures, the Twin Cities has the coldest winters, on average, of any major U.S. metropolitan area with an average temperature of 18.7 degrees Fahrenheit between December and February.[40] Additionally, the region experiences sub-freezing air temperatures on an average of 151 days per year with 24-25 days of sub-zero air temperatures.[40] Therefore, while many transit agencies across the county can largely plan BEB service assuming relatively warm average ambient temperatures, MVTA must plan BEB service around worst-case range estimates based on winter temperatures to ensure reliable service can be maintained throughout all seasons. Drawing upon Metro Transit's experience operating BEBs in Minnesota winters, our Transition plan utilizes the same worst-case energy efficiency of 3.5 kWh/mi outlined in Metro Transit's ZEB Transition Plan.

In addition to ambient temperature impacts, a BEB's operational speed 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 see greater energy use, owing to bus doors being open more often and for longer periods of time. When the doors are open, bus cabin heating and cooling is more difficult as extra energy needs to be drawn from the battery. Additionally, when buses are stuck in congested environments, they spend an increased time idling and accelerating from rest, thereby also requiring greater energy usage. Due to these considerations, blocks with an average speed of 8 miles per hour or less are assumed to have too significant of an impact on energy consumption to be considered for short-term BEB service.

Summary of BEB Service Analysis Assumptions

Table 2 summarizes the battery capacity and energy usage assumptions and criteria outlined above and used in assessing the suitability of MVTA's service blocks for BEB operation. In recognition of the speed at which BEB technology is advancing, battery capacities have increased by more than eightfold from 2014[41] to 2023,[36] three service analysis scenarios have been considered based on differing BEB technology assumptions as quantified by the buses' nominal battery capacity. The three scenarios include: Current Technology (588 kWh), Moderate Technology Improvement (675 kWh), and Significant Technology Improvement (880

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[40] Source: America's 20 Coldest Major Cities, NOAA, 2014

[41] Source: Foothill Transit Battery Electric Bus Demonstration Results, NREL, 2016

kWh). The current technology capacity was selected to align with the battery capacities identified as part of MVTA's Spring 2022 FTA Low-No Grant application, while moderate technology and significant technology improvements were selected to align with comparable nominal capacities included in other Midwest transit agencies' ZEB Transition plans including the Chicago Transit Authority (CTA)[42] and Metro Transit.[43]

Table 2: Assumptions for Fixed Route BEB Service Analysis

Item	Current Technology	Moderate Technology Improvement	Significant Technology Improvement
Battery size *Nominal capacity*	588 kWh	675 kWh	880 kWh
Battery size *Useable Capacity **	412 kWh	473 kWh	616 kWh
Average kWh per mile**	2.2	2.2	2.2
Average range in miles	187	215	280
Worst-case kWh per mile**	3.5	3.5	3.5
Worst-case (winter in Minnesota) range in miles	118	135	176
Minimum Average Speed	8 mph	8 mph	8 mph

Note: All analyses assume 40-foot garage-charged BEBs using auxiliary diesel heater

**Usable battery capacity defined as the bus mid-life battery capacity calculated as 70% of nominal battery capacity. This assumes a 2.4 percent annual battery capacity degradation and a total of 20% capacity reserved for a combination of battery health and operational flexibility.*

***Energy efficiencies sourced from Metro Transit's ZEB Transition Plan*

4.1.3.2 Fixed Route BEB Service Analysis Results

Using the criteria presented in Table 2, each of MVTA's bus blocks can be analyzed to assess BEB suitability. For each of the three technology scenarios, a block is determined to be technically viable if:

- The total block distance was less than the BEBs worst-case range; and
- The bus's average speed along the block was at least eight miles per hour.

Based on this analysis, the technical viability of the given service schedule for BEB service is summarized in three ways:

- Count (and percent) of total blocks that are technically viable;
- Percent of total annual bus platform and revenue hours that are technically viable;[44]
- Percent of total annual bus platform and revenue miles that are technically viable.[45]

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[42] Source: [Charging Forward–CTA Bus Electrification Planning Report](), CTA, February 2022
[43] Source: [Metro Transit Zero-Emission Bus Transition Plan](), Metro Transit, February 2022
[44] Note: Bus hours defined as the time between when a bus pulls out of a garage to when it pulls back into the garage
[45] Note: To calculate the portion of technically viable annual bus hours or miles for a given service schedule, the number of service days of each schedule type (Weekday or Weekend/Holiday) were multiplied by their respective share of technically viable bus hours or miles compared to all bus hours and miles in the schedule and then added together. Note that each quarterly service schedule change may have a unique number of Weekday and Weekend

As the length of buses operated on any given block is subject to change in the future, this service analysis is applied to all blocks regardless of the bus length currently operating on the block. BEB service viability analysis results are likely to fluctuate as MVTA's block characteristics may be modified up to four times a year due to service changes. 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 MVTA's May 2022 service schedule are summarized below (Table 3).

Table 3:Technically Viable Fixed Route Block Summary for 40-Foot BEBs for May 2022 schedule

	Current Technology (588 kWh)	Moderate Technology Improvement (675 kWh)	Significant Technology Improvement (880 kWh)
Number of Technically Viable Blocks	99	114	153
% of Total Blocks	56%	65%	87%
% of Total Annual Platform Hours	36%	46%	80%
% of Total Annual Platform Miles	38%	47%	77%
% of Total Annual Revenue Hours	33%	43%	79%
% of Total Annual Revenue Miles	32%	42%	75%

**Note: Bus Hours defined as the time between when a bus pulls out of a garage to when it pulls back into the garage and all analyses assume 40-foot garage-charged BEBs using auxiliary diesel heater*

This analysis indicates that over half (56%) of MVTA's May 2022 fixed route bus blocks representing approximately a third of both revenue and platform hours and miles can be served by the current technology 588 kWh 40-foot BEBs MVTA is currently pursuing funding for without altering existing block structures or using opportunity charging. If nominal battery capacities were to reach 880 kWh in the future, nearly 90% of these bus blocks representing approximately 80% of revenue and platform miles and hours would be technically viable. These results are specific to MVTA's May 2022 service schedule and are subject to change up to four times a year due to changes in block length and composition as a result of MVTA's service changes.

As shown in Table 3, it is anticipated that an increasing number of blocks will become technically viable in the coming years as BEB technology continues to improve. Given that such a significant percentage of MVTA's existing (May 2022) bus network is technically viable for BEB service, the primary limiting factors to large scale BEB deployment are lengthy timeframes necessary to electrify the bus garages, the need for expanded workforce development, the limited production capacity of BEBs, batteries, and chargers, and the amount of available funding for bus operation and maintenance.

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service days for that year. For the May 2022 schedule change, for example, it was assumed that there were 256 days of Weekday service and 109 days of Weekend/Holiday service across the entire year including New Year's Day, Memorial Day, Independence Day, Labor Day, Thanksgiving Day, and Christmas Day.

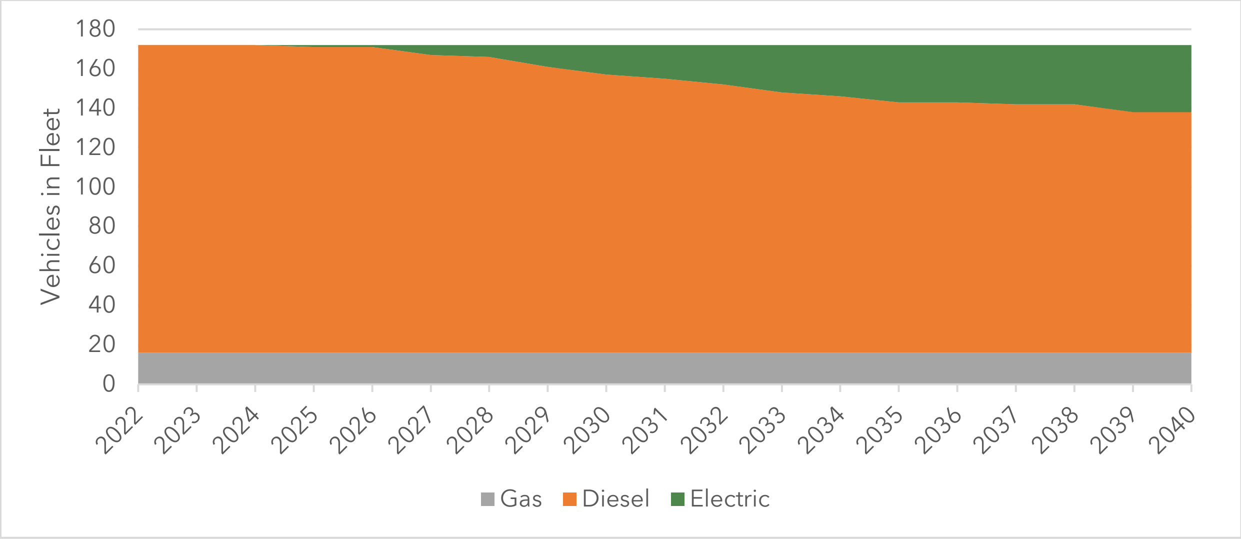
4.1.3.3 Fleet Transition Projection

To evaluate potential fleet transition, the percentage of block achievability with moderate technology improvement is applied to anticipated bus purchases. The same assumptions identified previously are applied to this evaluation, along with the moderate technology improvement scenario. Based on the block achievability associated with these assumptions, we can project that 65% of the fleet can be replaced with depot-charged BEBs at most given a moderate amount of technology improvement.

For the sake of preliminary analysis, future bus purchases will be projected to consist of 20% BEB to evaluate the speed of long-term fleet transition. This pace will be further refined during the Phase 2 transition plan evaluation, when a more thorough evaluation of block performance, infrastructure upgrades and requirements, and funding availability is performed. However, a 20% replacement timeline is a reasonable baseline to expect given these assumptions.

Figure 9 below shows the fleet fuel type composition year-over-year given the baseline assumption of 20% BEB replacement assumption on all future bus purchases. The 13 gas vehicles are constant throughout the period due to these being cutaway vehicles. There are several options for further consideration to increase this percentage further, such as on-route charging and block splitting.

Figure 9: MVTA Fleet Composition Projection



4.2 Facility Analysis

This section analyzes the suitability of MVTA's facilities to support a transition toward BEBs. This MVTA's two operating and maintenance garages (Eagan Bus Garage and Burnsville Bus Garage) were reviewed for existing configuration, current operational on-site vehicle flow, bus parking configuration and electrical service entrance, and size. MVTA's goal for both short- and longer-term electrification will be to incrementally add in BEBs as replacements to outgoing internal combustion engine buses. In preparation for this transition, existing operational bus site flow and bus parking configurations must be identified and documented to allow for the addition of new BEB charging infrastructure in a way that is compatible with a facility and site's existing physical arrangement. As introduced in the Chapter 3 BEB Technology Overview, there are multiple equipment options to charge a BEB. To plan for and identify BEB charging infrastructure that is most compatible with existing operations and mitigates potential operational impacts during BEB charger construction, the unique physical limitations and challenges of each bus garage were assessed as summarized in this section. Although opportunity charging is not a short-term charging strategy for MVTA, BEB infrastructure suitability was also assessed at the six Park and Ride and Transit Center facilities with associated MVTA ownership.

4.2.1 Eagan Bus Garage (EBG)

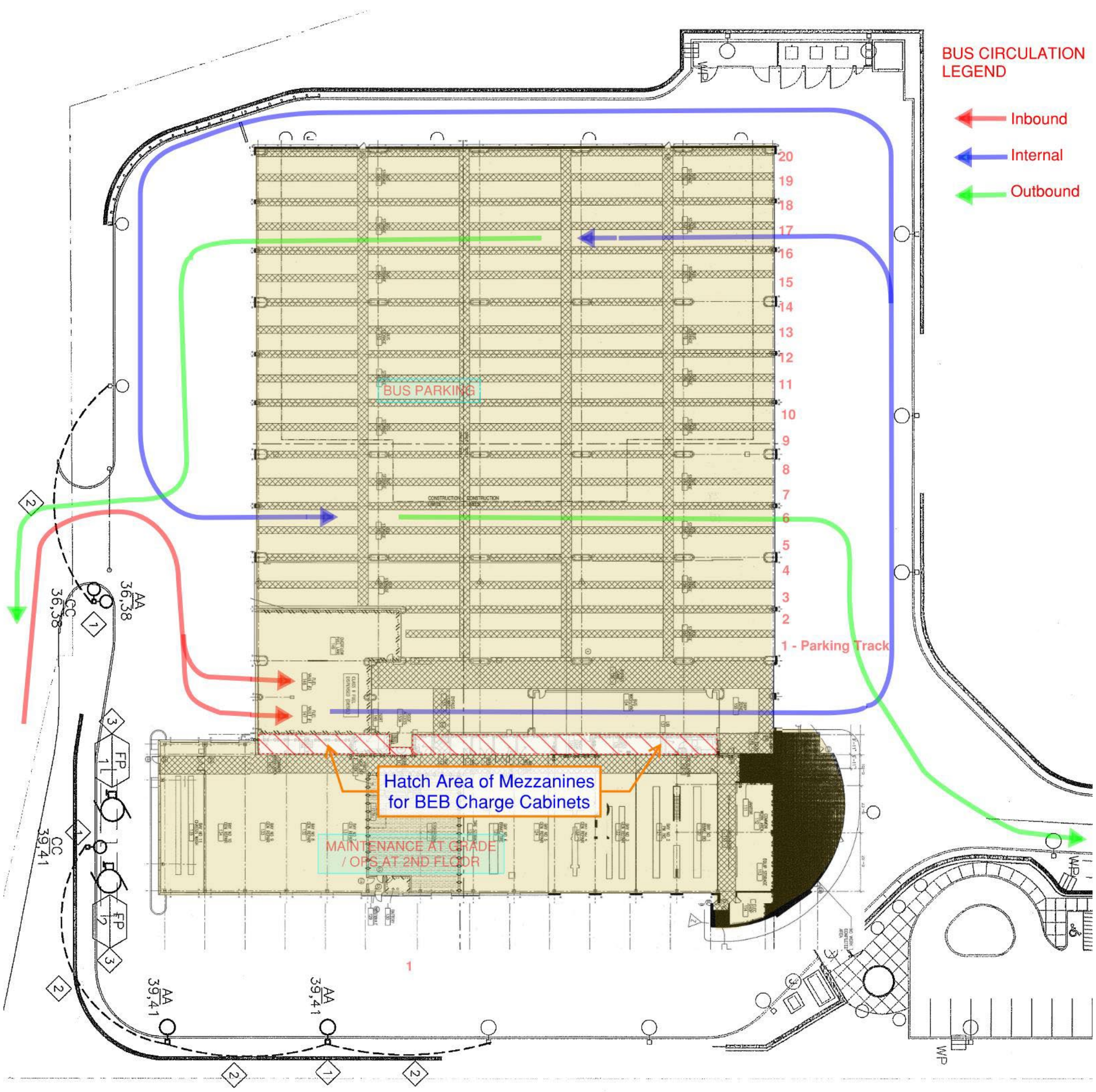
Eagan Bus Garage (EBG) is a purpose-built transit bus operations and maintenance garage with the capacity to park ninety-eight 40-ft bus equivalents in the enclosed bus parking storage area (Figure 10). EBG has a complete block frontage between Blackhawk Road to the north, Minnesota State Highway 13 to the east and Shawnee Road to the south. The western edge of the property is stepped with the northwestern portion extending up to Kennebec Drive and the shallower southwest portion terminating and abutting an adjacent commercial business park. The northwestern portion of the site contains a photovoltaic solar array system constructed over an existing ash land fill. The solar array does not provide power to the Eagan Bus Garage and the land under the array would not be usable for expansion of the garage due to the previous land fill use without significant remediation.

Figure 10: Eagan Bus Garage Overview

4.2.1.1 Existing Bus Circulation

At the end of the daily shift for PM pull-in, buses enter EBG from Shawnee Road, entering into one of the two fueling positions (Figure 11). Operators leave the buses at the fueling lanes, check out with dispatch and exit the site in their personal vehicles on Blackhawk Road. Nighttime service staff hostlers then fuel buses, collect the fares from bus vaults while waiting for fueling to complete, perform interior cleaning of bus, check tire pressure, and collect operator bus defect cards. After fueling is complete, the hostlers take the buses through the automatic drive-through bus wash. Buses exit the bus wash and drive out of the building to the north exterior bus circulation apron and, depending on the bus parking track the buses are assigned to park, either turn 180 degrees and enter the bus parking garage facing south or circulate around the garage on an exterior bypass lane and turn into the bus parking garage facing north. There are twenty assigned bus parking tracks, two per exterior overhead door that corresponds to a single structural bay of the garage. Pedestrian circulation aisles are located alongside, behind, and in front of the parked buses.

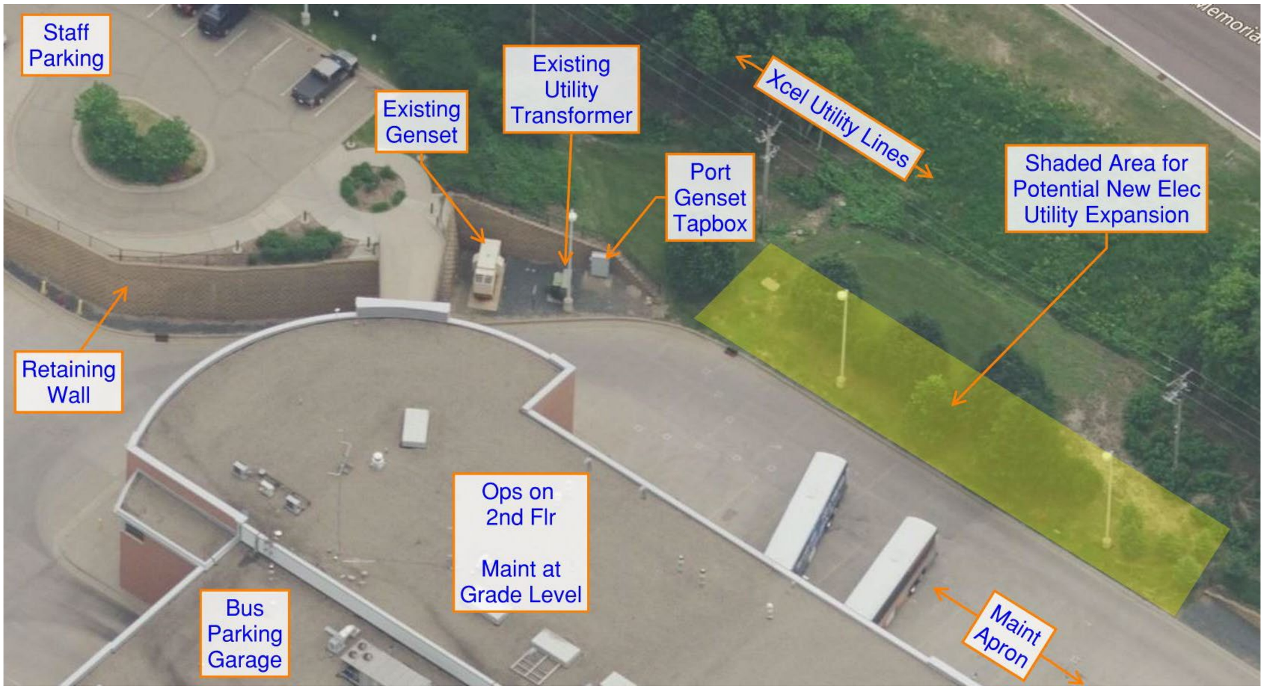
Figure 11: Eagan Bus Garage Bus Circulation



4.2.1.2 Short-Term Charger Opportunities

Six ground mounted remote plug-in dispensers are planned to be located between parking track four and five as part of MVTA's 2022 Low or No (Low-No) Emission Grant. The charging cabinets energizing those six dispensers are planned to be located on the storage mezzanine that runs the entirety of the bus parking garage from north to south. The DC charging power and charging control communications and data wiring from the charging cabinet would be suspended from the overhead existing parking garage roof structure and drop down to feed the remote plug-in dispensers. The original Eagan Bus Garage was expanded in 2013 significantly increasing the maintenance bays and covered bus parking. During the 2013 expansion, the electrical service was maintained with a 750kVA transformer from the local electrical utility provider Xcel Energy. After the facility expansion was energized, four 200 amp spare switches remain in the existing electrical main switchboard in addition to four spare spaces to accept future switches.

Figure 12: Eagan Bus Garage Existing Electrical Transformer–Aerial View



Between the existing installed spare switches and the space to install new switches, enough power would exist to power three to four BEB nominal 180kW chargers which in turn energize the six planned plug-in cord dispensers in the bus parking area and one plug-in dispenser in a maintenance bay. Specific maintenance bays or parking spaces in parking tracks 4 and 5 have not yet been identified to house the dispensers. This decision will be made during future detailed design during the development of the charger/dispenser installation project.

4.2.1.3 Long-Term Changes to Support ZEB Transition

EBG's existing configuration can support multiple BEB dispensers without significant modifications. The existing overhead roof structure can support the suspended distribution of the power/data from the mezzanine mounted chargers to the dispensers at the parking/charging positions. The existing circulation aisle can support ground mounted remote plug-in cord dispensers as well as overhead suspended plug-in cord dispensers. The clear height of the garage allows for either type of overhead conductive dispenser.

New electrical service will be needed to support any additional BEB deployments beyond the planned short-term BEB project identified in MVTA's 2022 Low-No application as this project will use all existing surplus power. The existing transformer is located between the existing backup generator and a portable exterior cabinet type generator tap box. The existing electrical service entrance is located at a lower grade adjacent and at the base of a retaining wall supporting the staff parking and circulation bridge above. Adjacent flat land nearby the existing transformer may be suitable for a new electrical service feed(s) from Xcel Energy. The available land area is large enough to house enough utility gear to support a full 100+ fleet conversion to BEBs. Additionally, the likely utility poles to supply any new service are adjacent to the potential expanded utility yard. EBG is a good candidate for full electrification of the 100 bus fleet because:

- There is available capacity in the surrounding utility power circuits based on preliminary discussions with Xcel
- There existing circuits consist of two separate feeders, one overhead and one underground, providing resiliency and redundancy to future charging service based on preliminary discussions with Xcel
- The is available land near the utility lines to add new utility transformers
- The existing mezzanine potentially has the space to house the new charging cabinets and distribution electrical gear needed for a full fleet
- The current parking configuration at EBG allows for either ground mounted dispensers next to the buses, overhead drop down cord at the buses, or overhead conductive charger at each of the 100 bus parking positions without loss to parking capacity

4.2.1.4 Long-Term Barriers to ZEB Transition

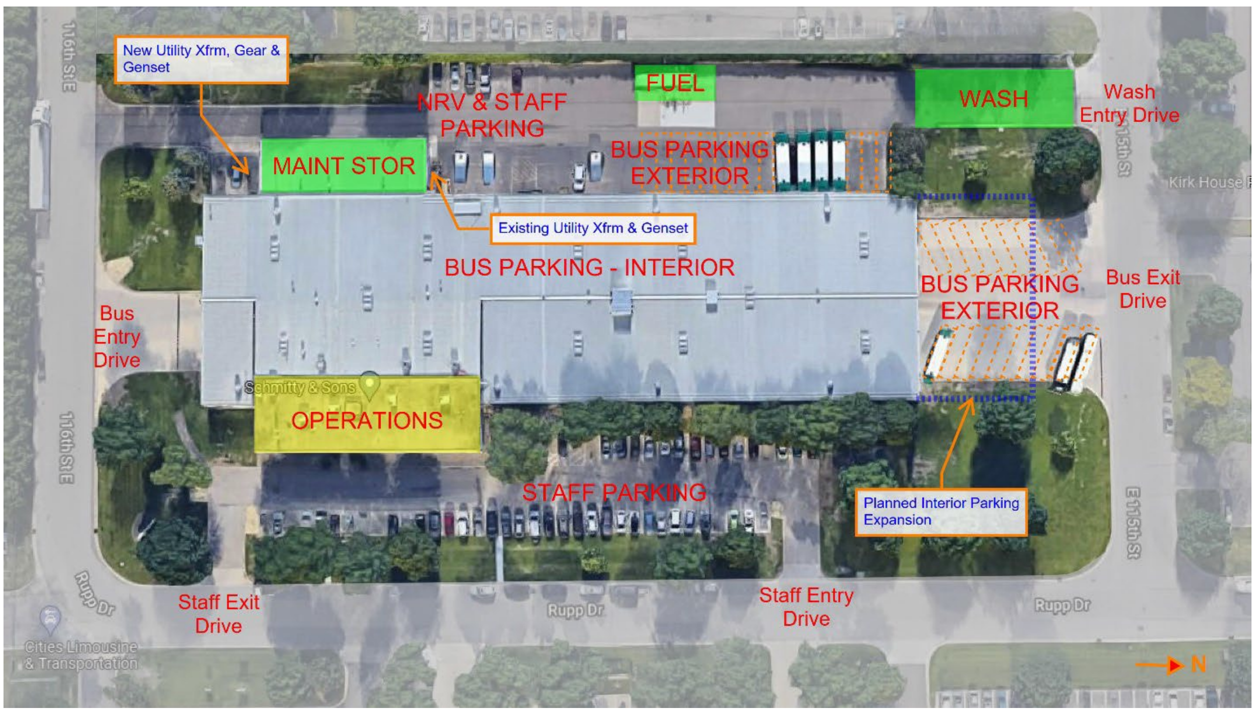
MVTA has held preliminary discussions with Xcel Energy about planning a transition towards an electric bus fleet. To support a widespread transition to BEBs, Xcel Energy would require offsite improvements and expansion to their grid capability. The existing roof structure over the parking deck and the structure of the mezzanines which will house future BEB chargers will need to be evaluated for ability to support additional weight. A typical 150-180 standalone charging cabinet weighs approximately 2,000 pounds, equivalent to the weight of a small car. Depending on the shared charger to dispenser ratio, the mezzanine would need to support 25-50 charging cabinets (1:4 – 1:2 charger to dispenser ratios) equivalent to an additional 25-50 tons of charger cabinets plus new distribution panels. Suspended plug-in cord dispensers and overhead conductor dispenses range from 150-700 pounds each and a fully electrified fleet would require up to 100 dispensers suspended from roof. If all dispensers were suspended, approximately 70,000 pounds/35 tons of load would be added to the facility based on the worst-case weight of full size inverted overhead pantograph. Beyond this load, the additional weight of the required power and data conductors and wires for all dispenser types including ground mounted plug-in dispensers would also need to be considered in any future detail designs.

As described in Section 4.2.1.3, space exists for an expanded new electrical service entrance. For resiliency, there is also land space that could be graded flat to support BEB backup generator(s) but a full backup would likely require multiple 2MW generators. In the future as the MVTA grows it's fleet of BEBs it will work with Xcel to explore redundant feeds, ideally from separate circuits from separate substations.

4.2.2 Burnsville Bus Garage (BBG)

The Burnsville Bus Garage, shown in Figure 13, was constructed in 1977 as a manufacturing facility in an industrial park and repurposed as a transit bus garage in 1996.[46] It is currently undergoing renovations and expansions including adding additional interior parking capacity, adding new bus washing facilities and upgrading the electrical service to support short-term and long-term BEB implementation. Taking up an entire block between 116th Street East to the south and 115th Street East to the north and Rupp Drive to the east, the fourth and western edge of the site abuts adjacent commercial property.

Figure 13: Burnsville Bus Garage Context Site Plan



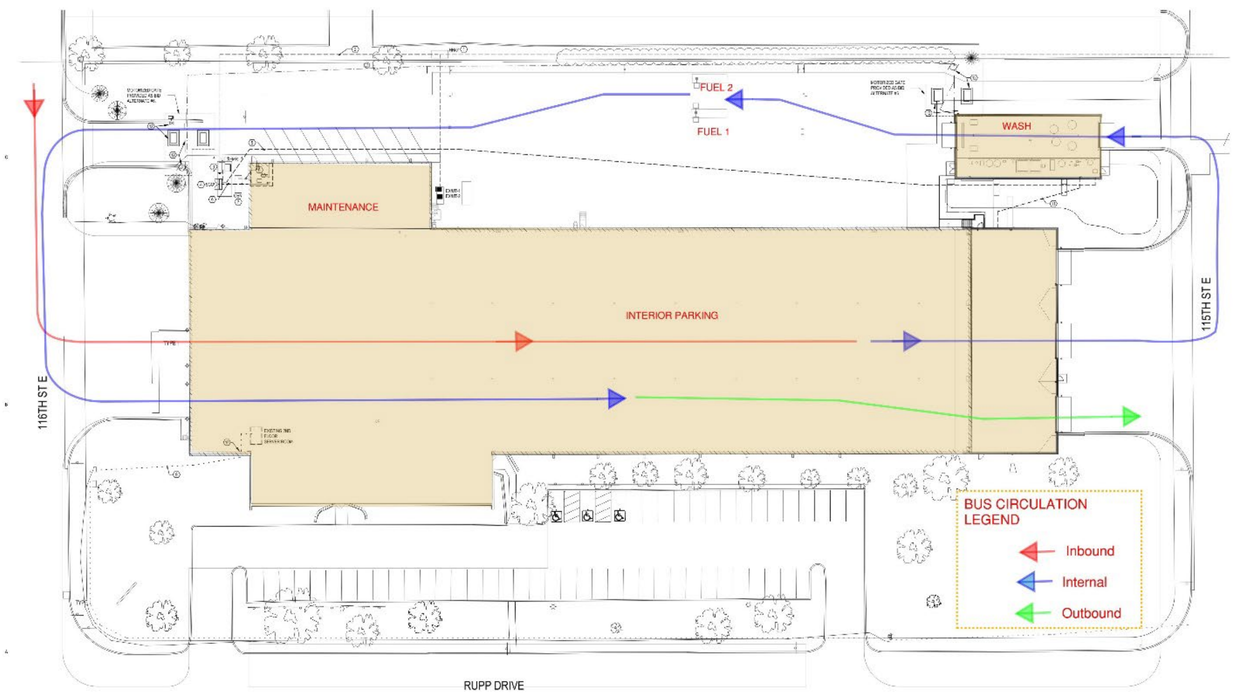
4.2.2.1 Existing Bus Circulation

Bus flow at BBG is generally from 116th Street East entering the covered parking garage from the south entry drive off of 116th Street East (Figure 14). Incoming buses from PM pull-in are parked and staged in designated staging parking track(s). Operators check out with Dispatch and exit the site in their personal vehicles on Rupp Drive. Post-modernization, the flow will consist of nighttime service staff hostlers move buses from the staged parking position out from the garage exiting to 115th Street East and then turning back onsite through the drivethrough automatic bus wash for exterior cleaning. After exterior cleaning, the buses then

[46] Source: Board Meeting, MVTA, June 23, 2021

will pass through one of the fueling positions. During the dwell time at the fueling position, the vaults will be pulled and fares collected, the interior of the buses cleaned, tire pressure checked, and the bus defect cards from the operators collected. After fueling, the hostler then parks each bus in its assigned track based on the next day's morning pull-out dispatch schedule. The process is repeated for every bus until all ready line buses used that day have been serviced and are ready to be dispatched for the next day's morning pull-out.

Figure 14: Burnsville Bus Garage Bus Circulation



4.2.2.2 Near-Term Changes

The Burnsville Garage is currently not being used for daily transit service as the facility undergoes construction and modernization. Improvements and expansion at BBG are being implemented in three phases. Phase 1 is under construction now while Phase 2 and 3 will be completed at a later date. As part of the Phase 1 expansion, a new electrical service will be installed at BBG in addition to a 1,000 kVA transformer along with a corresponding distribution panel and backup diesel generator. The new 1,000 kVA transformer included in Phase 1 will power the new bus wash equipment being installed concurrently. To support a long-term transition towards BEBs, provisions are being made in Phase 1 electrical plans including spare power capacity and underground conduits to the bus garage. Phase 3 of the project is planned to build upon the provisions made in Phases 1 and 2 through a variety of electrification initiatives designed to lay the foundation for electric vehicles.

4.2.2.3 Long-Term Changes to Support ZEB Transition

With the addition of the new Phase 1 transformer, approximately 800 amps of spare capacity are available for future BEB charging use. The quantity of BEBs supported by the spare capacity will depend on the battery configuration of the future BEBs and charging infrastructure. A nominal 150-180kW charger requires 180-210 amps per charger so 3 to 4 charge cabinets could be supported by the spare capacity of the Phase 1 transformer. If 1:3 or 1:4+ charge ratios are used this equates to the potential to add 9 to 12 dispenser charging locations before addition new electrical service is needed. There is additional ground space adjacent to the Phase 1 Improvement transformer for further electrical service and capacity to be added in the future if needed. Currently, space exists within BBG to house BEB charging support infrastructure and equipment along the inside perimeter of the bus storage garage as well as between the roof support column parallel with the bus parking tracks.

4.2.2.4 Long-Term Barriers to ZEB Transition

The nominal clear height of the BBG is 13 ft 10 inches from the top of parking slab to the underside of roof trusses above. This clear height does not support conductive overhead charging utilizing overhead inverted pantographs. The clear height, however, does support the piston garage type dispenser usage if the taller non-moving portions of the piston garage dispenser are not directly located under a roof truss. BBG's clear height also supports suspended overhead dropdown cords with remote plug-in dispensers nested between existing roof trusses energized by charging cabinets located at ground-level on the inside perimeter of the garage and between building columns. When planning for future BEB storage, sufficient space must be reserved for pedestrian circulation between obstructions including support beams and/or other buses when BEB charging port doors are open and charging cords are pluged-in. Prior to commencing construction modifications, approximately 67 buses were operated out of BBG utilizing interior and exterior parking spaces. At this or a similar quantity of buses on-site parked in a non-crushed configuration, buses could be parked two tracks per building structural bay instead of three tracks. While this would limit the number of BEBs that could be parked inside, this configuration would allow for more ground-mounted chargers and dispensers to be adjacent to the BEBs if all-in-one plug-in chargers are utilized. Two bus tracks per building structural bay would also allow room to open charging port doors and have plug-in charge connectors extending from the bus and still have adequate pedestrian circulation space alongside the parked buses parallel to the bus parking tracks.

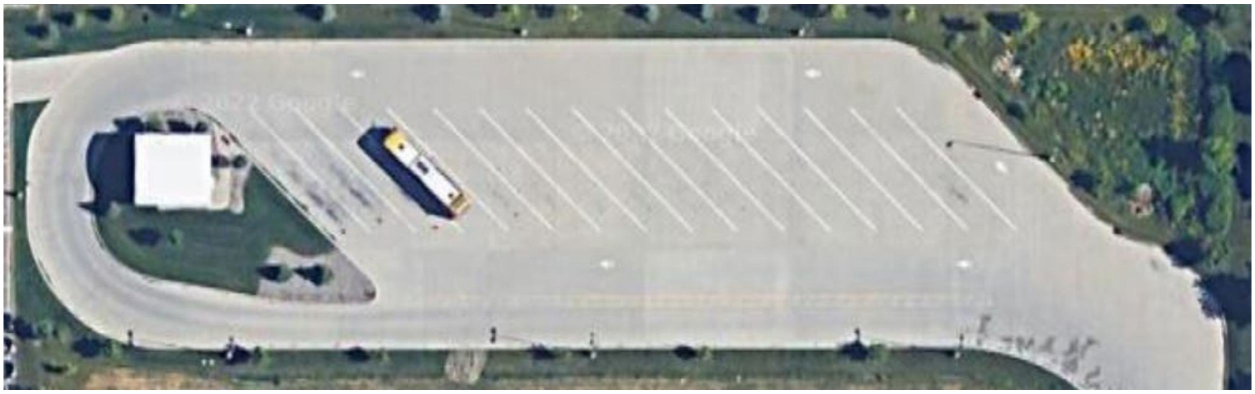
4.2.3 Other MVTA Facilities

Although MVTA is not currently considering "opportunity" charging in the short-term, a preliminary electrification suitability analysis was performed for the six park and ride and transit center facilities with associated MVTA ownership outlined in Table 1, a high-level summary of which is included below. This opportunity charging suitability/feasibility analysis is focused on overhead inverted pantograph (pantograph) dispensers from a pole mast or structure located at passenger drop off/pickup berths. Opportunity charging is assumed to require a higher capacity unit (250kW+). Each transit station / park and ride site was reviewed to find a portion of open site that had the ground area to fit new BEB charging infrastructure (transformer, meter, distribution panel) as well as a charge system (charging cabinet(s), pantograph support mast and pantograph dispenser). Ideally this site area will be close to the bus berths to limit distance between charger and dispenser but also reduce construction complexity and cost.

4.2.3.1 Apple Valley Transit Station

At Apple Valley Transit Station (AVTS), passenger drop-off/pickup berths are situated in two street cutoff of Cedar Avenue. The two sides of Cedar Avenue are connected by a pedestrian/passenger bridge to allow safe access across Cedar Avenue. The vertical circulation buildings on either side of the passenger bridge contain stair, elevator and interior waiting areas and public restrooms. There are overhang canopies on both vertical circulation buildings that overhand portions of the bus berths. The Apple Valley Transit Center also includes a large park-and-ride facility. To west of the park-and-ride facility is a bus layover facility. The layout of the site provides several potential locations to provide opportunity charging, either on the landscaped island or the west edge of the site.The layover facility is not public accessible and as such could use plug-in dispensers at this location.

Figure 15: Aerial View of Apple Valley Transit Station – Layover Facility



4.2.3.2 Burnsville Transit Station

Burnsville Transit Station has 12 angled berths and long stretches of curb that can be used as passenger pickup/drop-off areas or as layover spaces for a bus to dwell for ten or more minutes without being at a hard transit signed/defined passenger loading berth. Four of the 12 angled berths are canopy covered with lower canopies that do not extend over probable pantograph mast locations. There are four higher canopies that do extend over the probable pantograph mast locations but the heights would allow for a ground mounted mast or pantograph mounting directly from the high canopy structure if there is enough structural capacity identified during detail design. The remaining majority of berths and layout spots are canopy free and are adjacent to open landscaping areas suitable to support future BEB charging infrastructure and charge systems.

Figure 17: Aerial View of Burnsville Transit Station

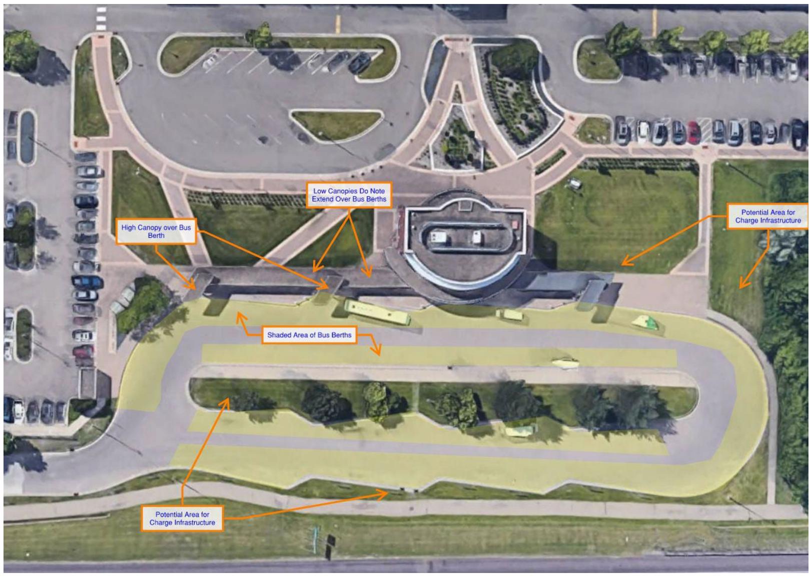


Figure 17: High/Low Canopies at Burnsville Transit Station Bus Berths

4.2.3.3 Eagan Transit Station

Eagan Transit Station passenger loading and unloading occurs at the ground level in a concrete three-story parking garage. Any new pantograph dispensers would need to be mounted to either a new mast or suspended from the overhead concrete structure. The clear height of the first-floor parking garage may limit the construction of the mast's typical drilled pier foundation and require a nominal nine-foot by nine-foot mat footing which may interfere with garage foundations. The transit station is part of a commercial transit-oriented development (TOD) commercial shopping center. There is open available space along Pilot Knob Rd and Yankee Doodle Rd for charging infrastructure installation, but such installation would require trenching across TOD drives. The existing parking garage structure could be utilized to support and distribute charge system wiring once charging power entered into the garage.

Figure 18: Aerial View of Eagan Transit Station

4.2.3.4 Palomino Hills Park & Ride

Palomino Hills Park & Ride has two passenger pick-up/drop-off berths. One berth is uncovered and the other is partially covered by a tall canopy. The tall canopy is high enough to allow a new pantograph mast to be installed. The canopy stops at the approximate center of the bus in the berth. The canopy could be used to support a pantograph but modifications would be required to allow the pantograph to reach the far/street side of roof-mounted charging bars on a BEB. Available land areas exist adjacent to the bus berths to house charging infrastructure and charging system cabinets.

Figure 19: Aerial View of the Palomino Park & Ride Passenger Berths

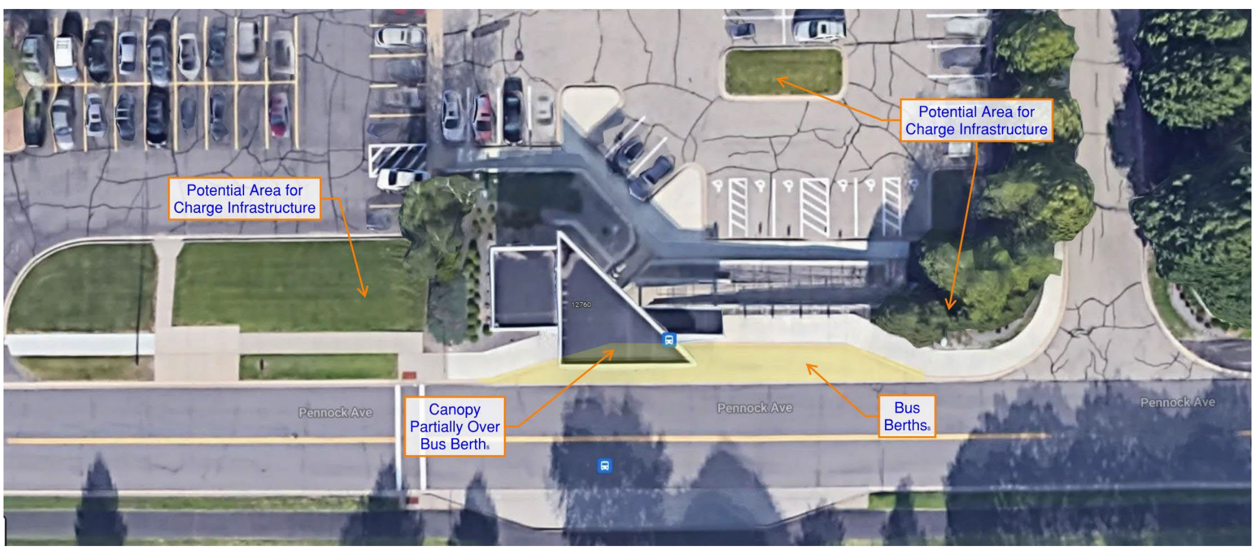
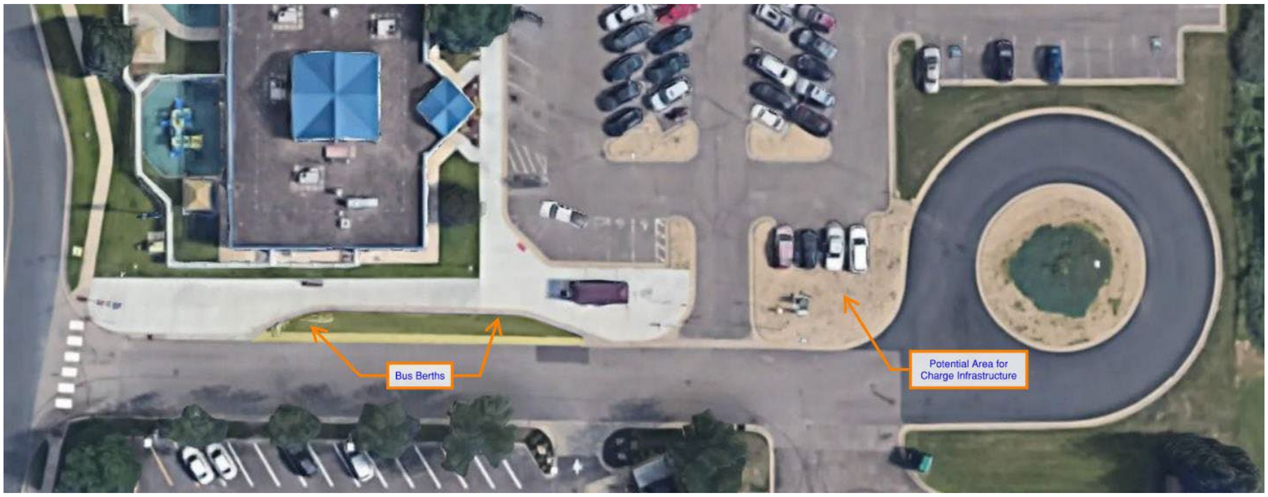


Figure 20: Street View of the Palomino Park & Ride Canopy Partially Covering the Front of a Bus

4.2.3.5 Savage Park & Ride

Savage Park & Ride has two uncovered passenger pick-up berths. Sufficient space and clearance currently exist at the site as well as available land close to the bus berths to support the installation of charging infrastructure and charging cabinet(s). Pavement is newer concrete and sections trenched or replaced during charger construction and installation would blend in to disguise new mast construction. A nearby raised curb with gravel currently houses electrical equipment for the park and ride lighting has space to add new electrical service and charging equipment to support the opportunity chargers.

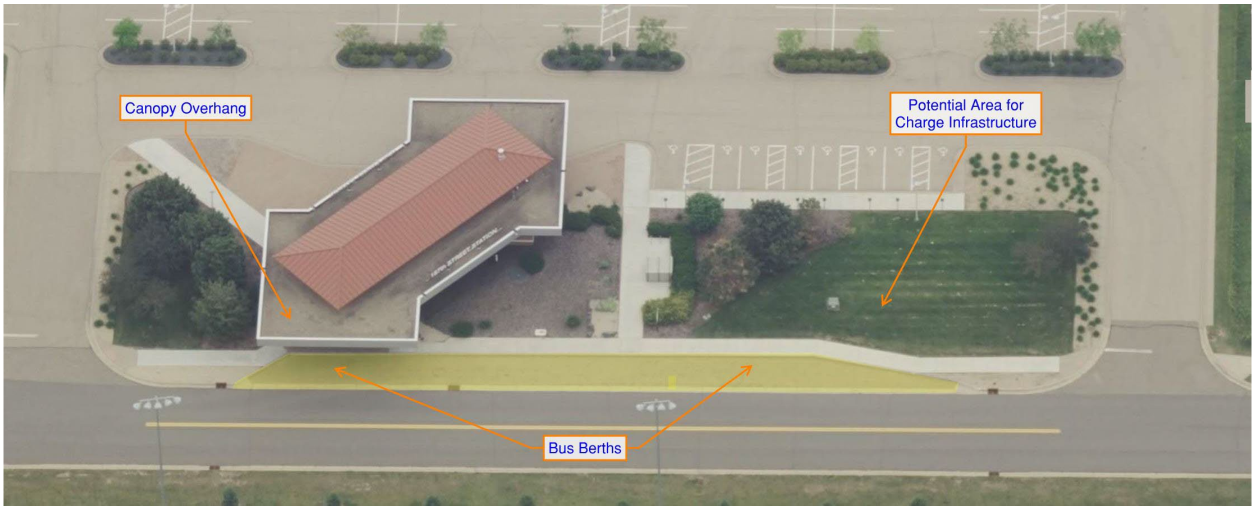
Figure 21: Aerial View of the Savage Park & Ride Passenger Berths



4.2.3.6 157th Street Station

157th Street Station has both uncovered and canopy-covered passenger loading berths. The canopy-covered berth is overhung by a taller canopy that nearly covers the street side of the bus. The height of the canopy would allow for the installation of a new charging pantograph and mast or, with some modification at its edge, the potential to support the pantograph. There is adjacent available land suitable to house charging infrastructure and charge system components. Pavement around the station is newer concrete and trenched sections or replaced sections would blend in to disguise new mast construction. Additionally, the available land for charge systems extends alongside half of the bus berths. This close adjacency to the backside of the passenger waiting platform could be conducive to boring under existing pavement to install wiring to new mast location.

Figure 22: Aerial View of the 157th Street Station Passenger Berths



5 Resource Availability

In addition to the anticipated goals, opportunities, and challenges identified for MVTA's fleet transition, other important elements for consideration include resource-related factors– notably, utility coordination, funding availability, and workforce development and training. While facility and operational considerations are necessary to identify opportunities for early deployments, long-term coordination with these items will help to ensure full fleet transition success.

5.1 Utility Coordination

MVTA is collaborating with Xcel Energy, the utility service provider for our garages, to ensure long-term planning for the BEB transition can help to curb future delays. While the power needs of short-term deployments can be met with minimal electrical upgrades, a full fleet transition could require significant upgrades to both the grid and onsite electric infrastructure. Based on preliminary analysis and conversations with Xcel Energy, no major barriers were identified associated with electrifying the Eagan Bus Garage (EBG). In collaboration with Xcel

Energy, two existing electrical service feeders (one overhead line and one underground) were identified as running next to EBG. These preliminary conversations indicated that 7.5 MW of capacity exists on these feeders which could substantially support full electrification at EBG.

Any near-term upgrades, such as placing a new transformer, are anticipated to require Xcel Energy approximately two years to complete. As MVTA continues electrification efforts, MVTA will continue to work with Xcel Energy to explore adding additional metered service to utilize electric vehicle rates, to ensure that a long-term zero-emission transition will be viable at both the EBG as well as the Burnsville Bus Garage, and to determine rough order of magnitude of cost to be borne by MVTA as well as the timeframe it will take for Xcel to make these improvements.

5.2 Funding Availability

BEBs and associated infrastructure 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. However, one of the primary opportunities for closing this gap includes competitive grant opportunities such as the Low or No (Low-No) Emissions Grant Program.

5.2.1 2022 Low-No Grant

Presently, MVTA is working on a Low-No Grant application for five 588 kWh long-range 40-foot Gillig BEBs, along with the supporting infrastructure for one lane at EBG to support these five vehicles. Should this grant be awarded, MVTA will be taking an important step towards its zero-emission future.

5.3 Workforce Development & Training

This section evaluates how workforce development and training will transition from supporting a fleet of vehicles with internal combustion engines to vehicles with electric drive propulsion and battery-electric power. MVTA will focus on building upon the skills of its workforce to ensure they are able to continue to operate this new fleet as effectively as possible.

5.3.1 Current Training Plan

MVTA's service operation and vehicle maintenance is performed by its contractor, Schmitty and Sons. The contractor has a thorough training program that empowers its workforce to safely and efficiently operate its gasoline and diesel-powered vehicle fleet. The maintenance department utilizes current training standards to ensure its workforce keeps the equipment in a state of good repair. The organization will be able to build off this foundation as it transitions to a zero-emission bus fleet.

5.3.2 Strategies to Integrate ZEB Training

MVTA will utilize future BEB OEMs to train bus operators on the differences between a diesel/gas powered vehicles and BEBs including any driving changes needed to ensure the battery is utilized as efficiently as well as safety considerations needed to operate BEBs. These changes will be folded into the organization's training program to ensure all new operators are sufficiently educated in the future.

The diesel technicians in the maintenance department already have an existing base level of understanding of electrical components from their experience in fixing diesel power buses. MVTA will assist technicians in expanding upon this knowledge with hands-on OEM training to diagnose and resolve BEBs issues, including working with high voltage equipment. Hostlers will also be trained on how to safely operate the charging equipment when parking a vehicle. Much like bus operators, this training will become part of the standard training protocol for future hires.

Safety is of paramount importance. To support the safe operation and maintenance of BEBs, MVTA plans to purchase the proper PPE, tools, and equipment mechanics will need based on OEM's recommendation. MVTA will also provide training to local first responders to help mitigate risks in case of a safety event in the future.

While the training upon the receipt of a new technology is a vital component of long-term success, it is crucial that the workforce is supported in the first few months of operation and beyond. OEMs are planned to provide on-site trained technician support to help maintain the equipment and the maintenance department will directly shadow these OEM technicians to learn best practices on how to keep the equipment running efficiently. MVTA will communicate with frontline workers, through its contractor, to learn what additional training is needed as they grow their experience with the equipment. By empowering its current workforce to maintain this new equipment, there will be no expectation of displacing any employee as the agency transitions towards ZEBs.

6 Conclusion

With both operational and facility opportunities to support near-term fleet transitions, MVTA is well-positioned to begin a fleet transition to ZEBs. While there are some near-term barriers to a full-fleet transition preliminary modeling results indicate that over half of MVTA's existing fixed route bus blocks, encompassing more than a third of revenue hours and miles, are currently technically viable.

6.1 Next Steps

Next steps identified to move MVTA's fleet transition forward in the short-term are as follows:

- Evaluate mitigation strategies such as opportunity charging and block splitting for blocks unsuitable for one-to-one garage-charged BEB transition;
- Deploy BEBs acquired via awarded grant funding in order to begin building experience with the technology; and
- Work with Xcel Energy to determine long-term strategies for site preparation and off site grid improvements needed to support electrification.

6.1.1 Strategies to Overcome BEB Barriers and Risks

While the physical short-term facility space and power requirements for electrification are in place, the funding, design, and selection of the charging technologies and BEB vehicles to support electrification need to be addressed. Funding is the initial step needed as MVTA will be limited in procurement of BEBs and design/construction detail design projects without a clear funding source and amount. Once funding is established, it will set the timeframe within which electrification projects can be completed. The goal is to have any facility modifications in place and commissioned 3-6 months ahead of first prototype BEB of an incoming BEB order. The goal of Xcel as utility provider will be to complete all off-site grid improvements before completion of any MVTA facility improvements. All these goals are achievable with continued coordination with Xcel, as well as local authorities with jurisdiction including fire marshals. MVTA's next step is to establish the ultimate full BEB master plan agency-wide to include all anticipated facilities, bus operation and maintenance systems as well as transit centers and park and rides. This high-level master plan will establish assumed BEB vehicle configuration and charging infrastructure and act as a basis of design to implement in smaller incremental designs / deployments but in such a way as the incremental design is phase of the master plan.

6.1.2 Updates to the Transition Plan

Moving forward, MVTA will be finalizing a phase two fleet transition plan, which will follow up on the items identified for further analysis in this report. Not only this, but the additional phase of planning will also incorporate a step to perform additional feasibility evaluations. This analysis will include performance modeling to project BEB performance on MVTA routes by leveraging physics-based simulation models to further refine fleet transition projections beyond the minimums evaluated in this report. Based on the outcomes of this assessment, MVTA will be able to further refine fleet transition projections and identify blocks in need of additional mitigation strategies for transition. These strategies can include opportunity charging, block splitting, and midday charging, based on scheduling, infrastructure, operational, and cost constraints. This phase of transition planning will also help to right-size infrastructure needs through charging analysis based on BEB schedules.