GTA ride. connected.

Zero Emission Fleet Transition Plan

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Executive Summary

Greensboro's transition to a cleaner fleet began with the City introducing diesel-electric hybrid buses into service more than 10 years ago. By 2016, Greensboro Transit Agency (GTA) began purchasing battery electric buses (BEBs), which have been in operation since early 2018.

Under the Bipartisan Infrastructure Law, transit agencies using the expanded Low or No Emission Program or the Grants for Buses and Bus Facilities Competitive Program to purchase Zero Emission Buses must submit a plan for implementing a transition to a Zero Emission Bus (ZEB) fleet. Federal Transit Administration (FTA) set guidelines for these plans in the Dear Colleague Letter dated December 1, 2021.

This Zero Emission Fleet Transition Plan (ZEFTP) outlines four scenarios in transitioning GTA to a fully zero emission (ZE) bus fleet. Each scenario follows two key steps:

1. Optimize current charging locations and approach to near-term bus fleet management and additions through 2028.
2. Continue to expand the fleet and charging approaches from 2029 through 2034 to achieve a full bus fleet conversion.

Base Scenario

The Base Scenario is based on existing service and assumes a relatively linear fleet transition based on GTA's historic BEB adoption rate and current funding allocations. As shown in the following figure, assuming a relatively consistent number of vehicle replacements in the later years of transition, it is estimated that GTA's bus fleet transition can be complete by 2034.

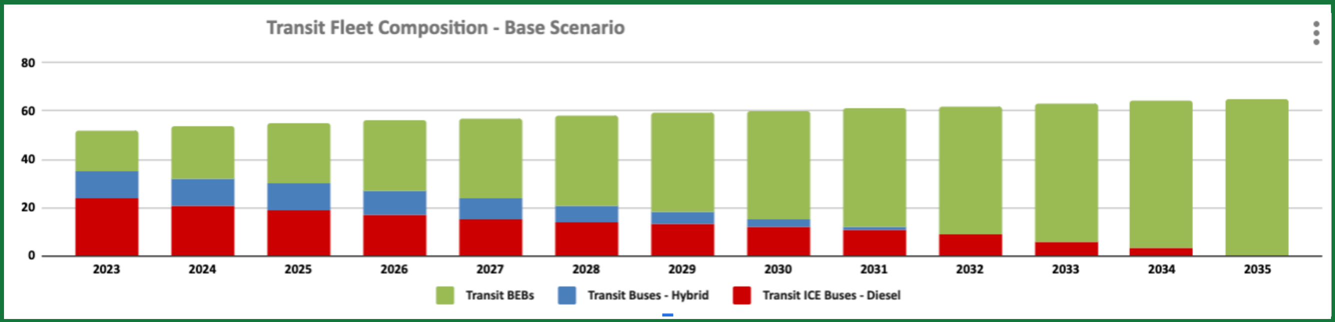


Figure 0-1 – Projected Transit Fleet Composition-Base Scenario

As the bus fleet transition is ongoing, the City also plans to move forward in transitioning its paratransit fleet. The transition of the paratransit fleet is anticipated to be complete by 2035.

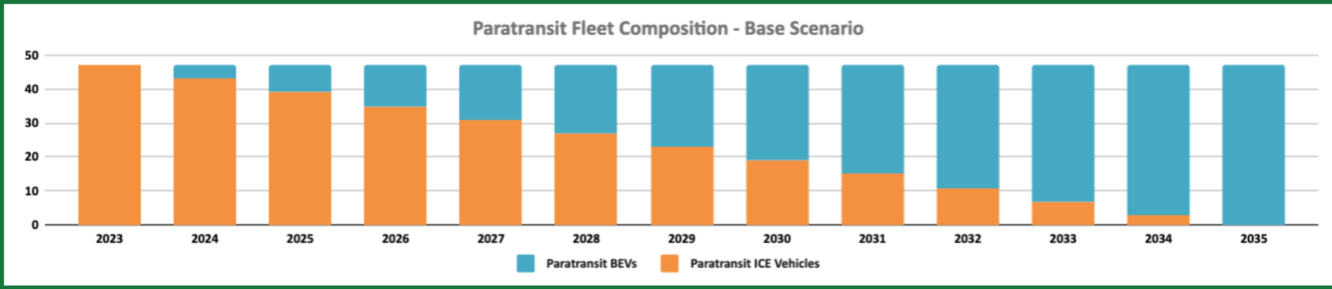


Figure 0-2 – Projected Paratransit Fleet Composition – Base Scenario

Existing Service + Technology Impacts Scenario

The Existing Service + Technology Impacts Scenario adapts the Base Scenario for current slow delivery times and challenges in obtaining BEBs. As the technology matures and becomes more readily available, the speed of transition can increase. Full electrification of the fleet would be achieved by 2033.

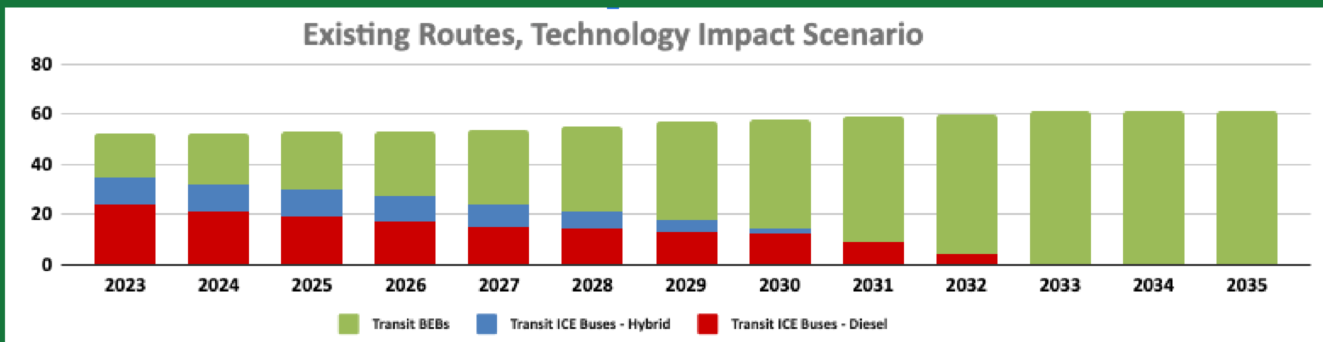


Figure 0-3: Projected Transit Fleet Composition - Existing Service + Technology Impacts Scenario

Future Mobility Plan Coverage Scenario

Greensboro is currently developing a long-range transit plan for 2045 considering two broad conceptual approaches. Future Mobility Plan scenarios were developed for each of these concepts to help GTA plan for future growth.

The Future Mobility Plan Coverage Scenario is based on the coverage concept, which priortiizes providing service to as many people and places as possible. This scenario would serve more routes at less frequent service intervals, and require fewer buses.

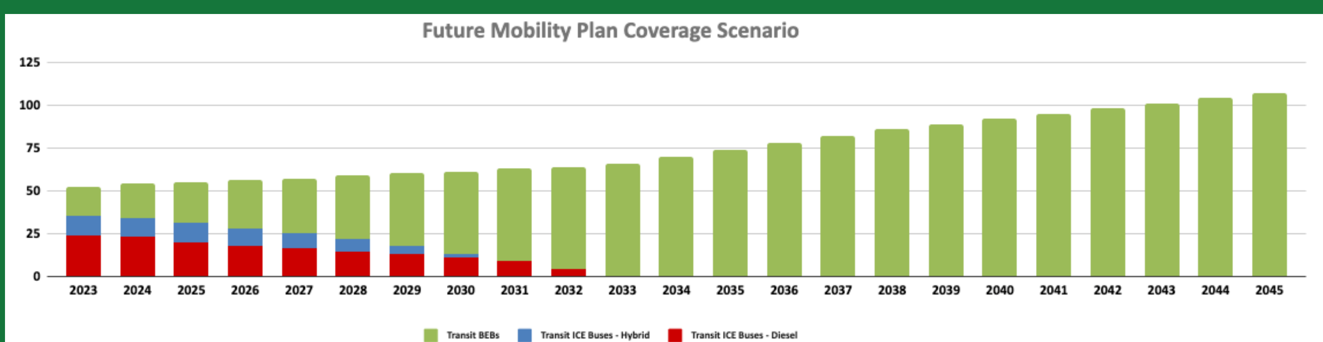


Figure 0-4: Projected Transit Fleet Composition - Future Mobility Plan Coverage Scenario

Future Mobility Plan Ridership Scenario

The Future Mobility Plan Ridership Scenario would prioritize maximizing ridership by focusing service on the routes that serve the highest number of people and destinations. This scenario would have fewer routes operating at higher intervals and would require more buses.

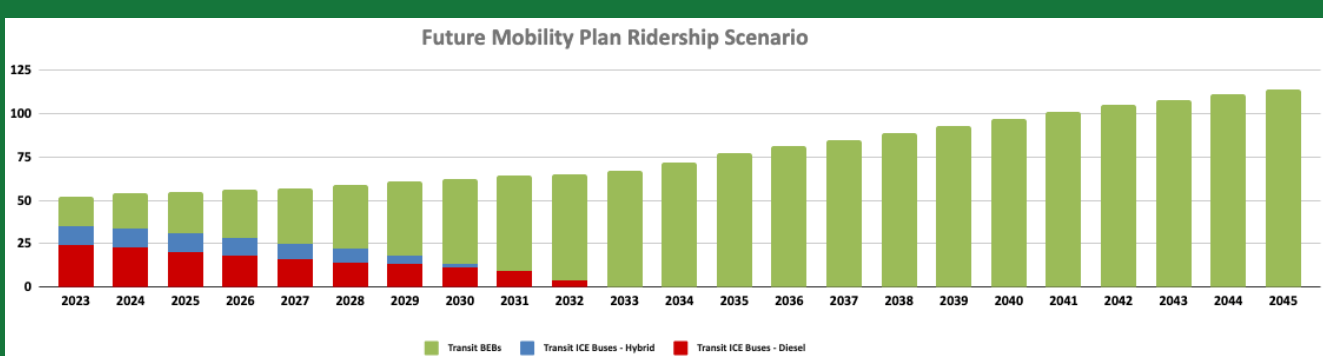


Figure 0-5: Projected Transit Fleet Composition - Future Mobility Plan Ridership Scenario

Introduction

Greensboro Transit Agency (GTA) is the public transportation service provider for Greensboro, North Carolina (NC). GTA operates nineteen fixed routes and nearly 1,100 bus stops with a fleet of more than 50 buses. Complementary paratransit services operate on the same schedule as fixed route. GTA currently has a fleet of 47 paratransit vehicles, with a maximum of 33 paratransit vehicles operating daily.

Greensboro's transition to a cleaner fleet began with the City using diesel-electric hybrid buses in 2011. By 2016, GTA was beginning to purchase BEBs, which have been in operation since early 2018. GTA's current fixed route bus fleet includes 17 BEBs, with four more in the procurement process. In February 2022, the City of Greensboro adopted a Strategic Energy Plan that lists recommendations for achieving 100% renewable energy in all City operations. As part of this effort, the City is committed to converting its transit fleet to zero emission vehicles by 2040.

The ZEFTP builds on GTA's past electrification efforts, evaluates scenarios for continuing to expand the agency's electric vehicles and charging infrastructure, and assesses available technologies, resources, facilities, and partnerships to develop a strategy for transitioning GTA to a fully zero emission fleet.

FTA Requirements

Under the Bipartisan Infrastructure Law, transit agencies using the expanded Low or No Emission Program or the Grants for Buses and Bus Facilities Competitive Program to purchase zero emission buses (battery electric, hydrogen fuel cell, or rubber tire trolley buses powered by overhead catenaries) must submit a plan for implementing a transition to a Zero Emission Bus (ZEB) fleet. The Zero Emission Fleet Transition Plan (ZEFTP) is being prepared in accordance with Federal Transit Administration (FTA) guidelines as set in the Dear Colleague Letter dated December 1, 2021.

Legislative and Policy Requirements

The ZEFTP is based on FTA guidance for preparing Zero Emission Transition Plans (2021) in alignment with statutory requirements for projects related to zero emission vehicles applying for funding under the Grants for Buses and Bus Facilities Program (49 USC 5339(b)) and the Low or No Emission Program (49 USC 5339(c)). FTA defines six key elements for these plans:

1. Demonstrate a **long-term fleet management plan** with a strategy for how the applicant intends to use the current request for resources and future acquisitions.
2. Address the availability of **current and future resources** to meet costs for the transition and implementation.
3. Consider **policy and legislation** impacting relevant technologies.
4. Include an evaluation of existing and future facilities and their relationship to the technology transition.
5. Describe the **partnership** of the applicant **with the utility or alternative fuel provider**.
6. Examine the **impact of the transition on the current workforce** by identifying skill gaps, training needs, and retraining needs of the existing workers to operate and maintain zero emission vehicles and related infrastructure and avoid displacement of the existing workforce.

Each element of the plan was evaluated for the specific agency and local operating context. Conservative base fleet and infrastructure scenarios were developed to guide the addition of battery electric vehicles (BEVs) and expanded charging infrastructure to GTA's transit and paratransit fleets. More detailed scenarios will be developed in future analyses to refine the fleet, facilities, and charging infrastructure actions needed in later years to fully complete the ZE transition. The overall ZEFTP analysis across elements is framed by GTA's prior efforts for a ZE transition and tailored to the unique circumstances present in Greensboro to address the challenges GTA faces. Key Findings and Recommendations, where appropriate, are identified in each section of the ZEFTP.

FTA Element 1: Long-Term Fleet Management Plan

The Federal Transit Administration (FTA) requires a long-term fleet management plan that shows how funding requests will support a strategic fleet transition. This section of the plan provides an overview of the existing GTA fleet, a comparison of the available technologies, and a detailed analysis of GTA's current and future fleet and routing to identify potential scenarios for the transition to zero emission vehicles (ZEVs).

FTA ELEMENT 1

Demonstrate a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions.

Fleet Overview

GTA operates 52 buses on its fixed routes in addition to 47 cutaways supporting paratransit services.

Transit Fleet

The active GTA fleet is comprised of 17 battery electric buses (BEBs), 11 hybrid-electric buses, and 24 diesel buses as shown in the table.

Number of buses in fleet	Manufacturer / Model	Bus Size / Description	Seated Passenger Capacity
16	Proterra Catalyst	40' BEBs with 440 kWh batteries	40
1	Proterra ZX5	40' BEB with 450 kWh battery	40
9	Gillig Phantom	35' diesel buses	35
6	Gillig Phantom Hybrid	40' hybrid buses	40
5	New Flyer Hybrid Xcelsior	40' hybrid buses	40
15	New Flyer Xcelsior	40' diesel buses	40

24 DIESEL BUSES

11 HYBRID-ELECTRIC

17 ELECTRIC BUSES

47 CUTAWAYS

52 BUSES

Note: Current fleet as of February 2023

Table 1-1: GTA Bus Fleet Composition

Transit buses operate throughout the year with both weekday and weekend schedules. For most fixed routes, vehicles operate between 5:00 AM and 11:30 PM on weekdays and 6:00 AM and 11:00 PM on weekends.

DIESEL TRANSIT BUSES

- 27,750 to 70,974 miles traveled every year
- Averaging 54,651 miles per vehicle every year
- Average fuel economy of 4.39 miles per gallon (MPG)
- Total fuel consumption of 454,404 gallons of diesel

EXISTING BEBS

- 15,463 to 30,679 miles traveled every year
- Average is 23,351 miles per vehicle every year
- Average fuel economy of 3.01 kWh per mile (kWh/mi)
- Total fuel consumption of 1,023,032 kWh

According to the fleet operational data from January 2022 to January 2023

The transit bus vehicle model years range from 2009 (9 units) to 2021 (5 units). GTA has 12 diesel buses from 2009-2011 that are suitable for replacement in fiscal year (FY) 2024.

Paratransit Fleet

The paratransit fleet consists of 47 gasoline-powered cutaways.

Number of vehicles	Make and Model	Passenger Seating Capacity
1	Ford E450 Eldorado	15
9	Ford E450 Glaval	15
37	Ford E450 Phoenix	15

Table 1-2: GTA Bus Paratransit Fleet Composition

KEY PARATRANSIT OPERATING STATS

- 4,519 to 44,409 total miles traveled every year
- Average is 25,884 miles per vehicle every year
- Average fuel economy of 6.19 MPG
- Total fuel consumption of 196,403 gallons of gasoline.

City of Greensboro Clean Energy and Fleet Transition Efforts

The Greensboro City Council unanimously adopted a resolution in 2019 to create a 20-year Strategic Energy Plan. The City also applied for and was awarded a grant as a city in the US Green Building Council's LEED for Cities (L4C) Certification Program and earned the Silver Certification. From 2007 through 2019, there was a 34% reduction in the city's greenhouse gas (GHG) emissions.

The City of Greensboro was identified as having the second largest fleet of BEBs on the east coast in 2019, the purchase of which began in 2016. The BEBs have been in service since 2018 with 17 in service currently and 4 more under procurement. Greensboro's commitment to sustainability is further demonstrated by the LEED Gold rating of GTA's Operations and Maintenance Facility and Administrative Offices.

City of Greensboro Strategic Energy Plan

In 2022, the City adopted the Strategic Energy Plan. Outlined below are the short-term actions and long-term measures related to alternative fuels included in the plan:

Short-Term Actions

- Adopt and implement hybrid purchase policy for fleet vehicles and purchase hybrid for replacement vehicles
- Replace fleet vehicles with EV of a justifiable cost & performance and purchase EV when cost is comparable to hybrid
- Budget for charging stations to meet needs of increased EV fleet and install appropriate EV charging stations to meet demand for City fleet vehicles
- Hire fleet technicians with hybrid/EV experience
- Identify energy efficiency renovations for the Depot that align with its historic designation and complete renovations

Long-Term Strategies

- Reduce gasoline and diesel consumption through integration of hybrid and EVs into fleets
- Create a Sustainable Fleet Policy to reduce the emissions from the City's vehicle fleet and equipment which account for 20% of total emissions
- Continue to install charging stations to meet demand for City fleet vehicles

Phase 1 Evaluation: High Level Comparison of Technologies

Bus fleets employing alternative fuels have become prevalent among cities in the United States and around the globe, owing to their benefits in reducing automobile emissions and improving air quality. Research on these and other benefits, costs considerations, and challenges for implementing alternative fuels was conducted to help inform Greensboro's continued transition to zero emission (ZE) fleets.

This section summarizes the research and contains;

• Information on the City's current fuels and technologies;

• A review of available clean and ZE fuel technologies, including their benefits and challenges;

• A brief review of case examples from peer cities; and

• Recommendations for implementation and assessment of continued fleet transition to ZE fuels.

CURRENT FUEL TECHNOLOGIES

GTA's existing fleet includes electric, hybrid-electric and diesel buses and gasoline cutaways. Table 1 lists the benefits and challenges of fuels currently in use by GTA.

Comparison of current fuels

	Description	Benefits	Challenges
Diesel	Diesel is a refined crude oil that is thicker than gasoline and takes longer to evaporate. GTA uses it for 24 diesel buses in operation.	• Lowest fuel cost and cost per mile • Burns at a lower rate than gasoline resulting in high fuel economy • Diesel engine's life expectancy may range from 250,000-300,000 miles	• High emissions • High maintenance costs compared to gasoline
Gasoline	Gasoline is another refined crude oil that has a relatively more complex refining process than diesel and burns quicker. GTA uses it for 47 cutaways in operation.	• Lower emissions than diesel • Lower maintenance costs compared to diesel	• Lower fuel economy than diesel • Higher total cost of ownership (TCO) than diesel
Hybrid-Electric	Hybrid-electric uses low sulfur diesel in combination with energy stored in batteries. GTA has 11 hybrid-electric buses in operation.	• Lower emissions than diesel • Higher fuel economy than diesel	• Higher TCO than diesel • Unsuitable for long distances due to reduced regenerative breaking
Battery Electric	Use on-board batteries to drive electric motors. GTA has 17 BEBs in operation.	• Zero tailpipe emissions and noise • Operating costs one-third of diesel	• Higher initial investment costs • Requires recharging for long distances due to range constraints

Table 1-3: Comparison of Current Fuels

ZERO EMISSION FUEL TECHNOLOGIES

Research for this report included the following zero emission fuel technologies:

- Battery electric buses
- Fuel cell electric buses (hydrogen)

The following pages provide more information on each fuel type. Comparisons of fuel economy and mileage ranges for 40 ft. and 60 ft. length buses for each type of alternative fuel are presented in the attached Figures A-1 and A-2. The vast majority of GTA buses are 40 ft. in length.

Battery Electric Buses

Research was conducted into alternative fuel types to determine the suitability of their application to an existing fleet of buses, along with the benefits and limitations they offer. BEBs are electric buses that are driven by electric motors and derive energy from on-board batteries. BEBs typically have a driving range of 90-100 miles, while some can go up to 300 miles before needing to be recharged. Comparatively, diesel buses have an average range of 690 miles. Shorter routes are especially well-suited to be serviced by BEBs owing to them being returned to a central depot for recharging. While the total cost of ownership (TCO) of electric buses is typically greater than other bus types, the parity between TCO of BEBs and other bus types is shrinking. Cost for electricity is subject to local/regional electricity rates and utility relationships and programs that may be designed to support BEVs. In certain regions and for certain applications, the TCO for BEBs is lower than conventional buses, making electric buses a viable option for some transit authorities. Research and policy center Environment America estimates that switching to BEBs saves up to $400,000 in lifetime fuel and maintenance costs even though the cost of purchase is around $200,000 more than diesel buses.

Charging Systems for BEBs

Pantograph (150-450 kW): Pantograph charges by making contact between the bus and the charging infrastructure in an automated way with the charger being mounted either on top of the bus or suspended from a mount. This method is comparatively faster, especially with an advanced system such as the single-blade charger. Proper alignment between a bus and a pantograph is critical in achieving proper charging. Improvements in charging technology may be incorporated by replacing chargers/dispensers and retrofitting existing vehicles.

Plug-in (50-250 kW): Slow paced charging requiring manual plugging in is most suitable for overnight/off-service charging. Plug-in chargers vary in the speed of charging during those hours based on the charger capacity and they can charge one to four buses per charger.

Ground-based: These chargers are either conductive enabling charging from a connector on the ground or inductive achieving charging wirelessly through electromagnetic field. Inductive chargers utilize a wireless power pad installed on the floor where bus alignment is critical for achieving proper charging.

Benefits

- Lithium-ion energy is **2.5 times less expensive** compared to diesel for the powering of vehicles. Lithium-ion battery pack prices dropped by 89% from 2010 to 2017 from $1,100 per kWh to $137 per kWh and is forecast to decrease a further 27% to $100 per kWh by 2023 (see Attachment A-4)
- Lithium-ion batteries can facilitate a standard-size bus to run **150 miles on a single charge**.
- BEBs **do not produce tailpipe emissions or noise**, unlike their diesel counterparts.
- Operating costs are **$0.63 less expensive** per mile than diesel buses.

Challenges

- While BEBs have a more efficient fuel economy compared to other alternative bus fuel options, they have **shorter ranges**. The ranges are further reduced in areas with hilly topographies or with the requirement for heavy air conditioning.
- BEBs call for **additional infrastructure** with new charging outlets and potential upgrades to transformers. High-speed chargers can cost up to $500,000 to install, and location restrictions can complicate implementation on certain routes.
- The **initial investment** of buying BEBs is more than that of buying diesel buses.
- Temperature drops from 50-60º F to 22-32º F may result in **35-40% loss in range**.

Fuel Cell Electric Buses (Hydrogen)

Hydrogen powered Fuel Cell Electric Buses (FCEBs) generate electricity by combining hydrogen from an onboard storage tank and oxygen from the air emitting only heat and water vapor. Fuel cells operating on natural gas are relatively less expensive than those powered by water as hydrogen extraction through steaming of natural gas is less expensive than through electrolysis, but still costs approximately four times as much as diesel fuel. In addition, natural gas fuel cells emit methane, a potent greenhouse gas. FCEBs offer better ranges and higher efficiency than BEBs that make them suitable for use in hilly terrain and remote areas despite the high procurement and infrastructure costs.

Benefits

- FCEBs offer **longer driving ranges** and quicker fueling times compared to BEBs.
- Much like BEBs, FCEBs **do not produce noise or tailpipe emissions**, and additionally, hydrogen fuel cell production through electrolysis produces **zero emissions**.
- Due to its higher efficiency, hydrogen fuel cells use 40-60% of the fuel's energy providing more power to a vehicle, compared to 33-35% usage by diesel, making FCEBs suitable for use in **hilly terrain and remote areas** by delivering greater power and longer driving distances.

Challenges

- Hydrogen fuel is about **four times as expensive** as diesel.
- The most common method of deriving hydrogen from natural gas leads to **methane emission** which is a greenhouse gas 28 times more potent than carbon dioxide (CO2).
- Heavy duty hydrogen stations for transit buses can fill up to 25 buses a day at about 6-10 minutes a bus cost around $5 million.
- Temperature drops from 50-60^{0} F to 22- 32^{0} F may result in **20-25% loss in range**.

Other Transit Technologies and Enhancements

The following technologies and enhancements may be appropriate to implement with existing non-zero emission vehicles until Greensboro is able to fully transition all vehicles to zero emission.

- **Diesel retrofits** reduce emissions of existing diesel engines through engine re-powering or installation of after-burn technologies.
- **Idle reduction technologies** reduce fuel use and emissions via turning off a vehicle's engine when not needed.
- **Telematics** lead to improvements in fuel efficiency by monitoring miles driven, fuel economy, idle time, driver behavior, and onboard vehicle system conversions.

CONSIDERING AND COMPARING CURRENT AND ZE FUEL TECHNOLOGIES

The following table summarizes key considerations pertaining to current and zero emission fuel. The adoption of an alternative fuel type depends on an agency's budget, bus route lengths, and overall costs.

Table 1-4: High level comparison of ZE fuel considerations

	Initial Ownership Costs	Operating Costs	Maintenance Costs	Drive Range (miles)	Emission Reduction Potential	Noise Levels
Battery Electric Bus	$$$	$	$	90-300	++++	+
Fuel Cell Electric (Hydrogen)	$$$	$$$	$$$	100-350	++++	+
Hybrid-Electric (Existing)	$$	$$	$$	540-780	++	++
Diesel (Existing)	$	$-$$	$$$	475-690	+	+++

KEY: $$$ High; $$ Moderate; $ Low; + Magnitude

Initial ownership costs: Cost of acquiring a bus and setting up infrastructure.

Operating costs: Cost to refuel/recharge a bus.

Maintenance Costs: Cost of upkeep of a bus.

Drive Range: Calculated using fuel economy, fuel tank/battery size and usable fuel per tank/battery.

Emission Reduction Potential: Overall reduction of GHG emissions compared to a diesel bus.

Noise Levels: Amount of noise emanated from a running bus.

PEER CITY AGENCY EXPERIENCES

Practices of transit agencies identified by GTA as peer systems to consider from other states implementing BEBs or other zero emission technologies were reviewed and the key features are highlighted in this section.

Greenville, SC

The City of Greenville began its diesel emissions reduction efforts in 2019 by replacing seven 35 ft. diesel transit buses that had been refurbished with new engines in 2010 to extend their useful life with five Proterra BEBs.

- In 2021, the City of Greenville came up with a sustainability plan called Sustainable GVL. The plan promoted investing in electric fleet vehicles and building a new Greenlink operations and maintenance facility that would support adoption of alternative fuel vehicles to enable a transition away from diesel in order to decarbonize transportation and reduce fossil fuel usage in the transportation sector.
- The 2018 Greenlink 2020-2024 Transit Development Plan was updated in 2021 to account for expansion of services and costs. Greenlink Transit acquired funds to purchase 6 Compressed Natural Gas (CNG) and 6 BEBs as response to the service expansion.
- From 2025 onwards, the agency estimated that it would require either 29 more 35 ft. CNG buses or 56 35 ft. BEBs to service its operations. Greenlink Transit noted that it was concerned about the on-street performance of BEBs and planned to charge BEBs overnight at its new maintenance facility.

Fort Collins, CO

The City of Fort Collins began converting the transit agency Transfort's fleet to CNG in 2008. Transfort aims to transition to 100% zero emissions by 2040 and has secured funding for 11 BEBs. The agency developed a Zero Emission Bus Transition Screening Assessment in 2021.

- Transfort currently has 50 CNG buses and 3 diesel buses in its fleet. The agency is exploring the following fleet scenarios through its assessment - BEB depot-only charging, BEB depot and on-route charging, fuel cell electric bus (FCEB) only, and Mixed BEB and FCEB.
- Disadvantages of BEB depot and on-route charging scenario when compared to BEB depot-only charging scenario included higher infrastructure costs, higher impacts from peak demand chargers, and obtaining of land rights at charging sites to install the required charging infrastructure.
- The assessment found that Transfort would have to increase its fleet from 53 buses to 73 buses in order to service all blocks by BEBs using depot-only charging. Including on-route charging would enable the agency to complete 85% of the service blocks using only 45 BEBs and the rest using either FCEBs or CNG buses.
- The assessment also looked at a future scenario where 82 CNG buses would be replaced by 115 BEBs to achieve 100% depot-charged service. The agency noted that since FCEB refueling is similar to CNG, a mixed fleet of BEB and FCEB might be able to cover all blocks of service.

Champaign-Urbana, IL

Champaign-Urbana Mass Transit District (MTD) prepared a Zero Emissions Transition Plan in 2022. MTD has been pursing zero emissions since 2017 and purchased its first diesel-electric hybrid buses in 2009. The agency developed the nation's first hydrogen fuel production station and deployed two 60 ft. FCEBs in 2021. The hydrogen production is powered by clean energy from a 5,500 panel solar array constructed in partnership with the Urbana-Champaign Sanitary District (UCSD).

The agency's fleet currently has 116 diesel-hybrid electric buses and 2 FCEBs. The fleet is anticipated to be FCEB dependent with the infrastructure already set up and expandable, with 70 FCEBs, 33 diesel-hybrid electric buses and 15 Renewable Energy Gas (RNG) buses by 2040.

MTD plans to procure RNG through another partnership with UCSD.

NORTH CAROLINA AGENCY EXPERIENCES

Chapel Hill, NC

Chapel Hill Transit performed pilot studies to determine the infrastructure needed to expand their battery-electric fleet and assess the feasibility for the use of solar power to assist power charging stations and energy demands at the transit facility. The Town is continuing to grow the pilot and incrementally add BEBs, with plans to have 10 BEBs by 2025.

- The Town noted that electric buses can significantly reduce emissions and plans to "replace all it's diesel buses and support vehicles with electric options within twenty years"
- The transition to BEBs and electric support vehicles should include on-site renewable energy, battery storage, and vehicle-to-building technologies to enhance economic and resilience benefits.
- Community partners provided support, advocacy, and significant funding. A student-run group at UNC-Chapel Hill named the Renewable Energy Special Projects Committee (RESPC) contributed $380,000 to the transit system to acquire a third BEB for their pilot. Additional funds for the $3 million pilot project came from FTA and local funding partners: Town of Chapel Hill, Town of Carrboro, and UNC-Chapel Hill.
- Another FTA grant of $5.6 million announced in 2020 enabled the Town to acquire 6 more BEBs with an additional BEB set to be received as part of the Environmental Protection Agency's Volkswagen settlement
- Chapel Hill Transit has 4 BEBs in its fleet with 7 more on order. The agency expects the number of BEBs to go up to 20 in a year.

Asheville, NC

In June 2019, the City deployed five ZE electric buses for the City's transit system, Asheville Rides Transit (ART).

- The City states that committing to BEBs will reduce fuel costs and dependence on imported energy resources.
- The transition to BEBs also aligns with the City's carbon-reduction goals.
- The estimated impact is an approximate reduction of 54 tons of GHG emissions per year per bus, adding up to a total approximate reduction of 270 tons of GHG emissions per year.
- The City has on order six diesel-hybrid electric buses to replace existing diesel-hybrid electric buses that are nearing the end of their useful lives through a $4.2 million Low-and No-Emission Program grant.

Other North Carolina cities such as Charlotte, Durham, and Raleigh have plans to implement or pilot and evaluate BEBs or other clean technologies such as RNG.

FTA EVALUATIONS AND KEY FINDINGS FROM AGENCIES IMPLEMENTING BEBs AND FCEBs

Federal Transit Administration (FTA) has funded evaluations of the results from agencies employing new technologies, including BEBs and FCEBs from different manufacturers operating in fleets located in both cold and hot climates in recent years. These evaluations have been prepared by the National Renewable Energy Lab (NREL).

Table 1-5 summarizes the key findings on charging infrastructure and costs from the Battery Electric Bus Evaluation of Foothill Transit with the agency's deployment of 34 BEBs in southern California since 2010. Table 1-6 summarizes the key findings regarding hydrogen fuel supply and bus ranges from the Zero-Emission Bus Evaluation Results for Orange County Transportation Authority.

Table 1-5: Highlights of Foothill Transit Battery Electric Bus Evaluation: Final Report (NREL, 2021)

Evaluation Factor	Observations
BEB range	After more than a decade since inducting BEBs into its fleet, Foothill Transit cannot use current extended-range BEBs to service all its blocks due to range limitations. Air-conditioning use lowers the effective range in warmer and cooler months. The agency has ordered 20 FCEBs and has a hydrogen fuel tank installed to service blocks that cannot be fulfilled by BEBs.
On-route chargers	Deploying on-route chargers was complicated, expensive and needed multiple sites to cover all the routes. Contingency plans should be in place to handle emergencies where traffic backups may cause depletion of charge in BEBs before the completion of routes.
On-route charger availability	Both the chargers at one location experienced thermal events resulting in fires and put the chargers out of service. This led to downtime due to the parking of the fast-charge BEB fleet and the agency had to service the routes using CNG buses. Having redundant chargers for on-route charging of buses might avoid downtime.
Coordination with charger installation and bus delivery	BEBs were delivered in 2017 but the charging infrastructure to put the buses in full service was ready only in 2020.

Table 1-6: Highlights of Zero-Emission Bus Evaluation Results: Orange County Transportation Authority (NREL, 2018)

Evaluation Factor	Observations
Fuel Supply	Retail prices for hydrogen fuel were found to be very high at $17/kg while the average fuel costs for agencies with their own hydrogen stations was at $7/kg making early deployment of hydrogen station desirable.
Fuel cell issues	The agency experienced issues with false warning signals from the fuel cell cooling system which prompted drivers to request replacement buses during service and this was rectified in later months of adoption.
Bus Range	Buses experienced range issues and some in part because of not getting a full fill at the hydrogen station forcing buses to be assigned to block of work below 225 miles.

ADDITIONAL ZERO EMISSION TRANSITION CONSIDERATIONS

Based on the experiences of other transit agencies in North Carolina and across the country, a number of other areas are important to consider as Greensboro continues to implement and evaluate alternative fuels for bus operations. This section summarizes known practices and possible tactics that GTA can consider in continuing to adopt alternative fuel buses in its fleet.

Marketing and Branding

Transitioning to a zero emission bus fleet is an excellent opportunity to promote public transit and wider environmental and community benefits. Best practices for marketing and branding efforts emphasize the need to improve public perception and the overall experience of riding public transit. GTA may consider the following practices when implementing marketing and branding for expanding its clean energy options.

- Cultivate positive, inspiring customer touchpoints along the entire **customer experience** and incorporate “feel good” story elements about GTA and the agency’s goal of transitioning to ZE by 2035.
- **Target Millennials and GenZ as they are more supportive of renewable energy** and shifts in transportation than previous generations.
- Incorporate amenities such as **charging plug-ins** and **Wi-Fi on buses** as fleets are updated.
- Focus on **marketing the engagement and positive feeling** of being connected to the positive climate and environmental impacts of public transportation. Transitioning to clean technology may not be the primary driver influencing a rider’s choices unless it relates to a rider’s core values, but for most, it does contribute to a greater sense of satisfaction when they understand that their choice has had a positive impact.

Environmental Justice

The US Environmental Protection Agency (EPA) promotes the goal of environmental justice so that everybody experiences the “same degree of protection from environmental and health hazards”. GTA may assess the following when deciding on routes and service areas and considering alternative fuel transit buses for service given that large sections of minority populations and low-income households tend to live near busy roadways and highways.

- Exposure to traffic-related pollution is linked to health issues such as asthma and cardiovascular disease. The continued implementation of zero emission transition for the transit fleet will have **positive equity impacts** in this area.
- Noise from traffic can lead to stress and sleep disturbances leading to higher risk for type 2 diabetes. Zero emission transit and paratransit vehicles **reduce the noise generated by transit**
- Zero emission vehicles should be **assigned to routes in an equitable manner**.

Justice40

The Federal Justice40 initiative aims to direct federal funds so that at least 40% of the overall benefits of such investments go to the disadvantaged communities. GTA may use the following indicators to assess transportation disadvantage.

- **Transportation Access:** Certain neighborhoods may spend longer time and more money to get to their destinations or may be more dependent on transit services than others
- **Health:** People who have disability and communities that have environmental exposures
- **Environmental:** Neighborhoods with high pollution burden
- **Economic:** Areas with poverty, low education attainment and low number of jobs
- **Resilience:** Areas vulnerable to natural hazards
- **Equity:** Ability for all areas to receive the same level of service. For example, GTA may implement a BEB rotation policy that may benefit all areas/routes

FIGURES

Figure 1-1: Ranges of Alternative Bus Fuels (Traffic21 Institute, 2017)

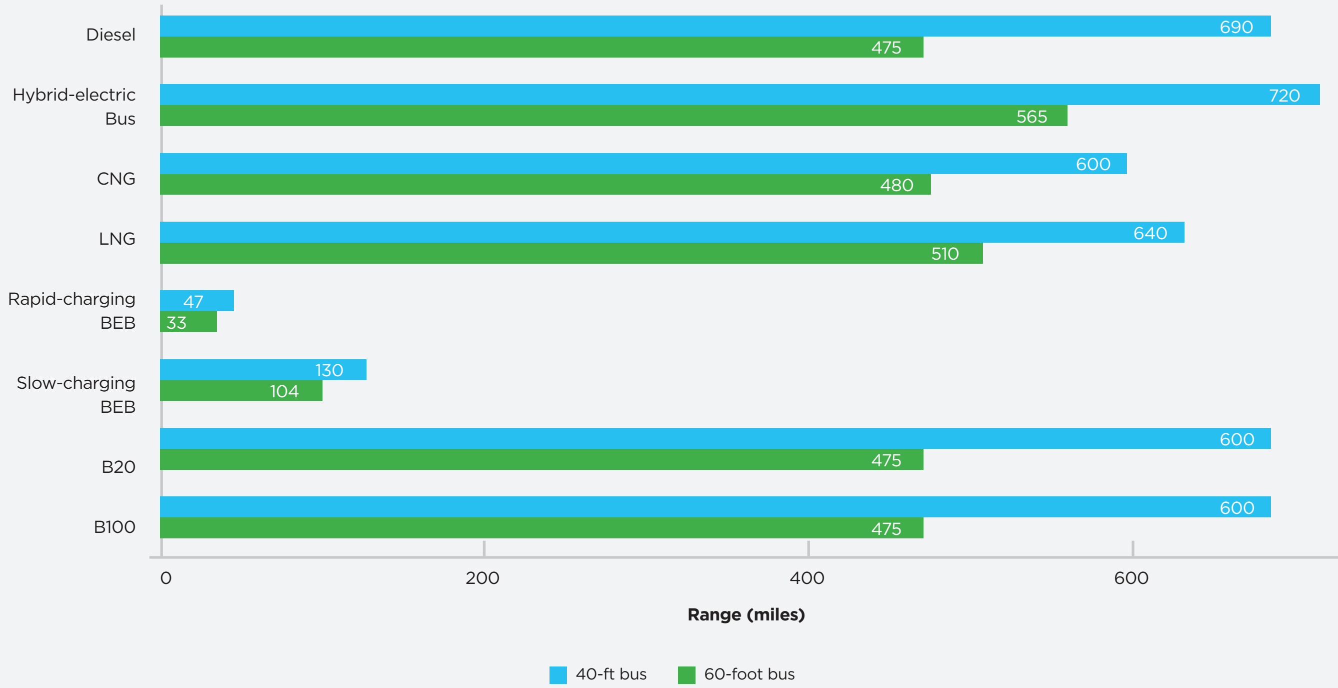
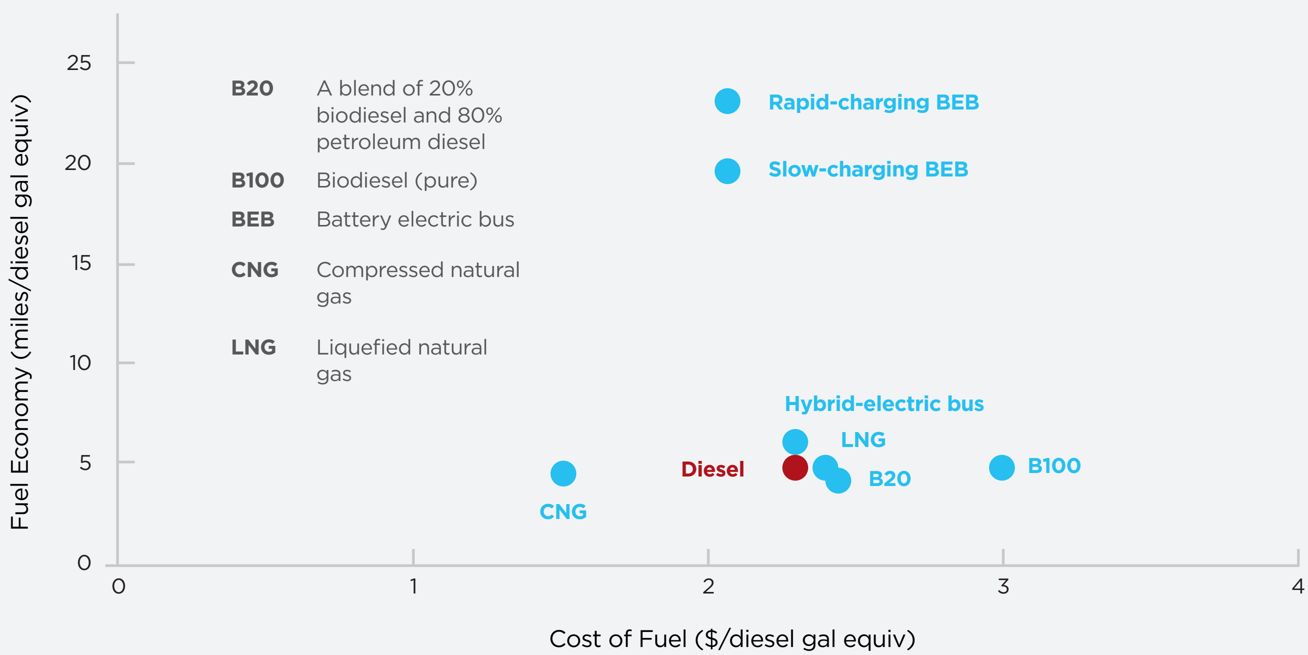


Figure 1-2: Cost Effectiveness of Alternative Bus Fuels (Traffic21 Institute, 2017)



Phase 2 Evaluation: Detailed Assessment and Modeling of Future Fleet Technologies

GTA is evaluating the optimal approach for its long-term fleet transition. The initial focus is to optimize GTA's charging capabilities to better utilize its current and planned BEBs. Analysis is ongoing to identify alternative scenarios that would most efficiently meet GTA's long-term goals for a zero emission fleet.

FLEET MANAGEMENT SCENARIO: CHARGING OPTIMIZATION BASE SCENERIO

Currently, the overnight charging equipment (60 kW chargers) at the maintenance facility limits the ability of the City's existing BEBs to serve evening hours of service due to the length of the overnight charging need and the morning start of fixed route services. The base fleet management scenario for this ZEFTP focuses on optimizing overnight charging, while continuing to expand the BEB fleet.

The initial base scenario calculates the addition of BEBs with only overnight charging to provide a conservative operating and financial assumption for adding these vehicles. GTA has 12 diesel buses from 2009-2011 that could be replaced immediately and eight other diesel buses from 2012-2015 that should be replaced in the coming years. Eight transit blocks can feasibly be electrified immediately with a single charge and overnight maintenance facility charging only; 11 additional blocks could potentially be electrified with opportunity (on-route) charging and minimal operational changes from this conservative base assumption. The City of Greensboro already uses opportunity charging at the downtown multimodal center and operates its existing BEBs on all but three routes.

Assuming that infrastructure for additional opportunity charging locations and minor changes to the operating schedule are phased in over time, the base scenario would result in BEBs operating for the 11 additional blocks by 2027. The City could continue to convert the existing bus fleet and expand on-route charging locations from there to achieve a full fleet conversion to ZE buses by 2034. More detailed full fixed route fleet electrification scenarios are in development.

The base scenario assumes a relatively linear fleet transition based on GTA's historic BEB adoption rate and current funding allocations. Fleet growth reflects the replacement ratio needed to replace diesel and hybrid buses with electric buses and provide the same level of service. The base scenario focuses on fleet conversion; however, additional purchases should be anticipated to replace older electric buses as they age out of the fleet in the later years of the transition.

Scenario	Total BEBs	Chargers Needed	Vehicles Served with Depot Charging	Vehicles Served with Endpoint Charging	Vehicles Served with Block Splitting	Unmanaged Charging Daily Peak Power / Transformer	Managed Charging Daily Peak Power / Transformer	Endpoint Charging Locations
1: Base Scenario	49	2 Depot chargers (500 kW); 16 Maintenance Center chargers (60 kW); 2 endpoint chargers (180 kW); 45 future Depot chargers (200kW)	4	4	45	6,060 kW / 8,350 kVA	2,946 kW/ 3,800 kVA	Four Seasons Mall, GTCC Wendover Campus
2: Existing Service +Technology Impacts	49	2 Depot chargers (500 kW); 16 Maintenance Center chargers (60 kW); 2 endpoint chargers (180 kW); 45 future Depot chargers (200kW)	4	4	45	6,060 kW / 8,350 kVA	2,946 kW/ 3,800 kVA	Four Seasons Mall, GTCC Wendover Campus
3: Future Mobility Plan Coverage Scenario	112 in 2045	107 (240 kW)	89	18		10,560 kW / 14,700 kVA	6,093 kW / 8,500 kVA	Pyramid Village Shopping Center, GTCC Wendover Campus, GTCC Main Campus, Joint School of Nanoscience and Nanoengineering, Four Seasons Mall, Coble Transportation Center
4: Future Mobility Plan Ridership Scenario	116 in 2045	116 (240 kW)	97	17		10,320 kW / 14,350 kVA	7,170 kW / 10,000 kVA	Coble Transportation Center, GTCC Main Campus, Joint School of Nanoscience and Nanoengineering, GTCC Wendover Campus, Pyramid Village Shopping Center

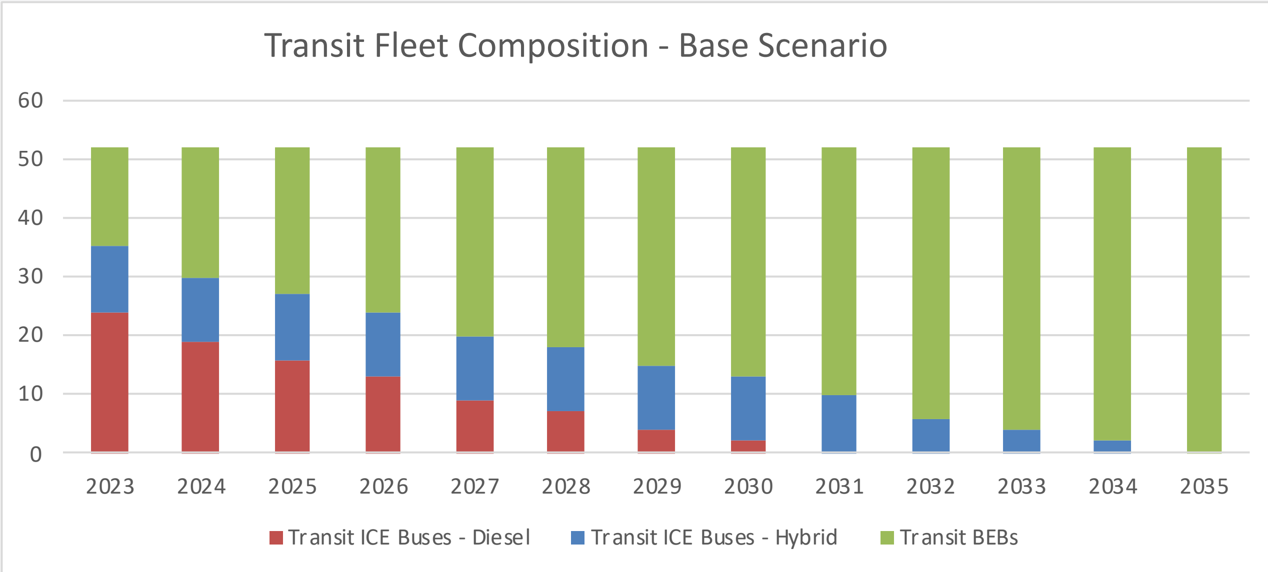


Figure 1-3: Projected Transit Fleet Composition – Base Scenario

The paratransit fleet is newer than the fixed route fleet, with the oldest vehicle purchased in 2015. None of the paratransit vehicles are past their usable life. The base scenario assumes replacement of four paratransit vehicles per year, gradually replacing vehicles as they near the end of their life span. Electrification of the paratransit fleet can be more easily accomplished with a single overnight charge, which is the base scenario for this fleet as well. The paratransit fleet transition is assumed to be the same for all scenarios.

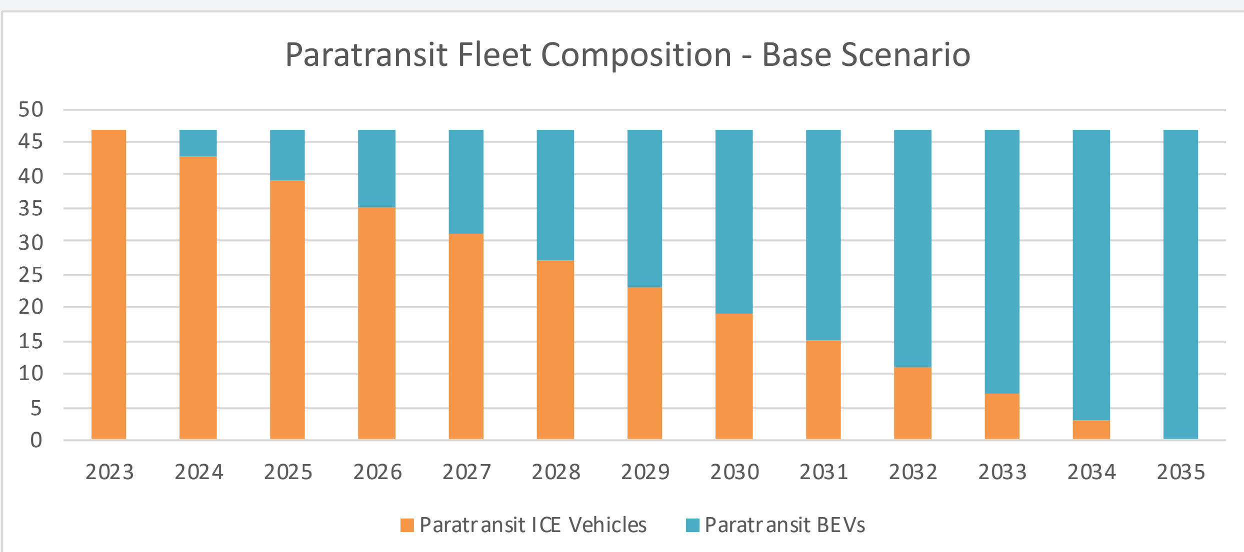


Figure 1-4: Paratransit Fleet Composition – Base Scenario

FLEET MANAGEMENT SCENARIO: EXISTING SERVICE + TECHNOLOGY IMPACTS SCENARIO

Many transit agencies, including GTA, are currently experiencing slower delivery times for BEBs than anticipated. Supply chain challenges have lengthened order fulfillment timeframes across the industry, and recently Proterra, GTA's primary supplier, filed for bankruptcy. In recognition of these challenges, a second scenario was developed using the same fleet and charger composition that assumes a slower initial rate of transition. Slowing the initial rate of BEB adoption means that GTA's existing aging fleet will need to be kept in service longer, with larger purchases needed in future years to replace aging buses.

While the BEB market is facing struggles right now, this scenario anticipates a more rapid adoption rate in the future as the technology matures. As a whole, the transit industry is moving towards electrification, and it can be anticipated that the current challenges are similar to those faced by early adopters of many new technologies. As the technology matures, BEBs are likely to become more readily available, more widely adopted, and more affordable relative to ICE buses, facilitating an accelerated transition in future years as shown in Figure 1-5.

Fleet growth reflects the replacement ratio needed to replace diesel and hybrid buses with electric buses and provide the same level of service. Like the base scenario, the Existing Routes + Technology Impacts scenario focuses on fleet conversion; however, additional purchases should be anticipated to replace older electric buses as they age out of the fleet in the later years of the transition.

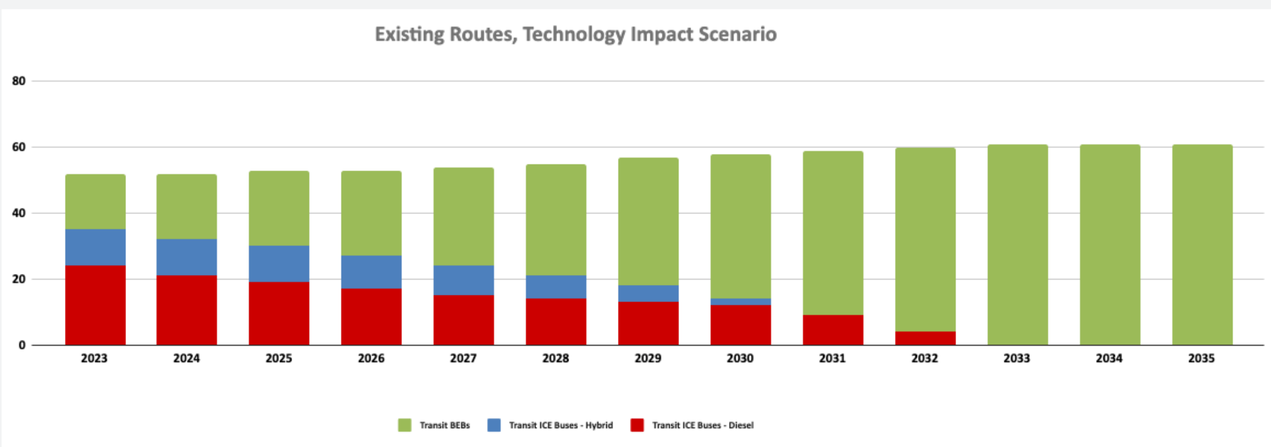


Figure 1-5: Transit Fleet Composition Existing Service + Technology Impacts Scenario

FUTURE MOBILITY PLAN COVERAGE SCENARIO

Greensboro is currently developing a long-range transit plan aligned with the goal of making the city car-optional by 2045. At this stage in the planning effort, two broad conceptual approaches have been proposed. The first of these is the coverage concept, which prioritizes providing service to as many people as possible. Under this scenario, GTA would serve a lot of routes, but at less frequent service intervals.

One additional route is assumed to come into service in 2034, which leads to a small increase in the total number of buses. It is assumed that other service increases would begin around 2032 and be implemented gradually through the plan horizon year of 2045. More rapid service expansion would require a more rapid increase in the number of buses, as the need for additional service is balanced with the needs to replace aging buses and transition to cleaner technologies.

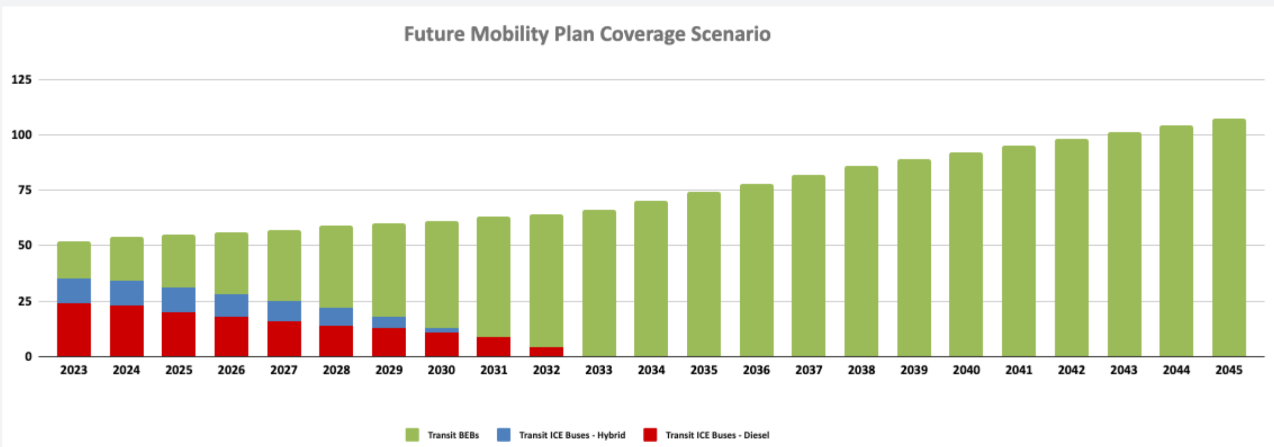


Figure 1-6: Transit Fleet Composition Future Mobility Plan Coverage Scenario

Two potential service block schedules were created to identify operational details representing 100% electrification of the coverage scenario. The service blocks were constructed using the following assumptions reflecting standard vehicle and personnel operations:

- Blocks are representative of year 12 vehicle operations.
- Block length is based on battery capacity of 600 kWh (usable capacity of 337 kWh) for routes that do not have endpoint charging.
- Revenue time is set to 27%.
- No interlining between blocks is allowed.
- Layover charging time is dependent on the trip schedule provided in preliminary Mobility Plan concepts.

The Mobility Plan is in the early stages of development and concepts are expected to evolve. These scenarios present an overview of how operations could look for each Mobility Plan concept and would need to be refined before implementation.

FUTURE MOBILITY PLAN RIDERSHIP SCENARIO

The second scenario considered in the long-range transit plan is based on prioritizing ridership. Transit service would focus on routes serving the highest number of people and destinations at higher frequency to maximize the number of people riding the bus. This scenario requires more buses than the coverage scenario.

The Future Mobility Plan Ridership Scenario is similar to the Future Mobility Plan Coverage Scenario. It also assumes a small increase in the total number of buses in 2034 to accommodate an additional route coming into service, and that the majority of service increases would begin around 2032.

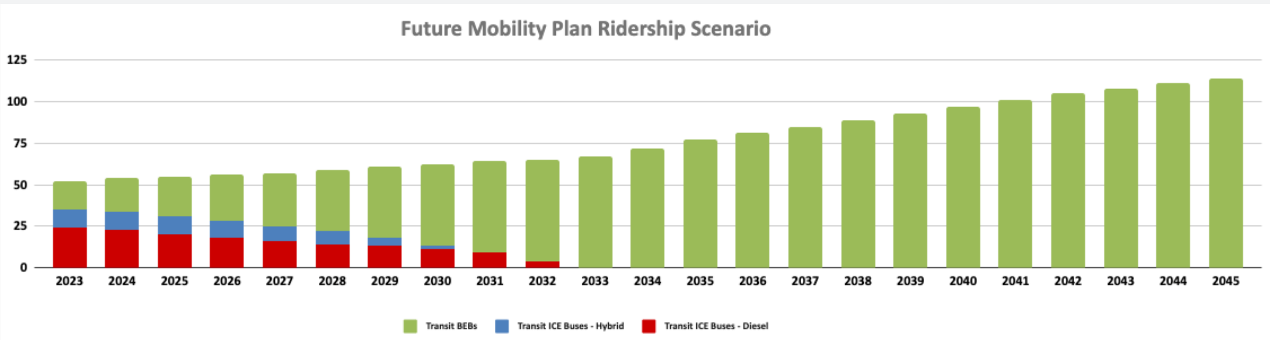


Figure 1-7: Transit Fleet Composition Future Mobility Plan Ridership Scenario

MODELING APPROACH

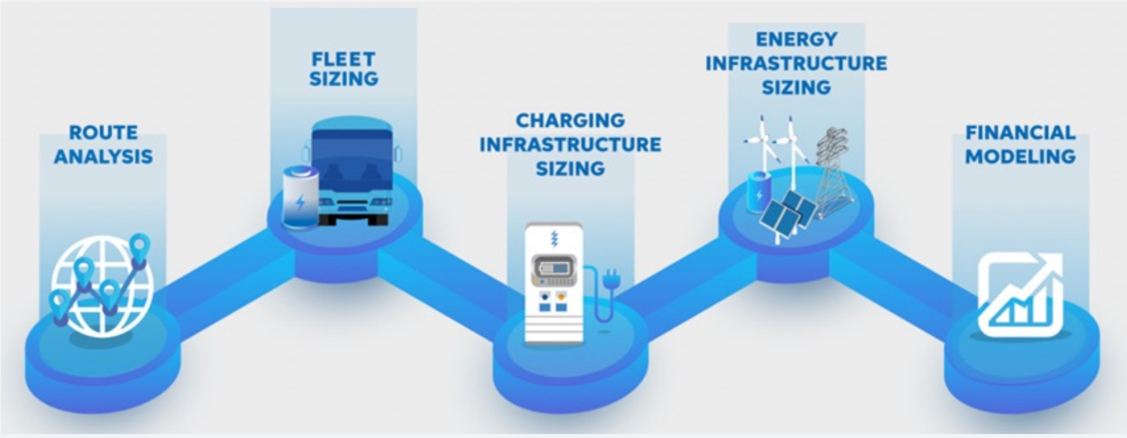
The modeling analysis relied on the results of the Fleet Assessment conducted with EVOPT , a planning and modeling tool for implementing and managing electric vehicles. The Assessment used information about the current active fleet as provided by GTA to extract the key input for the energy modeling effort, covering the following three categories:

- Vehicle make and model, and fuel type.
- Vehicle mileage and annual fuel usage.
- Operating schedule/hours,
    - o Operating schedule in the form of current Block data for the transit fleet.
    - o Hours of operation, and driver schedules to extract number of trips per day, driving time, and daily mileage per vehicle integrated with driver schedule for the paratransit fleet.

Modeling Platform

EVOPT® incorporates algorithms for route energy analysis, vehicle battery and charging infrastructure sizing, charging scenario simulation, financial modeling, and emission reduction calculations. Figure 1 illustrates the main EVOPT® modules. EVOPT® uses a rigorous energy modeling algorithm to accurately extract the real-world energy needs of an electric vehicle, which is important in cold and hot weather when the battery range can decrease up to 40% below the nominal values. These algorithms incorporate the effects of vehicle mileage, average payload, terrain gradient, and temperature and have been independently verified against real-world fleets in operation to confirm accuracy. The resulting route energy estimates includes two major elements: traction energy (required to move the vehicle); heating, ventilation, and air conditioning (HVAC) (required to heat or cool the vehicle cabin). The calculated energy values are then used to perform the vehicle battery charging equipment right-sizing assessment, extract the daily energy needs at the charging location, and inform the financial and emission reduction analyses.

Figure 1: EVOPT® analysis modules.



The operating schedule of the transit fleet and paratransit fleet were manually reconstructed from the received information, and then uploaded in EVOPT® for analysis.

Element 1 of the ZEFTP was developed using the results of an in-depth modeling analysis conducted by MGL with EVOPT®, a software-as-a-service (SaaS) platform specifically designed for fleet transition planning and optimization of vehicle deployments. The modeling analysis with EVOPT® informed operational recommendations and the long-term management plan.

The analysis conducted to fulfill this Element included:

1. Route energy analysis with integration of weather, terrain gradient, gross vehicle weight rate rating (GVWR), and passenger capacity.
2. Vehicle battery and charging equipment sizing.
3. Energy load profiles.

The overall goal of the technical assessment is to determine the suitability of blocks for electrification, and the most cost-effective options for GTA to electrify the fleet through equipment right-sizing while maintaining operational uptime of the vehicles, and to inform a long-term management plan.

ROUTE ENERGY ANALYSIS – BASE SCENARIO AND EXISTING OPERATIONS + TECHNOLOGY IMPACTS SCENARIO

The route energy analysis provides the energy required to complete a block based on real-world electric vehicle efficiency values calculated using vehicle mileage, GVWR, terrain gradient, and climate. A block means all the trips completed by a vehicle between the time it leaves and returns to its base. For the GTA fleet, the analysis was conducted for the wintertime temperature of 29°F (reflecting the historic 24-hr average of the daily temperature data collected for Greensboro, NC, by the National Oceanic and Atmospheric Administration, (NOAA) to size the vehicle batteries for conditions that can present operational constraints. (Note: the energy analysis does not include the energy that might be needed for battery preconditioning under certain cold temperature conditions)

A GVWR of 45,000 lbs was used to model the Gillig 40-foot low floor BEB based on the Altoona testing results, The GVWR chosen for the electric paratransit fleet was taken from commercially available ZEV equivalent to GTA's Ford E450 cutaway shuttle (14,500 lbs for the ZEV replacement).

Resulting energy efficiencies for the BEBs were 3.5 kWh/mile and for paratransit were 0.8 kWh/mile.

Figure 1-8 shows the total energy requirements obtained for the base scenario for the 33 analyzed blocks, ranging from 539 kWh to 1,062 kWh.

Figure 1-8: Results of the energy analysis for the GTA transit block IDs, sorted by increasing energy demand. The total energy is the sum of traction, HVAC, and auxiliary loads.

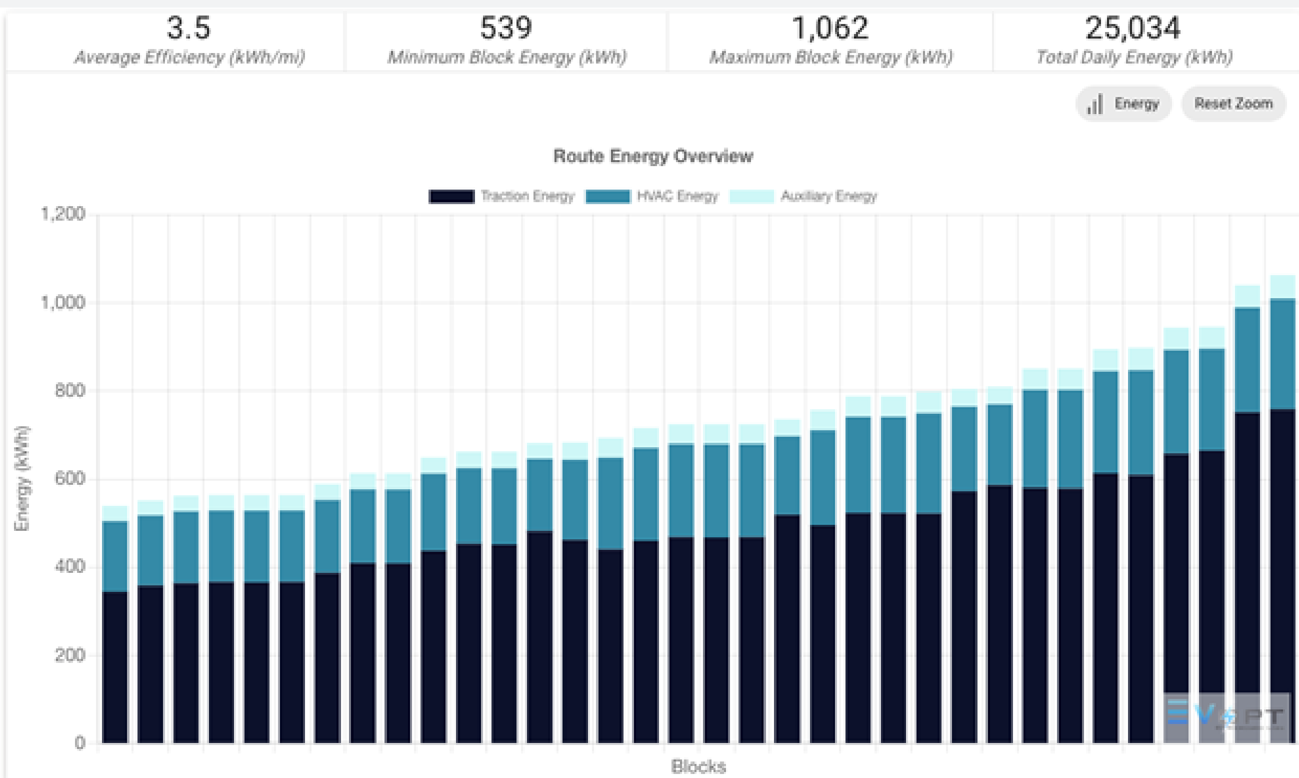
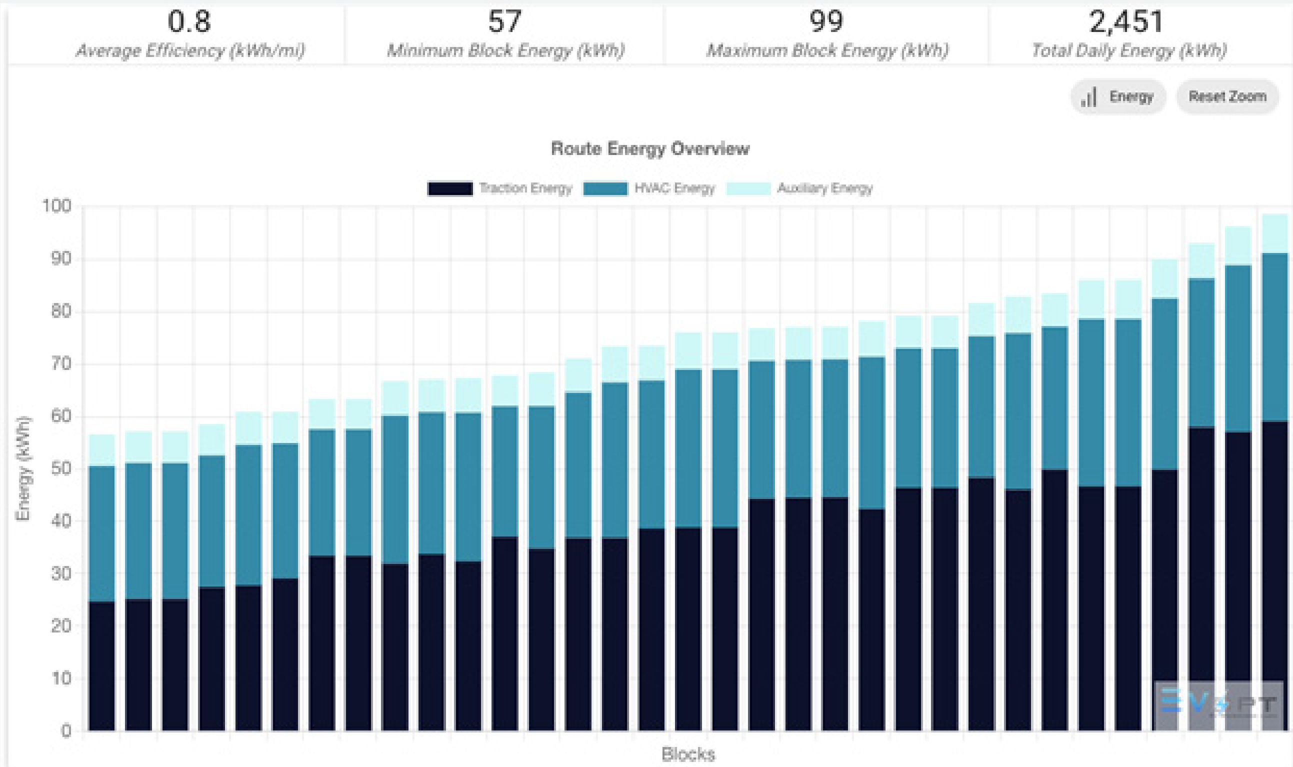


Figure 1-9 shows the total energy requirements obtained for the base scenario for the 33 paratransit vehicles that operate on a daily basis, ranging from 57 kWh to 99 kWh. 33 paratransit vehicles is the typical maximum number of vehicles that operate in a single day. The vehicles that were selected for modeling were the 33 vehicles of the 47 total paratransit vehicles with the highest annual mileage.

Figure 1-9: Results of the energy analysis for the GTA paratransit vehicles, sorted by increasing energy demand. The total energy is the sum of traction, HVAC, and auxiliary loads.



The results of the route energy analysis were used to size the vehicle batteries and charging equipment.

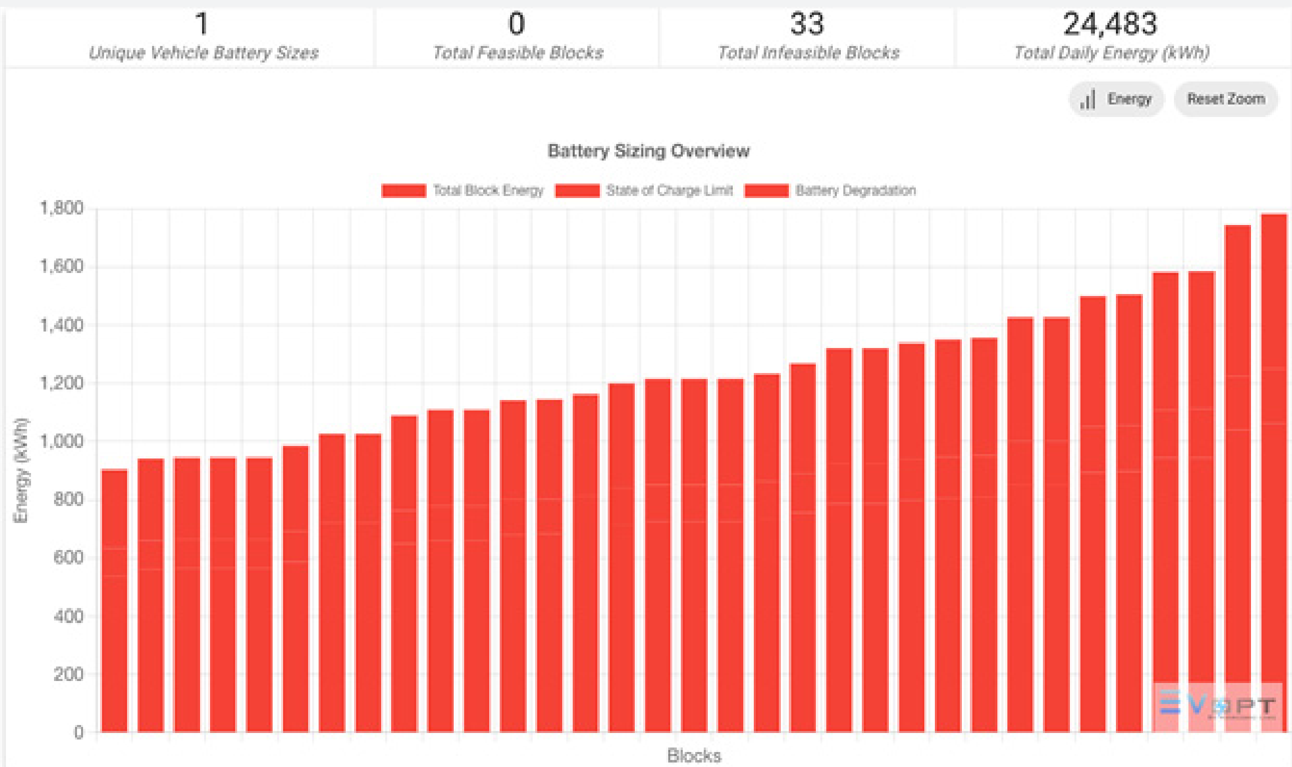
BEB FLEET AND BATTERY SIZING – BASE SCENARIO AND EXISTING OPERATIONS + TECHNOLOGY IMPACT SCENARIO

Fixed Routes

Overnight and Layover Charging

Figure 1-10 shows the battery sizes needed to operate each transit block under the base scenario in year 12, the average vehicle lifespan, after accounting for battery degradation (three percent degradation per year of operation) and in the worst-case temperature condition scenario. The modeling suggests that none of the blocks can be operated using overnight charging at the Maintenance Center without opportunity charging. A minimum battery requirement of 915 kWh under the modeled conditions will be required to plan adequately for charging infrastructure. The City of Greensboro already uses opportunity charging at the downtown multimodal center and operates its existing BEBs on all but three existing routes.

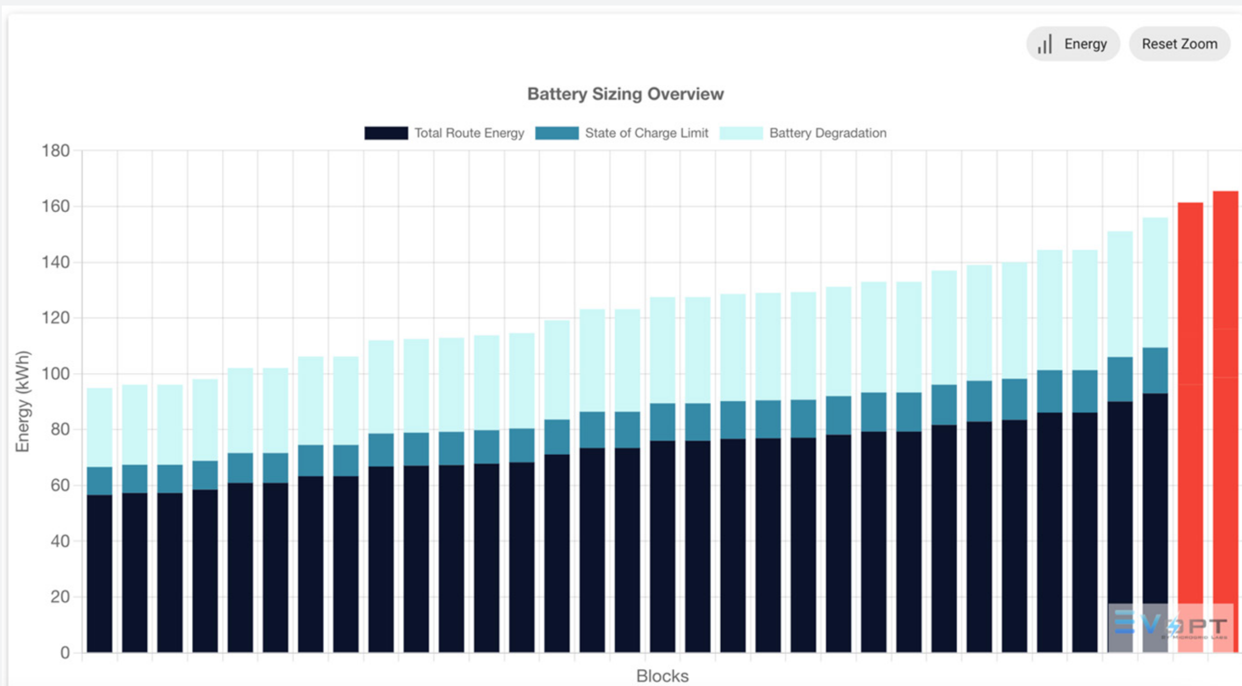
Figure 1-10: Chart of battery sizes needed for each transit block for year 12 of operation, sorted by energy requirements.



Paratransit

Figure 1-11 shows the battery sizes needed to operate paratransit vehicles under the base scenario in year 12, after accounting for battery degradation (three percent degradation for every year of operation). The modeling suggests that all 33 paratransit vehicles can be operated on one charge by a 160 kWh battery (the most typical battery size available on the market for these vehicle types) on year one of operation. Research conducted across vehicles manufacturers resulted in finding only one ZEV manufacturer that produces shuttles and vans for paratransit use with a 160 kWh battery. The feasibility decreases to 31 on year 12 due to battery degradation.

Figure 1-11: Chart of battery sizes needed for each paratransit vehicle for year 12 of operation, sorted by energy requirements.



CHARGING SCENARIOS/SIZING

Fixed Routes – BASE SCENARIO AND EXISTING SERVICE + TECHNOLOGY IMPACTS SCENARIO

None of the modeled 33 transit blocks can feasibly be completed on a single charge (typically overnight) with the existing 440 kWh Proterra BEBs. GTA currently operates 17 BEBs on all but three of its existing route. GTA chargers their BEBs overnight at the Maintenance Center with 60 kW chargers and has two 500 kW blade chargers at the Depot that can be utilized by the existing BEBs albeit not at a constant rate of 500 kw: in fact, the existing BEBs charge at 60 kW from 0-40% state of charge (SOC) and 70-100% SOC, and at 500 kW from 40-70% SOC.

A detailed trip level schedule was created to model this charging protocol that breaks each block down into start time, start location, distance, end time, end location, trip duration, and layover time for each trip of the block. This allowed the model to calculate the energy required for each trip and the SOC of the BEB after each trip, which determined whether the BEB would charge at 60 kW or 500 kW at the Depot.

With the given usable battery capacity of the existing BEBs and the trip level details for each block, the amount of layover charging available and required for each BEB at the Depot was calculated. The analysis found that there are eight blocks that could be electrified with a single BEB utilizing both Maintenance Center and Depot charging. These blocks are 101, 102, 141, 142, I121, I122, I131, and I132. However, the constraint of only having two chargers available at the Depot limits the operational viability of electrifying such blocks. In fact, an analysis of the charging timing during the layover periods revealed that only four blocks can be served with a single existing BEB, either blocks 101, 102, 141, 142 or I121, I122, I131, and I132.

The Team recommends that blocks I121, I122, I131, and I132 utilize Depot chargers as blocks 101, and 102 can utilize endpoint charging.

Block Splitting

After identifying the blocks that can be served by BEBs with overnight charging at the Maintenance Center and layover charging at the Depot, the next step was to determine how the remaining blocks can be served by the existing BEBs with only charging at the Maintenance Center. As such, the team completed a block splitting analysis to determine the optimal way to split blocks and get the highest usage of existing BEBs. Blocks 141, 142, 31, 32, 111, 112 were selected to be split into three sub-blocks each, creating 18 new blocks, based on their energy requirements. These 18 blocks can be served using 12 existing BEBs and can utilize the existing 60 kW chargers at the Maintenance Center.

The existing BEBs can be used as shown in Table 1-7.

Charging Strategy	Number of Blocks	Number of BEBs	Blocks Served
Overnight charging at the Maintenance Center and Layover Charging at the Depot	4	4	I121; I131; I132; I122
Overnight Charging at Maintenance Center with Block Splitting	18	12	141A; 141B, 141C 31A, 31B, 31C 32A, 32B, 32C 142A, 142B, 142C 111A, 111B, 111C 112A, 112B, 112C

Table 1-7: Charging Strategies for Optimized Use of Existing BEBs

Four of the 16 BEBs will utilize layover charging with the two 500 kW Depot chargers and overnight charging using the 16 60 kW Maintenance Center chargers, while the other 12 will just use the Maintenance Center chargers. Figure 1-12 shows that the existing charging infrastructure at the Maintenance Center will be adequate to charge the 16 buses serving these new 22 blocks.

Figure 1-12: Charging Assessment for GTA existing buses

Electric Vehicles (BEV) | Conventional Vehicles (ICE)

Rating	Charger Count	Vehicle Type	Vehicle Size	Battery Capacity	Total Blocks	Feasible Blocks	ICE Needed	Equivalent BEV	Replacement Ratio
60 kW	16	Transit	40 ft	450 kWh	22	22	12	16	1.33

Fixed Routes – Future BEBs

After allocating the existing Proterra BEBs onto specific blocks, the next phase of the analysis aimed at determining which blocks could be electrified with a 600 kWh BEB (largest available BEB on the market at the time of analysis) utilizing endpoint charging and which will require block splitting.

The modeling parameters for this phase are as follows:

- All future BEBs are modeled as a 600 kWh BEB that has a usable capacity of 337 kWh.
- There is no endpoint charging available during the first and last trips of the blocks.
- There is one minute for each pull in, pullout, and variable time per layover at the endpoint locations, with the rest of remaining time available for charging.
- Blocks that require splitting will be limited in energy use such that the operational requirements can be met using charging at the Maintenance Center only.

GTA identified locations within the city that could potentially be used for on route charging without altering routes. To this effect, five locations that coincided with the endpoint of a route were selected:

- o Four Seasons Mall: Route 2
- o GTCC Wendover Campus: Route 10

Currently all layover charging for these routes happens at the downtown Depot. To deploy endpoint charging on these routes, the layover location would have to be switched from the Depot to the endpoint to reduce changes in the operational schedule while still abiding by union trade rules, including mandatory break times and adequate facilities for drivers.

Having identified the routes with endpoint charging potential, the Team calculated the amount of layover time required for these routes to become electrified. Routes 2 (blocks 21 and 22) and 10 (blocks 101 and 102) can be electrified with a 15-minute layover and one 180 kW charger at each endpoint). Routes 4 and 6 (4 blocks) will require block splitting.

Block	Route	Endpoint Charging	Feasible	Layover Time Requirement	Chargers
161, 162	6	Pyramid Village SHopping Center	N		
141, 142	4	Joint School of Nanoscience and Nanoengineering NC A&T/UNCG	N		
21, 22	2	Four Seasons Mall	Y	15 min	#1 180 kW
101, 102	10	GTCC Wendover Campus	Y	15 min	#1 180 kW

Table 1-8: Routes with Endpoint Charging Potential

With the existing BEBs covering 10 of the 33 current blocks. and 4 blocks able to be served with future BEBs, there are 19 remaining blocks that will have to be split for the GTA fleet to become 100% electric. The modeling suggests that the 19 blocks be split into 95 new blocks based on usable battery capacity (337 kWh at year 12) and Maintenance Center charging only. The number of BEBs required to operate these 95 blocks depends on the size of the chargers installed. Figure 1-11 shows the results of the charging scenario modeling performed with EVopt. If GTA wanted to minimize the vehicle replacement ratio, it would have to choose the Scenario 1 option, which would add 45 BEBs charging at 240 kW each. Other options (Scenarios 2 to 4) would allow GTA to reduce the power rating of chargers, but would need more BEBs to maintain operations.

Figure 1-13: Charging Assessment for Future BEBs

Select Charging Scenario

	Scenario	Charger Count	Rating	Vehicle	Battery Capacity	BEV Needed	ICE Needed	Replacement Ratio
☑	Scenario 1	45	240 *kW*	40' Transit	600 *kWh*	45	35	1.29
☐	Scenario 2	47	180 *kW*	40' Transit	600 *kWh*	47	35	1.34
☐	Scenario 3	52	150 *kW*	40' Transit	600 *kWh*	52	35	1.49
☐	Scenario 4	55	120 *kW*	40' Transit	600 *kWh*	55	35	1.57

Paratransit Fleet

To assess the charging needs for the paratransit fleet, a fleet scenario was created to establish charging requirement boundaries. The City identified 33 vehicles as the maximum number of paratransit vehicles that operate on weekdays and this was set as the operating parameter to represent the scenario with the highest requirement.

- **Scenario:** Of the 47 paratransit vehicles in the fleet, 33 cutaways (battery size of 160 kWh) are used per day. The analysis is based on the 33 vehicles operating daily. Each vehicle was assigned a mileage based on the 33 paratransit vehicles in the GTA fleet that had the highest annual mileage. Daily mileage for each vehicle was calculated based on their respective annual mileage from January 2022 to January 2023. Based on daily paratransit operator schedule, three shifts were used. The morning shift had 11 vehicles that operated from 4:30 AM to 1 PM, the mid-day shift had 11 vehicles that operated from 6 AM to 5 PM, and the afternoon shift had 11 vehicles that operated from 1 PM to 11 PM.

For the base scenario, the assumptions were as follows:

- Every vehicle has the same efficiency or fuel economy (0.8 kWh/mi).
- Vehicles are available to charge for 90% of the time they are at the maintenance facility.
- Every vehicle has their own charging port.

The analysis indicated that 31 of the 33 modeled paratransit vehicles could be electrified in year 12 of vehicle life. Under these conditions, the minimum charger required is 19.2 kW (Figure 1-14).

Figure 1-14: Results for the 33 paratransit vehicles covering ‘feasible’ routes under average conditions, e.g., routes that can be operated on one battery charge.

Electric Vehicles (BEV) | Conventional Vehicles (ICE)

Rating	Charger Count	Vehicle Type	Vehicle Size	Battery Capacity	Total Blocks	Feasible Blocks	ICE Needed	Equivalent BEV	Replacement Ratio
19.2 *kW*	31	Van	14 *ft*	160 *kWh*	33	31	31	31	1

If upgraded chargers are purchased for the bus fleet, the existing chargers could be repurposed to charge future paratransit BEVs. As long as both the chargers and vehicles are compatible with standard SAE J1772 connectors, no upgrades or retrofits would be needed. Due to the difference in energy needs, cutaways would be expected to charge significantly faster than buses, allowing vehicles to be rotated to charge more vehicles in the same amount of time.

ROUTE ENERGY ANALYSIS – FUTURE MOBILITY PLAN COVERAGE SCENARIO

The blocking schedule assumes that some blocks can be served with identified endpoint charging, with the remaining blocks strictly charging at the Maintenance Center. Service blocks are organized in such a way to include identified endpoint charging locations where BEBs can charge while on route. These locations are:

- Pyramid Village Shopping Center – Routes 6, 14, 19
- GTCC Wendover Campus – Route 1, 5A, 5B
- GTCC Main Campus – Route 11
- Joint School of Nanoscience and Nanoengineering – Route 4
- Four Seasons Mall – Route 21
- Coble Transportation Center – Route 7A

The modeling yields 319 blocks and 107 BEBs needed for 100% electric operations. A charger rating of 240 kW at the Maintenance Center minimizes the number of BEBs required (Figure 1-15). The analysis shows that 298 of those blocks would require 89 BEBs that charge only at the Maintenance Center with 240 kW chargers. Another 21 blocks would be served by 18 BEBs with overnight charging at the Maintenance Center and charging during the day at the endpoint locations, with each endpoint having one 150 kW charger (and with layover times set by the GTFS trip schedule).

Figure 1-15: Fleet and Charger Size Assessment for Future Mobility Plan Coverage Scenario.

Select Charging Scenario

	Scenario	Charger Count	Rating	Vehicle	Battery Capacity	BEV Needed	ICE Needed	Replacement Ratio
☑	Scenario 1	107	240 *kW*	40′ Transit	600 *kWh*	107	88	1.22
☐	Scenario 2	116	180 *kW*	40′ Transit	600 *kWh*	116	88	1.32
☐	Scenario 3	120	150 *kW*	40′ Transit	600 *kWh*	120	88	1.36
☐	Scenario 4	129	120 *kW*	40′ Transit	600 *kWh*	129	88	1.47

ROUTE ENERGY ANALYSIS – FUTURE MOBILITY PLAN RIDERSHIP SCENARIO

The Future Mobility Plan Ridership Scenario organized service blocks in such a way to include identified endpoint charging locations where BEBs can charge while on route. These locations are:

- Coble Transportation Center – Route 9A, 4A
- Pyramid Village Shopping Center – Routes 6A, 6B
- GTCC Wendover Campus – Route 1, 5A, 5B
- GTCC Main Campus – Route 6A
- Joint School of Nanoscience and Nanoengineering – Route 4A, 4B

The modeling yields 374 blocks and 114 BEBs needed for 100% electric operations. A charger rating of 240 kW at the Maintenance Center minimizes the number of BEBs required (Figure 1-16).

Under Option 2, 338 of those blocks would require 97 BEBs that charge only at the Maintenance Center with 240 kW chargers. Another 36 blocks would be served by 17 BEBs with overnight charging at the Maintenance Center and charging during the day at the endpoint locations, with each endpoint having one 150 kW charger (and with layover times set by the GTFS trip schedule).

Figure 1-16: Fleet and Charger Size Assessment for Future Mobility Plan Ridership Scenario

Select Charging Scenario

	Scenario	Charger Count	Rating	Vehicle	Battery Capacity	BEV Needed	ICE Needed	Replacement Ratio
☑	Scenario 1	114	240 *kW*	40′ Transit	600 *kWh*	114	91	1.25
☐	Scenario 2	126	180 *kW*	40′ Transit	600 *kWh*	126	91	1.38
☐	Scenario 3	131	150 *kW*	40′ Transit	600 *kWh*	131	91	1.44
☐	Scenario 4	143	120 *kW*	40′ Transit	600 *kWh*	143	91	1.57

Table 1-9: Block schedule for existing BEBs

Block/Route Id	Start Time	End Time	Bus ID
111 A	4:49	10:30	b1
111 B	10:20	15:30	b13
111 C	15:20	20:14	b1
112 A	5:56	10:30	b6
112 B	10:20	15:30	b14
112 C	15:20	19:12	b6
141 A	4:50	9:50	b2
141 B	9:40	14:50	b11
141 C	14:40	19:12	b15
142 A	6:01	13:01	b7
142 B	12:50	18:00	b2
142 C	17:50	0:46	b7
31 A	4:50	9:50	b3
31 B	9:40	14:50	b12
31 C	14:40	19:15	b16
32 A	6:01	13:01	b8
32 B	12:50	18:00	b3
32 C	17:50	0:46	b8
I121	4:50	19:08	b4
I122	6:01	0:42	b9
I131	4:50	19:15	b5
I132	6:01	0:49	b10

Transit Scenario Snapshot

Scenario	Total BEBs	Chargers Needed	Vehicles Served with Depot Charging	Vehicles Served with Endpoint Charging	Vehicles Served with Block Splitting	Unmanaged Charging Daily Peak Power / Transformer	Managed Charging Daily Peak Power / Transformer	Endpoint Charging Locations
1: Existing Routes, Base Scenario	49	2 Depot chargers (500 kW); 16 Maintenance Center chargers (60 kW); 2 endpoint chargers (180 kW); 45 future Depot chargers (200kW)	4	4	45	6,060 kW / 8,350 kVA	2,946 kW/ 3,800 kVA	Four Seasons Mall, GTCC Wendover Campus
2: Existing Routes +Technology Impacts	49	2 Depot chargers (500 kW); 16 Maintenance Center chargers (60 kW); 2 endpoint chargers (180 kW); 45 future Depot chargers (200kW)	4	4	45	6,060 kW / 8,350 kVA	2,946 kW/ 3,800 kVA	Four Seasons Mall, GTCC Wendover Campus
3: Future Mobility Plan Coverage Scenario	112 in 2045	107 (240 kW)	89	18		10,560 kW / 14,700 kVA	6,093 kW / 8,500 kVA	Pyramid Village Shopping Center, GTCC Wendover Campus, GTCC Main Campus, Joint School of Nanoscience and Nanoengineering, Four Seasons Mall, Coble Transportation Center
4: Future Mobility Plan Ridership Scenario	116 in 2045	116 (240 kW)	97	17		10,320 kW / 14,350 kVA	7,170 kW / 10,000 kVA	Coble Transportation Center, GTCC Main Campus or Pyramid Village, Joint School of Nanoscience and Nanoengineering, GTCC Wendover Campus, Pyramid Village Shopping Center

Key Findings

- Full electrification will take a combination of optimal deployment of existing BEBs, procuring new BEBs, and implementing a combination of overnight and end point charging and block splitting.
- 100% of paratransit vehicles are feasible and can be operated on a single charge by a 160 kWh battery in year one of operation. In year 12, 31 of the 36 vehicles are still feasible with a 160 kWh battery. Vehicles requiring more energy due to longer daily mileage will require additional charging to complete a daily route.

Recommendations

- The existing transit BEBs can serve four blocks with overnight and depot charging, and 18 blocks with block splitting.
- Future BEB acquisitions should be rated for at least 600 kWh, which will require endpoint charging and block splitting.
- For the paratransit fleet operating under average conditions, a 19.2 kW charger is appropriate to maintain vehicle operability.
- GTA can use the 12-year battery sizing results to inform vehicle procurement and a long-term fleet management plan. For example, GTA can deploy newer vehicles with more battery capacity on routes and schedules that require more energy, and older buses with degraded batteries on less energy demanding routes.
- To minimize the number of buses required, future overnight chargers should be 240 kW. A total of 49 chargers are recommended at the maintenance center.
- Four 180-kW endpoint chargers are recommended to support current routes.

FTA Element 2: Current and Potential Funding Summary

2

GTA is planning to continue its transition to a fully zero emission fleet. This analysis outlines the past and planned future funding that can support this transition and identifies additional funding sources that may be available to fill any funding gaps.

FTA ELEMENT 2:

Address the availability of current and future resources to meet costs for the transition and implementation.

Current and Planned Funding for Zero Emission Vehicles

GTA receives funding from federal, state, and local sources. State and federal funding are allocated to GTA by formula. The overall GTA program is budgeted for approximately $30,864,000 for the 2023-2024 budget year, with more than half of the budget allocated to fixed route service maintenance and operations.

GTA has received both federal and state grant funding in the past to support the transition to electric vehicles. Nearly half of GTA's current bus fleet is electric, with several more planned electric bus purchases funded through a 2022 North Carolina grant.

The City of Greensboro's Capital Improvements Program identifies planned capital expenses from 2023 through 2033. The table below summarizes planned expenses that may support the ZEV transition and anticipated funding sources.

Planned Vehicle and Charging Infrastructure Expenses

Purchase	FY 23-24	FY 24-25	FY 25-26	FY 26-27	FY 27-28	FY 28-33	TOTAL
Federal/State Grants (Identified)							
Electric Bus Replacements	$3,539,765						**$3,539,765**
Paratransit Vehicles (fuel type unspecified)	$733,750	$733,750	$733,750	$733,750	$733,750	$4,402,500	**$8,071,250**
Replacement Buses (fuel type unspecified)	$4,788,000	$1,596,000	$532,000			$10,100,996	**$17,016,996**
Future Federal/State Grants							
BEB Infrastructure	$1,500,000	$1,000,000	$1,000,000				**$3,500,000**
Mobility Greensboro 2040 Expansion Buses				$2,660,000	$2,128,000	$6,384,000	**$11,172,000**

Table 2-1: GTA Planned Vehicle and Charging Infrastructure Expenses

Regional transportation funding is identified in the 2045 Metropolitan Transportation Plan (MTP). The projected capital budget for regional transit is summarized in the table below.

Forecast Transit Capital Budget (2045 MTP)	
Time Period	Transit Capital Budget (in thousands of dollars)
2021-2025	$50,753
2026-2035	$136,363
2036-2045	$165,469

Table 2-2: 2045 MTP Budget Forecast

Capital funds available to GTA may be used to support ZEV purchases and needed infrastructure. Additional funding sources are likely to be needed to support the full ZE transit fleet transition desired.

Potential Grants and Other Funding Sources

While funds allocated to GTA may be used to support the ZEV transition, additional funding sources are also available. The following programs may provide funding that supports planning for, transitioning to, implementing, operating, and maintaining ZEVs.

Table 2-3: Potential Grants and Funding Resources for GTA

Potential Grants and Funding Sources		
Agency	**Program**	**Program Description & Eligible Activities**
Federal Funding Sources		
United States Department of Transportation (USDOT)	Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grant Program	**Program Type:** Competitive grants **Project Types supported:** Investments in surface transportation projects that will have a significant local or regional impact; Capital projects and planning projects. **ZE Transition Applicability:** Could be used for future ZEV purchases, related infrastructure, or planning assistance.
	Transportation Infrastructure Finance and Innovation Act (TIFIA) loans, loan guarantees, and standby lines of credit	**Program Type:** Credit assistance **Project Types supported:** Projects of regional and national significance. **ZE Transition Applicability:** Unlikely to be needed for current GTA plans, but may be applicable for future significant projects or expansions.

Potential Grants and Funding Sources		
Agency	**Program**	**Program Description & Eligible Activities**
Federal Funding Sources		
	Capital Investment Grants (CIG) Program, including New Starts, Small Starts, Core Capacity, and Bundles of CIG Projects	**Program Type:** Competitive grants **Project Types supported:** Investments in surface transportation projects that will have a significant local or regional impact; Capital projects and planning projects. **ZE Transition Applicability:** Could be used for future ZEV purchases, related infrastructure, or planning assistance.
	Bus and Bus Facilities Grant Program	**Program Type:** Competitive grants **Project Types supported:** Purchase, replacement, or rehabilitation of buses, related equipment, or bus-related facilities. **ZE Transition Applicability:** Could be used to purchase ZE buses as replacements or for fleet expansion, purchase charging or other ZE fueling equipment and infrastructure, future facility expansions, and other elements needed for full fleet transition.
	Low or No Emission Vehicle Program - 5339(c)	**Program Type:** Competitive grants **Project Types supported:** Purchase or lease of zero emission and low-emission transit buses as well as acquisition, construction, or lease of required supporting facilities. **ZE Transition Applicability:** Could be used for future ZE bus purchases and related infrastructure.
FTA	Accelerating Innovative Mobility Program	**Program Type:** Competitive grants **Project Types supported:** Activities leading to the development and testing of innovative mobilities. **ZE Transition Applicability:** This program may be valuable if GTA chooses to test new ZEV technologies, service models, equipment, software and other emerging innovations, potentially through partnerships with other organizations.
	Bus Exportable Power Systems Program	**Program Type:** Competitive Grants **Project Types supported:** Projects and technologies that enable access to resilient and flexible power options during major power disruptions, such as transforming hybrid-electric and fuel cell buses into mobile power generators following a natural disaster. **ZE Transition Applicability:** Can support development of not only a resilient transit fleet, but one that supports community resilience as well.
	Zero Emission Research Opportunity (ZERO) Program (as part of consortium led by a nonprofit organization)	**Program Type:** Competitive grants **Project Types supported:** Efforts to research, demonstrate, test, and evaluate zero emission and related technology for public transportation applications. **ZE Transition Applicability:** Program is applicable to non-project organizations; however, GTA could participate as part of a consortium led by a non-profit.

Potential Grants and Funding Sources		
Agency	**Program**	**Program Description & Eligible Activities**
State of North Carolina Funding Sources		
Department of Environmental Quality (DEQ)	Diesel Bus and Vehicle Replacement Program	**Program Type:** Competitive grants **Project Types supported:** Replacement of older diesel transit and shuttle buses. Program funding can be combined with Congestion Mitigation and Air Quality (CMAQ) funding to cover the portion of a purchase not covered by CMAQ. Electrification projects are prioritized, though funding is available for all fuel types. **ZE Transition Applicability:** GTA could potentially use this program to replace any diesel vehicles
	Mobile Sources Emissions Reductions Grant	**Program Type:** Competitive grants **Project Types supported:** Replacement of diesel vehicles with cleaner alternatives, including vehicle replacement or converting vehicles to run on alternative fuels. **ZE Transition Applicability:** GTA could potentially use this program to replace any diesel vehicles

Additional funding and grant programs may be available through private entities or created by future legislation. Examples of such past programs have included:

- Duke Energy provided grants to fund environmental projects as part of a settlement agreement related to the Clean Air Act. Projects include clean energy and energy efficiency projects, replacing wood-burning stoves with lower-emission residential heating appliances, and installation of electric vehicle charging stations and electrical infrastructure at rest areas and truck stops. Greensboro has previously received $450,000 in funding from Duke Energy for an electric charging station to support electric buses in 2016.
- In 2020 the NC Clean Energy Technology Center (NCCETC) offered grant funding through the Clean Fuel Advanced Technology Project (CFAT). This program is funded through the CMAQ funding by NC Department of Transportation (NCDOT) and Federal Highway Administration (FHWA) and administered by NCCETC.

Multiple funding sources may also be integrated into existing programs, such as Volkswagen Settlement Funds integrated into state grant programs like the Diesel Bus and Vehicle Replacement Program. No local or private grant funds were identified that are currently offering funding for transit projects, but GTA should monitor all potential funding opportunities.

Total Cost of Ownership

BASE SCENARIO AND EXISTING OPERATIONS + TECHNOLOGY IMPACTS SCENARIO

The financial and emission analyses were conducted for the Base Scenario with the active current BEB fleet (16 BEBs) and their equivalent ICE vehicles (12 buses) as well as the future BEB fleet (49 BEBs) and their equivalent ICE vehicles (39 buses).. The primary inputs for the financial analysis used a combination of fleet specific and industry average capital and operational costs. The per-mile and per-gallon costs were combined with the annual mileage and fuel usage obtained from GTA to calculate the total costs for the existing transit and paratransit fleet. For the simulated BEB and ZEV fleets, electricity usage and costs were calculated for both the unmanaged and managed charging scenarios, using the Duke Energy tariff NCEC-LGS, summarized in Table 2-4. The electricity costs were calculated for each month and accounted for the average monthly temperature to scale the charging needs (for instance, the fleet will use less energy in April compared to January because of the higher springtime temperatures, requiring less HVAC load, allowing the battery to maintain charge longer and require less charging).

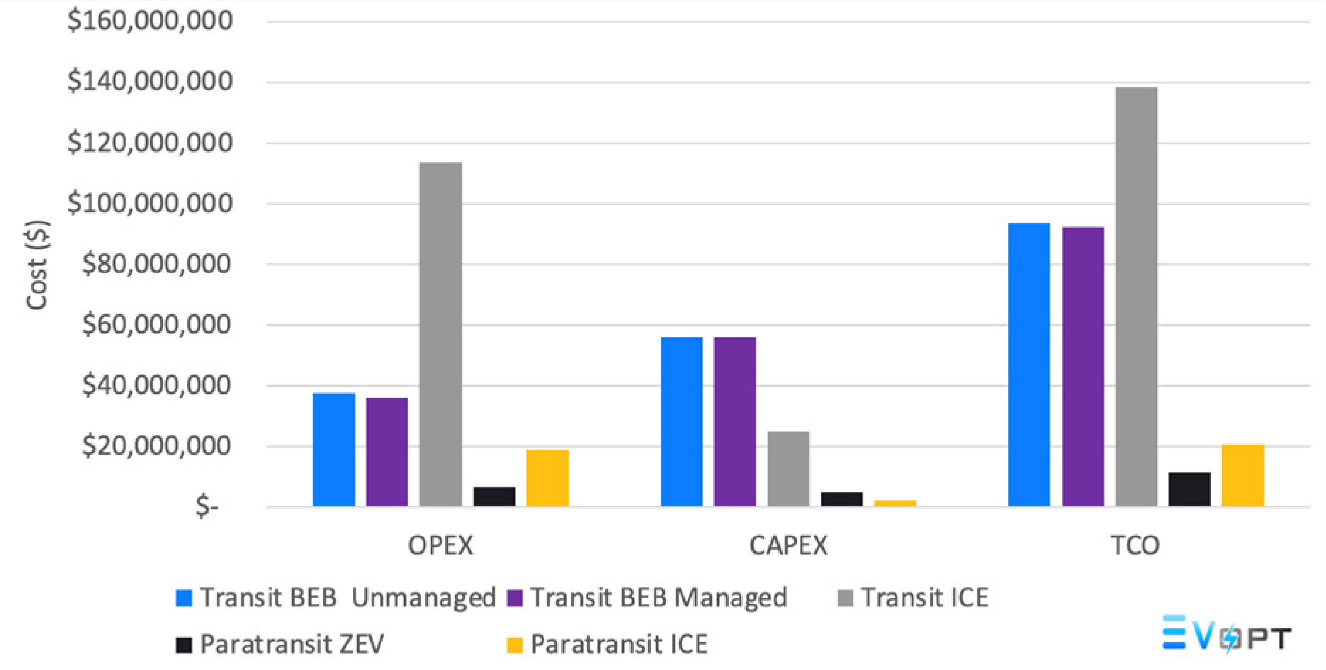
The analysis assumed an average vehicle life expectancy of 12 years.

Table 2-4. Data inputs for the financial modeling on EVOPT®. The inputs are categorized by Capital and Operational costs. The numbers are on a per-vehicle and per-charger port basis.

Capital Costs	Transit Diesel	Paratransit Gasoline	Existing Transit BEB	Modeled Transit BEB	Paratransit ZEV
Vehicle cost	$487,382	$68,442	$716,546	$950,000	$200,000 (average of van and cutaway price, with ADA compliant features)
Vehicle incentives	n/a	n/a	n/a	75% of cost	75% of cost
Charging equipment costs including installation	n/a	n/a	$36,000	$250,000 for a 240 kW charger port ($1,040/kW)	$ 11,520 for a 19.2kW charger port ($600/ kW)
Charging infrastructure incentives	n/a	n/a	n/a	75% of cost	75% of cost
OPERATIONAL COSTS					
Fuel ($/gallon or $/ mile)	$ 3.90 per gallon	$3.00 per gallon	Electricity rate ($/kWh) = $0.11 Demand charges ($/kW) = $4.02 Monthly charge: $23.91		
Maintenance ($/mile)	$1.50	$1.50	$0.53	$0.53	$0.53

Figure 2-1 shows the results of the financial analysis for the GTA fleet. Capital costs (CAPEX), operating costs (OPEX), and total costs (sum of CAPEX and OPEX) are shown for the 100% electric fleet that includes the existing BEBs (16) and future BEBs (40) compared to the equivalent ICE fleet (52 vehicles) and 31 paratransit ZEV (BEV fleet). The TCO incorporates an estimate for installation costs of the chargers, however, this cost varies for every project and it does not include utility infrastructure upgrade requirement costs. While the CAPEX associated with the existing ICE fleet are lower than that of the BEV fleet, the total lifetime costs are lower for a BEV fleet due to the much lower OPEX. The small difference between the costs of the unmanaged and managed scenarios for the BEV fleet are due to managed charging reducing peak power demand and lowering overall charging costs. The lifetime cost of the Technology Impact Scenario would be $89.8 million, since it would require four fewer buses than the Base Scenario.

Figure 2-1: Financial analysis for the GTA fleet. The lifetime cumulative costs at the 12-year mark are $138.4 million for ICE transit vehicles, $20.8 million for ICE paratransit vehicles, $93.6 million for the unmanaged BEV transit vehicles, $92 million for the managed transit BEB fleet, and $407,000 for the BEV paratransit vehicles.

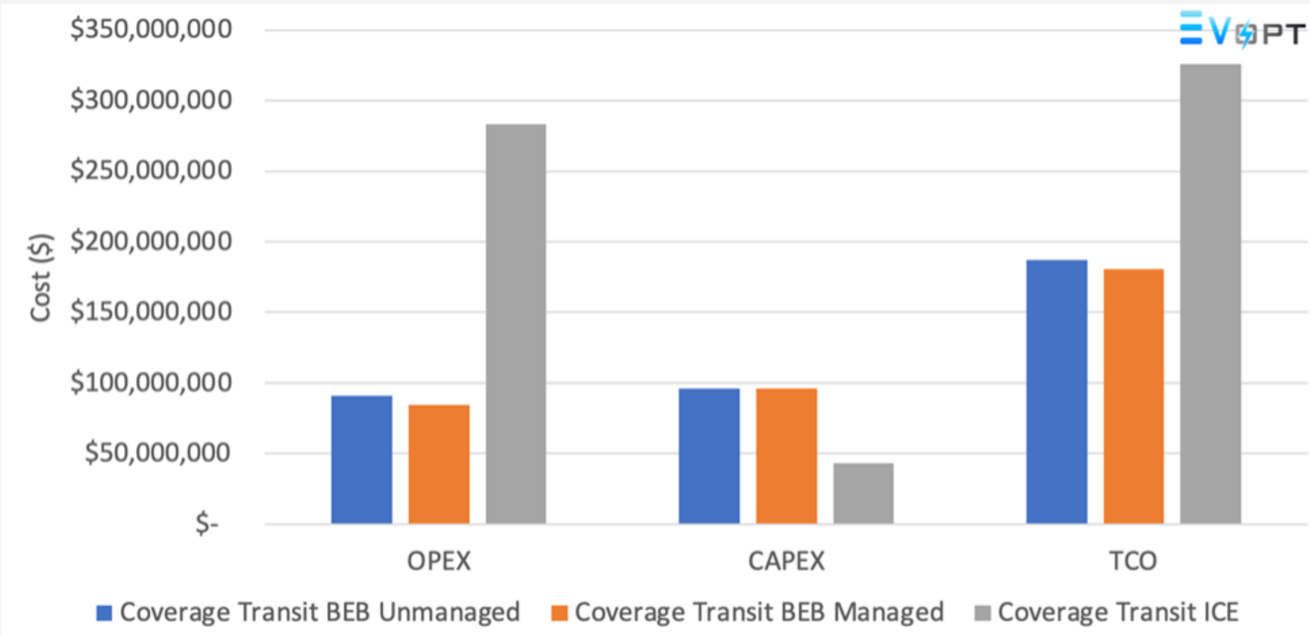


[2] EPA Power Profiler (2021). Available at https://www.epa.gov/egrid/power-profiler#/

FUTURE MOBILITY PLAN COVERAGE SCENARIO

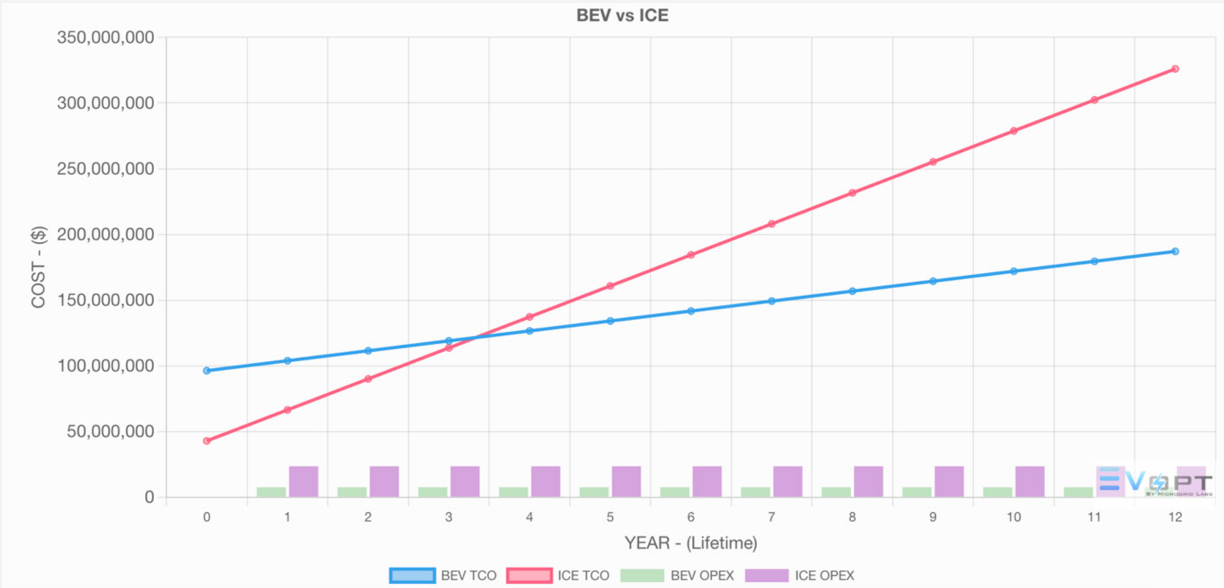
The financial analysis for the Future Mobility Plan Coverage Scenario uses the same capital and operational expense parameters and the same incentive scheme as in the financial analysis for the future BEBs in the Current Fleet.The cost, including capital costs for 107 (600 kWh) BEBs and 240 kW chargers at the Maintenance Center is $187,086,000 for the BEB fleet (for unmanaged charging), $325,964,000 for an equivalent ICE fleet (88 diesel buses). The financial analysis does not include the price of charging at the endpoint locations.

Figure 2-2: Financial Analysis for Future Mobility Plan Coverage Scenario



The break-even point for BEBs compared to ICEs for this scenario would be reached before year 4 of operations (Figure 2-4).

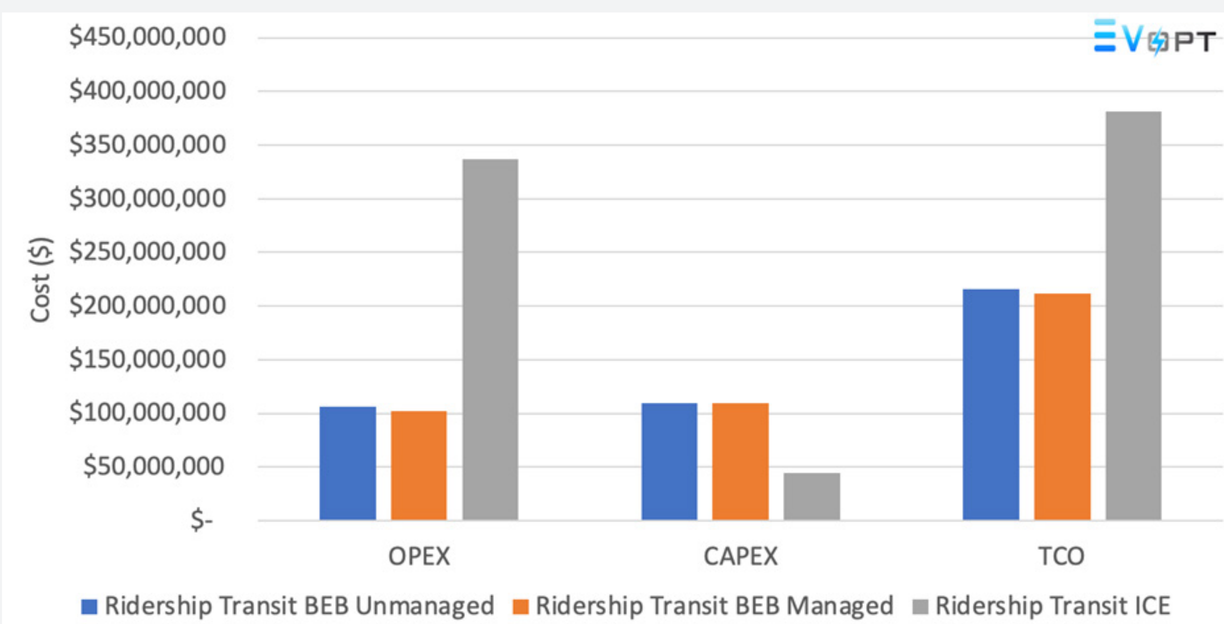
Figure 2-3: Total Cost of Ownership for Future Mobility Plan Coverage Scenario



FUTURE MOBILITY PLAN RIDERSHIP SCENARIO

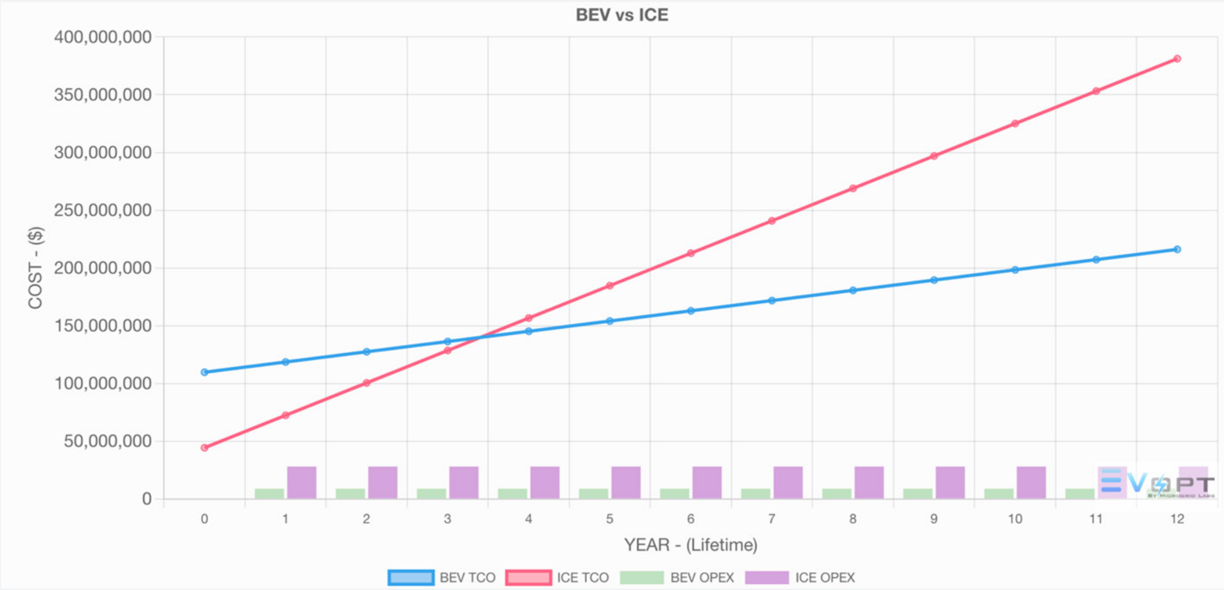
The financial analysis for the Mobility Plan Ridership Scenario also uses the same capital and operational expense parameters and the same incentive scheme as in the financial analysis for the future BEBs in the Current Fleet. A second option utilizing endpoint charging was also developed for the Future Mobility Plan Ridership Scenario using the same assumptions and parameters. The cost for is option, including capital costs for 114 (600 kWh) BEBs and 240 kW chargers and unmanaged charging at the Maintenance Center, is $216,105,000 for the BEB fleet and $381,219,000 for an equivalent ICE fleet (91 diesel buses). The financial analysis does not include the price of charging at the endpoint locations.

Figure 2-4: Financial Analysis for Future Mobility Plan Ridership Scenario



The break-even point for this scenario would be reached before year 4 of operations (Figure 2-5)

Figure 2-5: Total Cost of Ownership for Future Mobility Plan Ridership Scenario with Maintenance Center and Endpoint Charging



Initial (Model-based) Emissions Analysis

BASE SCENARIO AND EXISTING OPERATIONS + TECHNOLOGY IMPACTS SCENARIO

The emissions analysis was performed for both greenhouse gas (GHG) and nitrogen oxides (NOx), and for both diesel and gasoline vehicle tailpipes, and emissions coming from electricity generation needed for vehicle charging. The analysis used emission factors (EFs) obtained as follows, and listed in Table 2-5:

- Diesel and gasoline tailpipe EFs
  - GHG EFs were obtained from the EPA Emission Factor Inventory. GHGs were reported as carbon dioxide equivalent (CO2e) which includes CO2, CH4, and N2O.
  - NOx EFs were obtained from the Argonne National Laboratory AFLEET tool which has state and vehicle age specific EF values (in this case we used EF values from North Carolina, and 2015, which is the average fleet age).
- Electricity grid emissions
  - GHG EFs (as CO2e) and NOx EFs were obtained from the EPA Power Profiler eGRID Summary Tables[2], which lists specific EFs for each state.

Table 2-5: Fuel specific CO2e and NOX EFs for diesel, gasoline, and electricity used in the analysis.

Emissions Factors (EFs)	CO2e	NOx
Diesel (lbs/gallon)	22.64	26.8
Gasoline (lbs/gallon)	19.41	0.5
Electric Grid (lbs/MWh)	672.7	0.4

Figures 2-6 and 2-7 show the results of the emission analysis for the GTA fleet on a per-vehicle basis. CO2e and NOx emissions are shown for the existing diesel and gasoline vehicles (ICE fleet).

The electrification of the GTA fleet would eliminate 134,000 tons of CO2e and 134 NOx emissions over the lifetime of the transit fleet. Electricity production for fleet charging would still emit a non-negligible amount of CO2e. Electrifiction of the paratransit fleet would eliminate 7,000 tons of CO2e and have negligible savings of NOx over the fleet lifetime.

Actual lifetime emission reductions are presumed to be higher than estimated, as the electric grid will incorporate cleaner sources over the next decade, which would result in changes to the EF over time. The City has established a target of 100% renewable energy sources for municipal operations by 2040, which means all ZVs will reach zero associated emissions at that time.

Figure 2-6: CO2e emissions analysis for a 100% electric GTA fleet

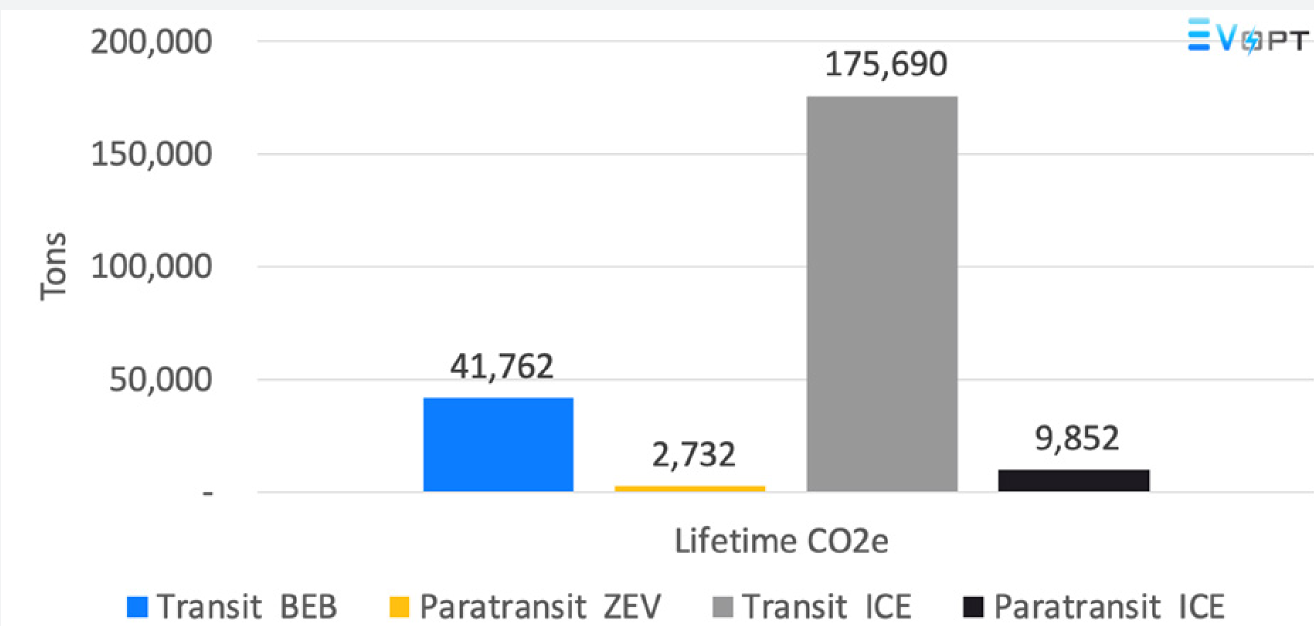
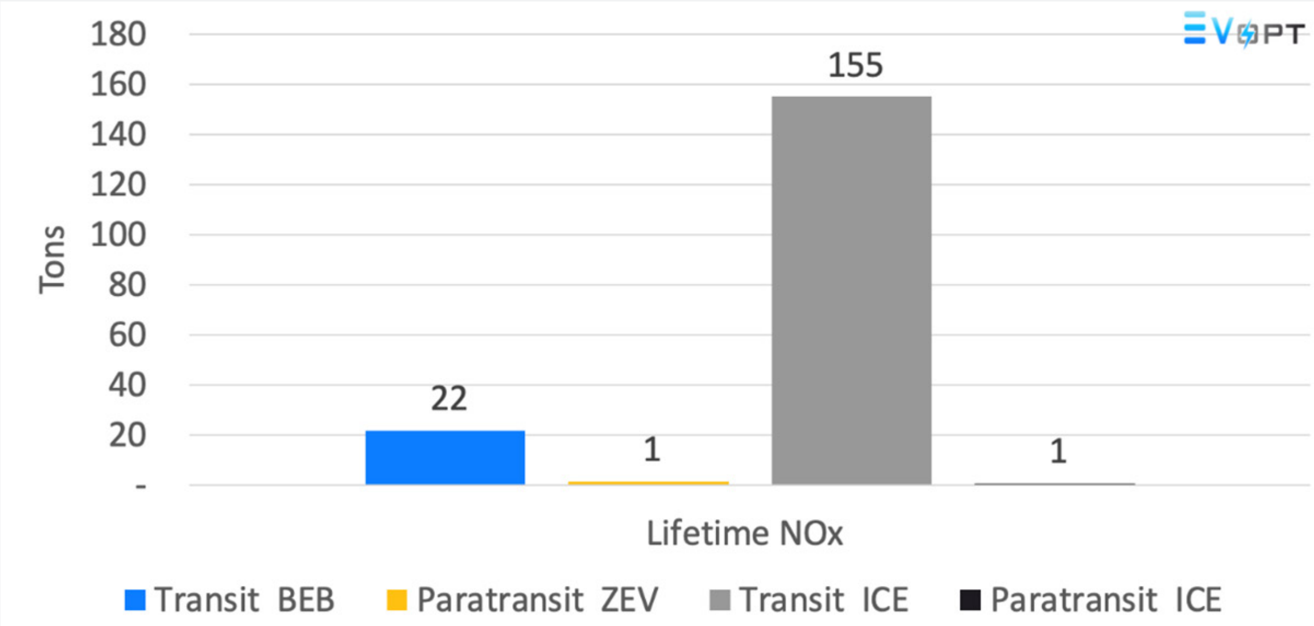


Figure 2-7: CNOx emission analysis for a 100% electric GTA fleet.



Future Mobility Plan - Coverage Scenario

The fully electric fleet with 112 BEBs and 240 kW chargers would save 40,039 tons of CO2e per year compared to a fleet of 88 diesel buses that would be required to serve this scenario (Table 2-5). The GHG savings represent the net savings obtained from removing emissions from diesel tailpipes and incorporating emissions from the electricity generation needed for charging.

Future Mobility Plan - Ridership Scenario

The fully electric fleet with 116 BEBs and 240 kW chargers would save 45,788 tons of CO2e per year (Table 2-5). The GHG savings represent the net savings obtained from removing emissions from diesel tailpipes and incorporating emissions from the electricity generation needed for charging.

Mobility Plan Scenario	BEBs Required	ICE Buses Required	Emissions Savings (Net CO_2e)
Coverage	112	88	40.0 MTCO2e per year
Ridership	116	91	45.8 MTCO2e per year

Table 2-5: GHG emissions savings for the Future Mobility Plan Scenarios

Key Findings

- When compared to ICE vehicles, electrification of the entire transit fleet would net GHG savings of 134,000 tons of CO2e and 134 tons of NOx over the lifetime of the BEB fleet, and would net 7,120 tons CO2e savings over the lifetime of the paratransit fleet.
- Emissions associated with transit operations will decrease over time as the electric grid becomes cleaner.

Recommendations

- GTA should continue to monitor potential grant sources to identify new grant opportunities.
- GTA should explore the possibility of implementing a managed charging strategy for the BEB fleet to reduce operational costs, especially if the number of BEBs deployed become significant overtime. A managed charging strategy will require specific equipment and software controllers, and GTA is encouraged to gather information about availability and costs to make informed decisions and select the equipment that fits the agency's operational needs and the financial bottom line.

FTA Element 3: Policy and Legislation Impact Analysis

3

FTA ELEMENT 3:

Consider policy and legislation impacting relevant technologies.

GTA's transition to a zero emission fleet is guided by federal, state, and local policies and legislation. Many policies support the fleet transition, while some may create challenges. The analysis below outlines key relevant policies, legislation, plans, and guidance and summarizes how they may impact or provide opportunities for GTA.

Federal Policies and Legislation

Reducing carbon emissions is a global priority, demonstrated by the agreement of 196 countries at the 2015 United Nations Conference of the Parties in Paris to limit global warming to less than two degrees Celsius compared to pre-Industrial Revolution levels. Federal orders, legislation, and policies support this goal.

Federal Executive Order 14057

100% ZEV acquisitions by 2035

Local

100% Renewable Energy for City operations by 2040

NC Executive Order 80

Reduce GHGs to **40% below** 2005 levels by 2025.

NC EO 246 and NC Clean Transportation Plan

Reduce GHGs by **50%** by 2030, **Net Zero by 2050**.

Table 3-1: Federal legislation, regulations and guidance supporting reducing carbon emissions

Federal Legislation, Regulations, And Guidance		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
Executive Order 14008: Tackling the Climate Crisis at Home and Abroad (2021)	• Creates a new position and climate task force and sets intention to participate in forums and develop plans to meet Paris Agreement. • Sets policy for government-wide approach to climate, including procurement to support climate action including zero emission vehicles for government fleets. • Promotes assessment, disclosure, and mitigation of climate risks. • Develops climate finance plan and focuses on aligning investments with climate action. • Established Justice 40 Initiative and other environmental justice efforts.	• Establishes policy supporting zero emission fleets. • May lead to available federal resources.

Federal Legislation, Regulations, And Guidance		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
Justice 40 Initiative	• Sets an intention to provide 40 percent of the benefits of federal investments to disadvantaged communities. • Focuses on investments related to climate change and clean energy.	• Implementation of ZEVs may need to demonstrate the level of benefit to disadvantaged communities.
Federal Sustainability Plan	• Plan to implement EO 14008. • ZEV strategies include optimizing agency fleet management, aligning financial planning, expanding charging infrastructure, improving workforce understanding for cultural change, seeking opportunities for State, Tribal, and local government fleets to benefit, and establishing a Zero Emission Vehicle Fleets Federal Leaders Working Group.	• Establishes policy supporting zero emission fleets. • May lead to available federal resources.
Executive Order 14057: Catalyzing Clean Energy Industries and Jobs through Federal Sustainability (2021)	• Seeks to reduce emissions across federal operations. • Includes a goal of 100 percent ZEV acquisitions by 2035, with 100 percent of light-duty vehicle acquisitions to be ZEVs by 2027.	• Provides detailed goals for ZEV acquisitions at the federal level. • May lead to available federal resources.
Bipartisan Infrastructure Law (BIL) and Related Implementation (Pub. L. 117-58) (2021O	• Includes requirements for zero emission transitions for some Federal transit grant programs. • Federal Transit Administration (FTA) requires transit agencies applying for competitive funding to include a Zero Emission Transition Plan with the application for funding for. • Grants for Buses and Bus Facilities Competitive Program (49 USC §5339(b). • Low or No Emission Program (49 USC §5339(c)).	• Requires completion of a Zero Emission Transition Plan to apply for certain federal grants.
FTA Guidance for Zero Emission Transition Plans (Dear Colleague letter dated December 1, 2021)	• Provides guidance on preparing Zero Emission Transition Plans. • Refers applicants to the Guidebook for Deploying Zero Emission Transit Buses published by the Transit Cooperative Research Program (TCRP) in 2021 for additional information.	• Establishes FTA Expectations for key grant programs. • TCRP Guidebook is a valuable resource for transit agencies at any phase of zero emission deployment, from initial needs assessment through monitoring performance and evaluating data.
USDOT Innovation Principles	• USDOT Innovation principles support policy priorities related to creating high quality jobs, achieving racial equity, increasing opportunity, and tackling the climate crisis, driving innovation. • Seeks to increase adaptability and resilience to future-proof infrastructure. • Focused on empowering workers. • Allows for experimentation, learning opportunities, and collaboration. • Promotes flexibility and adaptability to technology changes.	• Sets policy direction for transportation innovation. • May provide resources for testing and piloting new technologies. • May provide support for training and developing staff.

State of North Carolina Policy and Legislation Impact Analysis

Executive Order 80: North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy was passed in 2018 to set a goal of reducing statewide greenhouse gas emissions to 40 percent below 2005 levels by 2025. In 2022, Executive Order 246: North Carolina's Transformation to a Clean, Equitable Economy reinforced the state's commitment to reducing greenhouse gas emissions and brought equity forward as a central component of the economic transition. Executive Order 246 updated emissions reduction goals to align with the United States Nationally Determined Contribution to achieving the 2015 Paris Agreement and U.S. Climate Alliance commitments, including achieving net-zero GHG no later than 2050 and a 50 to 52 percent reduction in emissions by 2030. A number of state energy and transportation plans have been developed to help fulfill the aims of these state directives.

Table 3-2: Washington State Policies and Plans supporting reduction in emissions

State Policies and Plans		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
Executive Order 246: North Carolina's Transformation to a Clean, Equitable Economy (2022)	• Sets emission reduction goals at 50 to 52% reduction by 2030 and achieving net zero no later than 2050. • Sets equity as a focus for clean economy transition and requires cabinet agencies to actively incorporate environmental justice and equity considerations into their work. • Requires development of Clean Transportation Plan.	Established state level policies that will require GTA to contribute to emission reduction goal and incorporate equity considerations.
Executive Order 80: North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy (2018)	• Goal of reducing statewide GHGs to 40% below 2005 levels by 2025. • Requires development of certain plans, including a ZEV Plan and Clean Energy Plan. • Requires cabinet agencies to prioritize ZEVs in purchase or lease of new vehicles.	Established state level policies will require GTA to contribute to emission reduction goals, comply with developed plans, and may lead to requirements for ZEV prioritization based on how cabinet agencies implement.
State Plans		
North Carolina ZEV Plan (2019)	• Primary goal is expanding adoption of zero emission vehicles throughout the state. • Sets a medium-term goal of transitioning transit fleets to electric vehicles.	State goal (medium term) for transitioning transit fleets to electric buses are likely to require GTA action and may result in available resources to support transition. At this point, a taskforce is making recommendations for goals and strategies to electrify transit fleets so impacts are uncertain.
Clean Energy Plan (2019)	• Sets goal of reducing electric power sector GHGs by 70% from 2005 levels by 2030 and achieving carbon neutrality by 2050. • Accelerate clean energy development and deployment.	Provides a cleaner power supply over time to support GTA BEV operations, resulting in greater reductions in total GHG emissions from "well to wheel" - from the source to the bus tailpipe.

State Policies and Plans		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
State Plans		
Clean Transportation Plan	• Plan goals are to reduce economy-wide GHGs to at least 50 percent below 2005 levels by 2030, achieving net zero by 2050, increasing total registered ZEVs to at least 1,250,000 by 2030 and increasing the sale of ZEVs to 50 percent of new vehicle sales by 2030.	The plan establishes a dedicated team and interagency task force and encourages strategies to increase equity, ensure access and affordability of clean transportation, and maximize funding availability. GTA should continue to track progress as recommendations are implemented.

Local Plans and Policy Impact Analysis

Greensboro was the first city in the Southeast to integrate electric buses into its transit fleet and continues to be a leader in electrification. In January 2023, Guilford County, including Greensboro, had the highest electric vehicle adoption rate in North Carolina. A full zero emission transit and paratransit fleet transition would build on GTA's past success and align with the local and regional plans described below.

Table 3-3: Greensboro Local and Regional Plans

Local and Regional Plans		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
City of Greensboro Strategic Energy Plan: Pathways to 100% Renewable Energy (2022)	• Calls for transitioning all City fleets to electric vehicles when feasible, including vans and other vehicles used for special transportation services, such as Access GSO. • Prioritizes EVs when comparable models are available and a plan for charging systems is in place, hybrid vehicles if suitable electric models are not available, and internal combustion engines only if electric or hybrid options are not available. • Recommends a sustainable fleet policy focused on electrification.	• Aligns with fleet transition to ZEVs. • Emphasizes including special transportation service vans and support vehicles in the transition plan. • Establishes Evs as priority and identifies when other options such as hybrid models should be considered.
Sustainability Action Plan (2020)	• Transportation and land use strategies focus on increasing sustainability by linking development with transportation infrastructure to reduce dependence on automobiles. • Aims to increase transit system use and improve mass transit corridors. • Fleet electrification is not a focus of the sustainability plan; however, at the time of the last plan amendment, full electrification of the bus fleet was already complete.	• Implementation may lead to increase in transit ridership.

Local and Regional Plans		
Legislation, Regulation, or Guidance	**Key Provisions**	**Impacts/Opportunities for GTA**
GSO 2040 Comprehensive Plan (2020)	• Structured around six “big ideas” for implementing the City’s vision, including prioritizing sustainability and becoming car optional.	• Implementation may lead to increase in transit ridership.
Greensboro Capital Improvements Program FY 2024-2033	• Funding has been allocated for electric bus replacements, paratransit vehicles, and replacement buses.	• Funding is available in support of the ZE transition.
Mobility Greensboro 2040 (2018)	• Identifies needed service improvements and route strategies to increase ridership.	• Charging strategies and route optimization may change over time as service changes are implemented.
Regional Plans		
2045 Greensboro MPO Metropolitan Transportation Plan (2020) Greensboro Urban Area Metropolitan Planning Organization (GUAMPO)	Transit is one of the five primary elements of the transportation system addressed in the plan. The plan’s goal for transit is to provide “a well-integrated, connected public transportation network that: • Provides mobility to the transit-dependent (those with few or no other travel choices), • Ensures that transportation is not a barrier to access employment, services, or daily needs, • Provides travel choices to the community and the region, • Mitigates growth in traffic congestion, • Contributes towards improved air quality, • Reduced dependence on fossil fuels, and • Supports livable, compact patterns of development.”	• Implementation may lead to increase in transit ridership. • Acknowledges the City’s vision and goals, including its goal of becoming car optional. • ZEV transition supports regional goals to improve air quality and reduce dependence on fossil fuels.
Coordinated Human Services Transportation Plan for the Greensboro Urban Area (2019) GUAMPO	• Describes unmet transportation needs, establishes priorities for addressing unmet needs, and develops competitive selection process for projects serving the transportation needs of older adults, individuals with disabilities, and people with low incomes. • Identifies paratransit vehicle capital expenses as a priority category for GTA. • Establishes ranking criteria for determining how Federal Section 5310 program funds should be allocated.	• Does not prioritize or evaluate ZEVs; however, maximizing benefit to cost is a primary ranking criterion that can either support ZEV adoption, if based on lifecycle costs, or present barriers to adoption, if based on upfront capital costs only.

The ZEFTP is aligned with Federal, State, and local plans, policies, and goals. No legislative or policy barriers have been identified that would make a full ZE transition challenging for GTA.

Key Findings

- The ZEFTP fulfills a wide variety of policy goals and requirements, including federal, state, and local climate goals, national and state climate goals, a transition to clean energy, and the state's goals for clean transportation.
- No legislation or polices were identified that would hinder GTA's efforts to transition to a ZEV fleet.

Recommendations

- Ongoing mobility and transit planning efforts should consider the impact of recommendations on the ZEFTP. As substantial changes to transit service are planned, the ZEFTP timeline and recommendations may require adjustments to align with future transit services.

FTA Element 4: Evaluation of Current and Future Facilities

4

FTA ELEMENT 4:

Include an evaluation of existing and future facilities and their relationship to the technology transition.

Transitioning to a ZE fleet may require modifications to or construction of transit facilities to support ZEVs, such as charging and fueling stations or maintenance facilities and equipment. This section outlines existing, proposed, and potentially needed facilities.

An analysis of distributed energy resources (DER) evaluates opportunities for power generation and storage that can reduce impacts on the grid and increase resilience to power disruptions. The assessment includes analysis of the existing electrical capacity at the facility where the EVs would be charged, while the scope and timing of future upgrades were informed by the technical analysis conducted for Element 1 of the ZEFTP. Transit fleet operators need to make sure that implementing and deploying new technologies do not create major disruption to service. For a fleet running on electricity, power disruptions are a major concern for fleet operators, as any grid-level disruption can effectively disable their fleet. Thus, GTA must ensure that they can continue to operate their fleet and provide critical mobility services even in the event of a grid outage.

The primary mission of transit agencies is to provide reliable and safe public transportation services to the members of a community, especially to the most vulnerable populations that depend on the existence of these public services. In the era of transit fleet electrification, the deployment of ZEVs has the great potential of reducing emissions of GHGs and other criteria pollutants that are harmful to the local communities served by transit services. Thus, this section also outlines the social and environmental context of GTA operations to provide an initial screening of recommended sites for future facilities. As GTA develops future facilities and services, demographic and social factors should be considered to inform equitable distributions of the benefits and burdens associated with transit services and facilities. When possible, facilities should not be placed in areas at risk due to environmental hazards such as flooding, and potential environmental and climate hazards. Those intersecting with areas of social vulnerability should be incorporated into planning a resilient transit system.

Existing and Planned Facilities

TRANSIT CENTERS AND MAINTENANCE FACILITIES

GTA operates two primary facilities: The J. Douglas Galyon Depot, located at 236 E. Washington Street, and the Maintenance Facility and Administrative Offices located at 223 W. Meadowview Road.

The Depot is a historic railway station that was refurbished for multimodal transportation use in 2003. Solar panels were installed after GTA began transitioning to EVs to offset the costs of quick charging buses at the depot.

The maintenance facility, known as the Base, was constructed in 2011 to house all GTA vehicles, vehicle maintenance, and administrative and operations personnel. The 65,000 square foot facility received a Leadership in Energy and Environment Design (LEED) Gold Certification and includes a green roof, solar panels, local materials, incorporation of recyclable and rapidly renewable resources, and other energy efficiency features.

No new facilities or facility upgrades are currently planned or programmed.

EV CHARGING INFRASTRUCTURE

BEB chargers have been installed at both facilities. The Base has overnight chargers, while the Depot has rapid charging facilities (blade style pantograph chargers). As an early adopter of BEBs, GTA's charging units represent an earlier generation of the technology and are less efficient than many of the units that are now available. GTA intends to apply for grant funding in fiscal years 2023, 2024, and 2025 to support upgrades and expansions of BEB infrastructure.

Future Facilities Needs

GTA and the City of Greensboro's strategic vision calls for transit to play an important role in the future of the city, and transit services are expected to expand over time. As the transit system grows, facilities will need to expand. Both facilities have limited parking as a constraint for expansion.

The current maintenance facility can handle approximately six to ten additional buses; a larger garage would be needed for further fleet expansion.

The Depot has limited space availability. There is potential for the area around the site to be targeted for mixed use development in the future, but no specific plans are in place. Future development in the area may result in additional constraints or opportunities for meeting GTA's future needs.

Power infrastructure upgrades would be needed at both facilities.

Endpoint charging locations would be installed at existing businesses and other facilities through partnership with the facility owners. Recommended endpoint charging locations for each scenario are shown in Table 4-1.

Scenario	Recommended Charging Locations
Base Scenario & Existing Service + Technology Impacts Scenario	• Four Seasons Mall • GTCC Wendover Campus
Future Mobility Plan Coverage Scenario	• Pyramid Village Shopping Center • GTCC Wendover Campus • GTCC Main Campus • Joint School of Nanoscience and Nanoengineering • Four Seasons Mall • Coble Transportation Center
Future Mobility Plan Ridership Scenario	• Coble Transportation Center • GTCC Main Campus • Joint School of Nanoscience and Nanoengineering • GTCC Wendover Campus • Pyramid Village Shopping Center

Table 4-1: Recommended Charging Locations by Scenario

Distributed Energy Resources & Resiliency Analysis

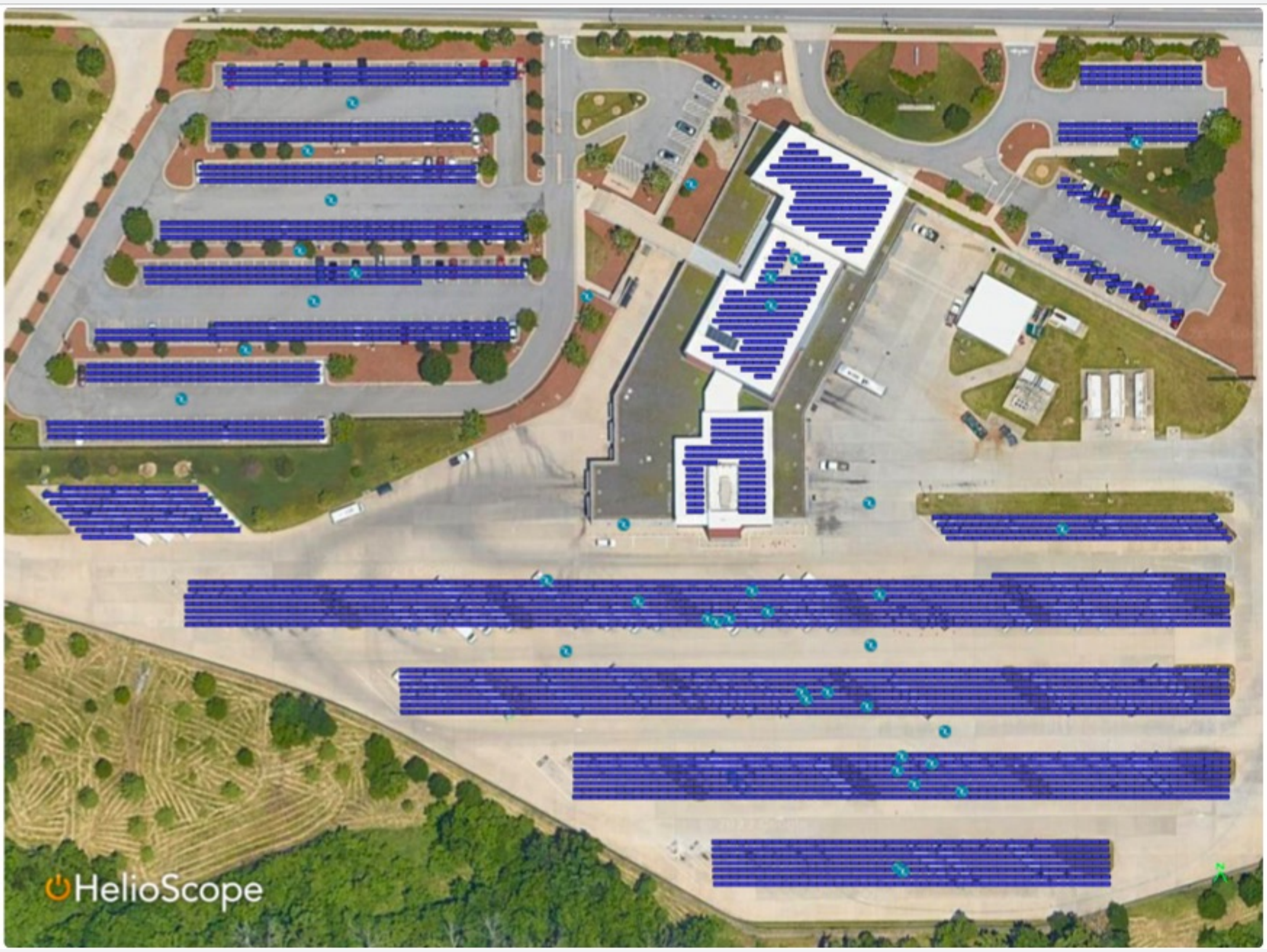
A transit facility with charging infrastructure and DER assets to support a fleet of EVs has the potential to function as an advanced electric grid that can charge the fleet at the lowest possible cost and lowest impact on the grid, while generating and storing energy.

A key point of consideration for an all-electric fleet can be the ability to disconnect from grid and fully support the local loads during an outage (i.e., island mode). This can be achieved with implementing a microgrid at the maintenance facility. Microgrids also provide the opportunity to integrate local renewable energy generation to reduce lifecycle carbon emissions and increase resilience.

A DER and resiliency analysis was performed to help GTA plan risks associated with power disruptions for a long-term electric fleet management scenario. The analysis consisted in estimating a solar photovoltaic (PV) output from the current GTA maintenance facility, and in designing an integrated solar PV and battery energy storage system (BESS) that can function as a local microgrid when coupled with a controller software that can direct power generated and stored onsite to the vehicle charging stations. In such concept design, the microgrid can instantaneously island itself in the event of a power outage, allowing GTA to operate their fleet and thus providing the needed resiliency, in addition to reducing electricity costs through local energy generation and charging management measures.

First, the analysis assessed the maximum solar PV generation potential of the GTA main facility by utilizing available roof space and adding carport solar where vehicles park. The analysis was conducted with the software Helioscope, which allows the user to design a solar array system and to estimate the solar output potential of a location on an annual basis by considering seasonality (see Figure 4-1). The analysis indicates that the GTA rooftop and carport at the Maintenance Center have ~1.03 megawatt (MW) AC solar peak generation potential, corresponding to ~1,749,500 kWh of annual production.

Figure 4-1: Solar PV generation potential estimated for the GTA rooftop and carport at the GTA facility



The downtown Depot has 530 kW AC solar peak generation potential, corresponding to approximately 944,000 kWh of annual production. To put these numbers in perspective, the existing 17 BEBs had an annual energy requirement of 1,023,032 kWh in 2022, meaning solar PV just at the Maintenance Center could nearly offset the charging load from the existing BEBs, while the energy produced at the Depot could offset a significant portion of charging from the future BEB fleet. With improved charging efficiency and future improvements in BEBs, solar could offset a greater portion of energy needs in the future.

Figure 4-2: Solar PV generation potential estimated for the downtown Depot.

This microgrid system was modeled with the Tesla Megapack BESS rated at 1264 kW and 2529 kWh coupled with the onsite solar array of 1.03 MW. The DER analysis results were used to explore resiliency options for the GTA fleet, by simulating operations in a power outage for the 25% Scenario (16 BEBs and 31 Paratransit ZEV). Assuming that the power outage begins at 1 am on a weekday, the analysis calculated the number of hours that the fleet can operate in resilient mode. Analysis for additional scenarios will evaluate improvements or expansion needed for existing solar infrastructure at the downtown transit center.

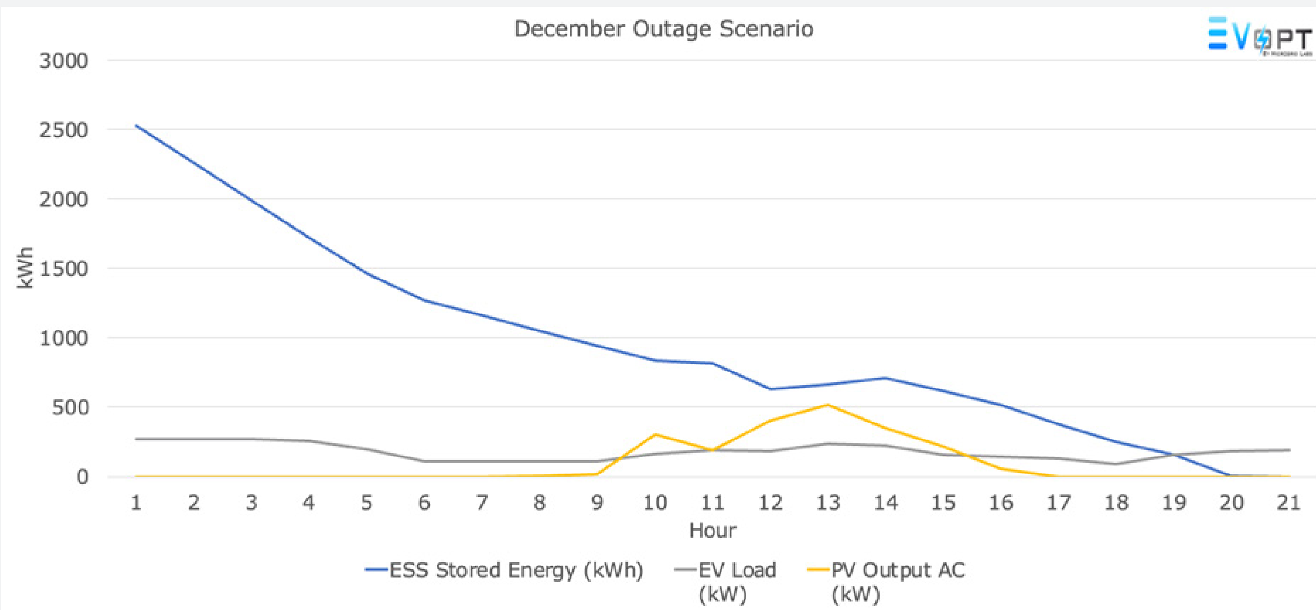
Table 4-2 shows that length of operations that could be sustained in the case of a grid outage with the solar array and BESS supporting all charging loads at the Maintenance Center. During January, February, March, November, and December, when solar production is the lowest, an outage lasting 1-2 days can be handled, while the other months can sustain operations for more than a week.

Table 4-2: Estimated hours of operation in resilient mode during a hypothetical power outage. In this simulation, the power to the vehicle chargers is supplied by solar onsite generation combined with a BESS system in a microgrid design.

Month	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Resilient Mode Hrs.	24	27	49	>168	>168	>168	>168	>168	>168	>168	25	20

Figure 4-3 shows a more detailed simulation for the month of December. It is worth noting that power outages are most likely to occur during the coldest and hottest months of the year due to winter snowstorms or blackouts that are caused by grid stressors such as high air conditioning usage in summertime. In these instances, the GTA fleet operator would need to decide which transit routes and paratransit services can be discontinued and which ones are most essential to be covered in a power outage situation.

Figure 4-3: Simulation of a grid outage in the month of December with solar output (kW), BESS stored energy (kWh), and needed EV load (kW) for the fleet of 16 BEBs and 31 paratransit charging fully at the maintenance facility.



The results provided by this analysis will become most relevant for a long-term management plan of the GTA fleet, when the number of BEVs become large enough for operations to be disrupted significantly by a power outage. In the long-term, GTA will have to prepare emergency response plans that incorporate resilient operation scenarios. While power outages are often impossible to predict, accurate weather forecasting can allow operators to predict in advance when an outage event is likely to occur and take the appropriate measures to prepare the system by ensuring BESS is completely charged and altering operating strategies as necessary.

Context/Screening for Future Facilities Planning

GTA provides fixed route and paratransit services throughout the City of Greensboro. The growing city has ambitious goals for the future of its transit system which may require new or expanded facilities to support its growing zero emission fleet. Future facilities planning should consider the social and environmental context of proposed facilities to support a resilient and equitable transit system.

SOCIAL CONTEXT AND DEMOGRAPHICS

Greensboro is the 3rd largest city in NC. It is centrally located in the Piedmont Triangle region, and is nicknamed the “Gate City” for its easy accessibility to other cities and destinations in NC. The city boasts a mix of industries and several colleges and universities.

Social context and demographics were examined using two tools: the Social Vulnerability Index (SVI) and the Climate and Economic Justice Screening Tool developed to support the federal Justice 40 initiative. GTA’s fixed route services are often densest in areas with higher social vulnerability. Appendix A includes detailed maps of the social context.

The locations of disadvantaged populations and their characteristics can inform equitable distribution of transit services and benefits. Many vulnerable communities are exposed to higher levels of hazards like air pollution. Risk factors like asthma can increase the severity of impacts related to these exposures. Replacing conventional vehicles with ZEVs improves air quality and reduces exposure to harmful emissions on and near roads. The benefits of ZEVs should be distributed as equitably as possible. In general, ZEVs should be shared among all routes or prioritized for use in disadvantaged communities.

GTA currently rotates buses across all routes except where constrained; routes 12A, 73, and 75 do not have access to charging facilities; therefore, BEBs are typically not used on these routes. BEBs are also rarely used on Routes 5 and 8 due to schedule constraints that do not allow sufficient time for charging between runs. Most of these routes serve areas with moderate to high social vulnerability; future strategies should consider ways to extend the benefits of BEBs to these areas.

Environmental Context

Greensboro is located in the Piedmont ecoregion, which stretches from Alabama to Virginia along the foothills of the Appalachian Mountains. This region is characterized by rolling hills with broad ridges. Rivers and streams generally run southeastward and have relatively narrow floodplains. Much of the region is forested, with forest types including dry coniferous woodlands of loblolly and slash pine, mesic forests of mixed hardwoods, and oak forests that range from pine-dominated to hardwood-dominated forests depending on the local moisture regime. Floodplain forests, riverine aquatic, and small wetland communities occur along waterways. Early succession habitats, including grasslands, shrublands, hayfields, pasture, clear-cut and regenerating forests, row crops, and other canopy gaps are associated with agricultural or forestry activities and are common in the region.

TEMPERATURE

Greensboro has warm, muggy summers and short, cold winters. Typical temperatures range from 31 degrees to 87 degrees Fahrenheit. Extreme temperatures are uncommon, with temperatures rarely dropping below 18 degrees or rising above 94 degrees Fahrenheit. The Piedmont region has been warming since the 1970s and average temperatures are expected to rise. The number of very hot days is expected to increase, along with very warm nights. Occurrences of very cold days are rare and anticipated to decrease with climate change.

Many of GTA's routes intersect with areas at the highest risk of heat severity. Most of these areas also have higher levels of social vulnerability. GTA may consider including shade and water in future improvements to bus stops and shelters to help protect passengers from extreme heat. Figures 4-4 through 4-6 show heat risk for the routes associated with each scenario.

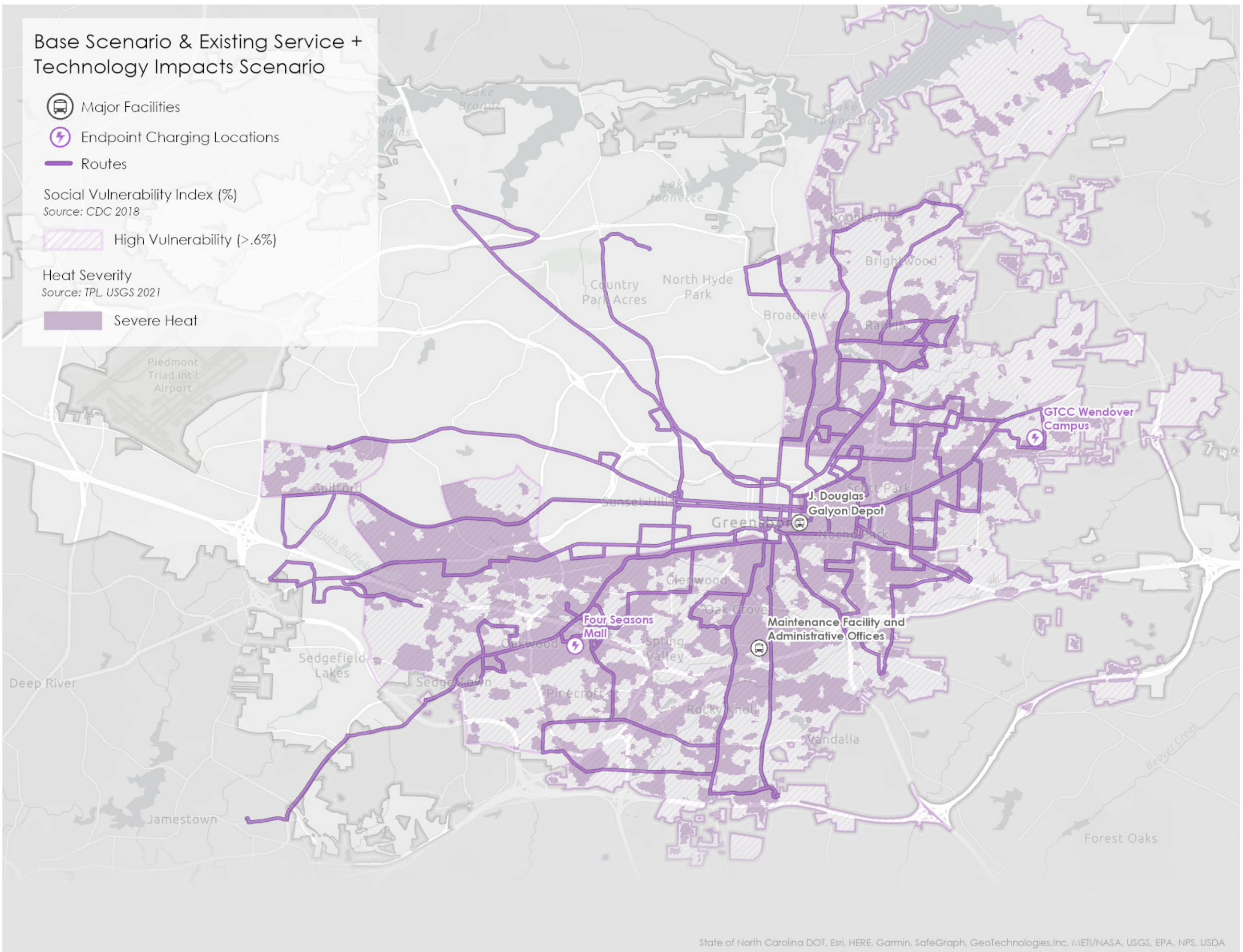


Figure 4-4: Heat Severity and SVI for Base Scenario and Existing Service + Technology Impacts Scenario

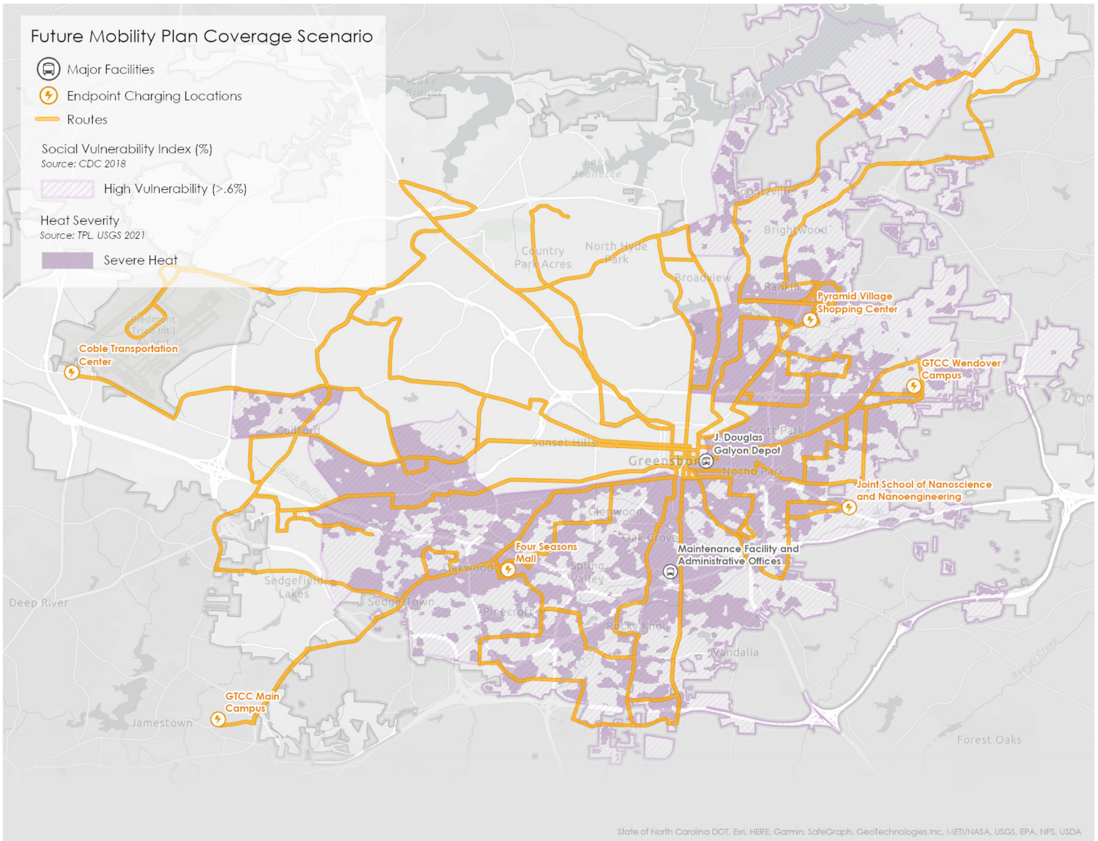


Figure 4-5: Heat Severity and SVI for Future Mobility Plan Coverage Scenario

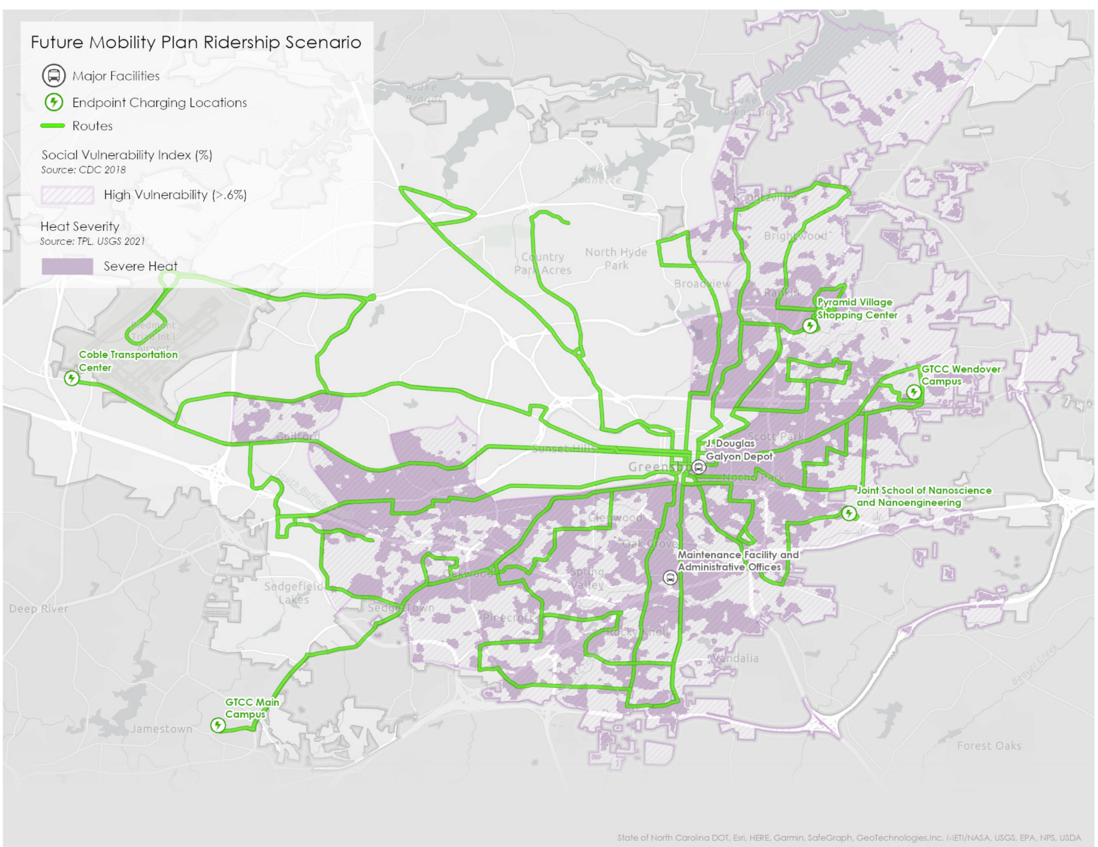


Figure 4-6: Heat Severity and SVI for Future Mobility Plan Ridership Scenario

PRECIPITATION AND FLOOD RISK

Greensboro is typically partly cloudy year-round, with October as the clearest month. The wettest season in Greensboro is from May to August, with the most days of rain typically occurring in July and the greatest accumulation in August. There may be snowfall from late November to mid-March, with the most snowfall occurring in February. The Piedmont region is the driest region in NC. Climate models predict a wide range of precipitation scenarios, but the greater number of models show that annual precipitation is likely to increase. Weather patterns are anticipated to become more extreme, with an increase in frequency and severity projected for both droughts and extreme precipitation events. While there is low confidence in the likelihood of increased winter storms, it is anticipated that the amount of precipitation caused by winter storms will increase. Increases in precipitation amounts also increase the risk for flooding.

As the risk and severity of storms, wildfires, floods, and other climate-related events increases, planning for effective emergency management and response is essential. The potential for power outages or other fuel disruptions should be considered when planning for a resilient ZE fleet. The fleet transition may offer opportunities to improve community resilience through continued adoption of BEBs and implementation of Vehicle to Grid (V2G) and Vehicle to Building (V2B) technologies. These strategies would allow transit fleet vehicles to serve as resilience hubs for communities in Greensboro. Implementing V2G and V2B strategies can better and more efficiently integrate transit energy consumption with energy generation and provide another way for transit to support community resilience day to day and following climate and other emergency events.

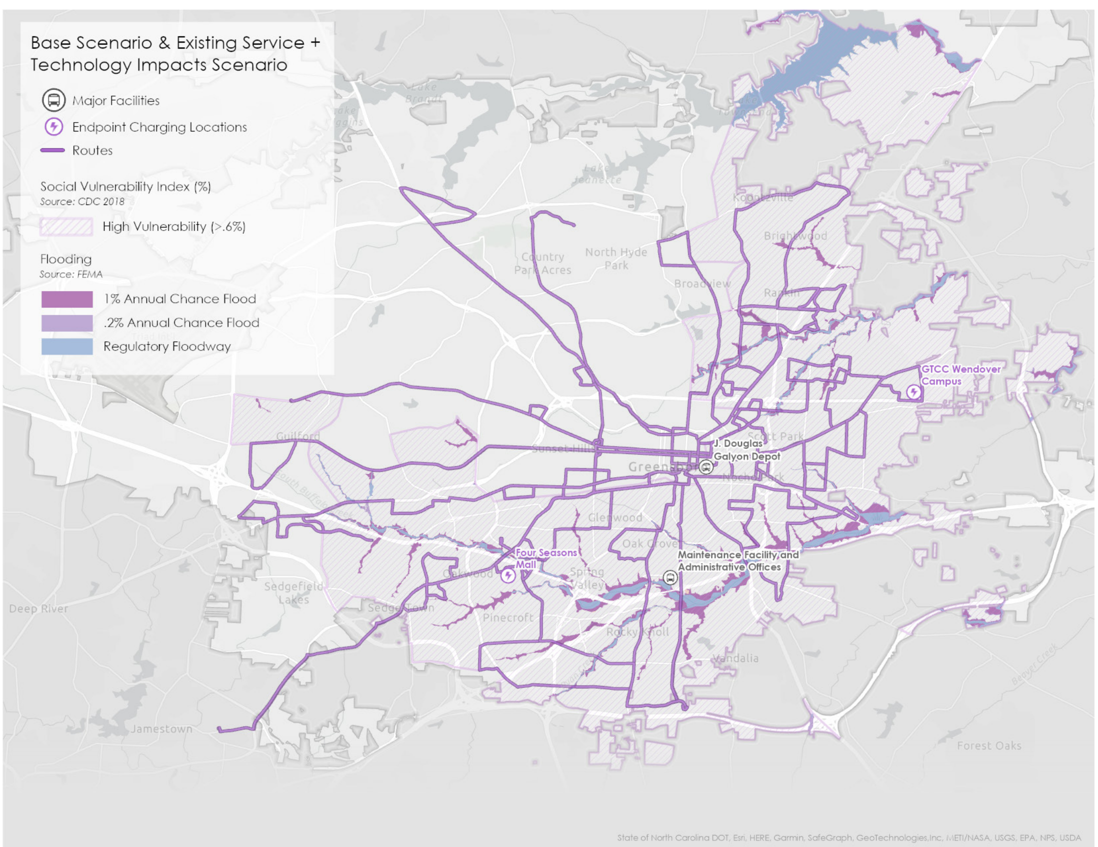


Figure 4-7: Flood Risk and SVI for Base Scenario and Existing Service + Technology Impacts Scenario

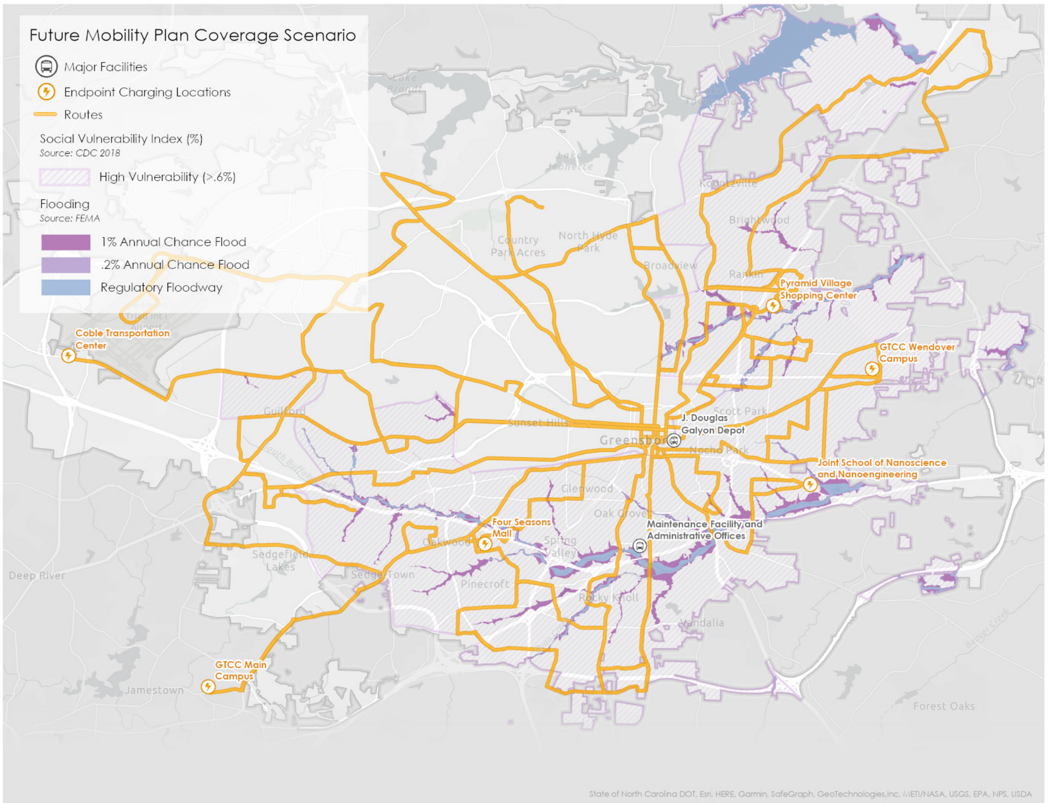


Figure 4-8: Flood Risk and SVI for Future Mobility Plan Coverage Scenario and Figure

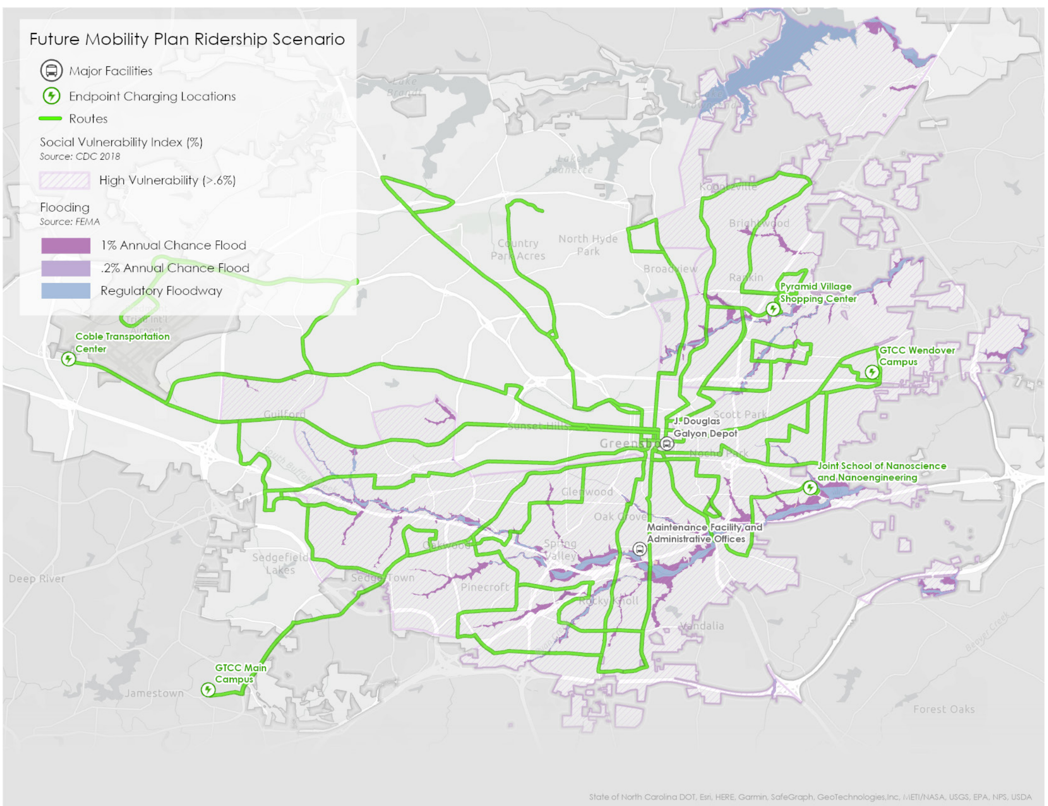


Figure 4-9: Flood Risk and SVI for Future Mobility Plan Ridership Scenario

A few of GTA's routes cross areas with high flood risk and GTA's facilities are not located in areas of increased flood risk. Flooding may temporarily affect routes or scheduling, but is not anticipated to be a significant risk factor in the transition to ZEVs.

Key Findings

- GTA currently rotates buses across all routes except where constrained; routes 12A, 73, and 75 do not have access to charging facilities; therefore, EVs are typically not used on these routes. EVs are also rarely used on Routes 5 and 8 due to schedule constraints that do not allow sufficient time for charging between runs. Most of these routes serve areas with moderate to high social vulnerability.
- Many of GTA's routes intersect with areas at highest risk of heat severity, often in areas with higher levels of social vulnerability.

Recommendations

- GTA should consider the implementation of a microgrid backed by onsite solar generation and a BESS to enhance resiliency and ensure that fleet operations can be sustained in the event of a grid outage.
- The benefits of ZEVs should be distributed as equitably as possible. ZEVs should be shared among all routes or prioritized for use in designated disadvantaged areas. Future strategies should consider ways to extend the benefits of BEBs to areas and routes that are not currently served by BEBs.
- Potential facility locations should be assessed based on social and demographic characteristics to ensure that both benefits and burdens are distributed equitably.
- GTA should consider opportunities to incorporate shelter from extreme heat in its facilities.
- Evaluate potential for vehicle to grid (V2G) and vehicle to bus (V2B) applications to support community resilience as BEB fleet and charging infrastructure continue to be expanded.

FTA Element 5: Utility Stakeholder and Energy Considerations

5

FTA ELEMENT 5:

Describe the partnership of the applicant with the utility or alternative fuel provider.

GTA's transition to a ZE fleet will require coordination with other entities. Utility stakeholders are particularly important, as ZEVs can create additional demand on utilities. Partnerships may also be beneficial in pursuing the development of hydrogen fueling infrastructure and implementing other new technologies. This section outlines the existing and potential stakeholder partnerships that can support the ZEFTP.

In order to support conversations with utilities and other potential partners, a predictive load profile with peak power demands was calculated based on the technical analysis in Element 1. This information can be used to inform the utility of GTA's potential needs and facilitate strategic partnerships for necessary infrastructure upgrades, demand management, and other collaborative strategies.

Utility Stakeholders

It is important for transit agencies transitioning to a ZEV fleet to work closely with utility providers. The transit agency needs assurance of a reliable supply for its power and other needs, while the utility needs to understand the agency's needs as well as the impact of the transition on overall demand.

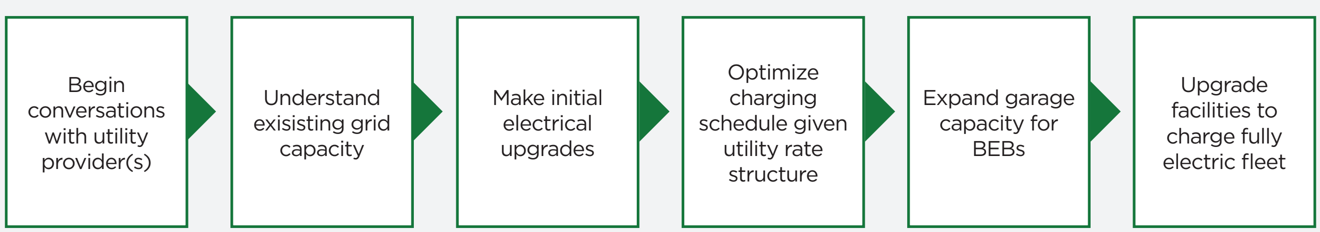
Greensboro has previously worked with Duke Energy to fund charging stations for its existing BEBs. Duke Energy will continue to be a key partner as the electric fleet expands.

The City of Greensboro operates the water system. Coordination with the City Water Resources Department will be needed to limit the impact of the ZEV transition on the overall water system.

Future Utility Coordination

Early and frequent coordination with utility providers is recommended throughout the fleet electrification process. Collaborative approaches allow the transit agency and utility to effectively plan and implement upgrades that will maximize efficiency and meet future needs. Deploying Battery Electric Buses at Scale: A Toolkit for New York State Transit Agencies (2021) provides a framework for utility coordination and examples of successful collaboration between transit agencies and utilities.

Figure 5-1: Utility Coordination Process



Other Stakeholders and Partnerships

Partnerships with utility stakeholders are critically important for supporting GTA's fleet transition. GTA may also wish to pursue partnerships with other entities that can provide additional expertise or support opportunities for funding. For example, partnerships with universities or manufacturers could provide opportunities to participate in testing new technologies or systems. Community organizations or non-profits may be able to provide support or help with equitable implementation of ZEVs. Some funding programs may require partnerships; for example, FTA's ZERO program provides funds to consortiums led by non-profit organizations.

The Partnership Matrix in Table 5-1 identifies utility stakeholders as well as other entities that GTA may consider partnering with in the future.

Table 5-1: Potential Utility, Energy, Climate, and Community Partners

Partner Organization	**Partner Type(s)**				**Type**	**Description**
	Utility	**Energy**	**Climate**	**Community**		
University of North Carolina (UNC) Greensboro, Guilford College		x	x	x	Public	GTA will benefit from partnerships with educational institutions that would enable knowledge sharing and training of staff. During the agency's fleet transition to zero emission, graduates may be recruited and/or allowed to intern at the agency's shops and the agency may explore options to share knowledge and technical expertise with the college.
Climate Reality Project: Guilford County Chapter Shad Smith, giving@ climatereality.com		x	x	x	Non-Profit	Climate Reality Project is a non-profit that works on training and educating people about climate solutions and energy transition around the world. The organization is working on major steps towards zero emissions. GTA may partner with the organization to enable knowledge sharing and best practices on reducing community and municipal emissions and to help staff and commuters learn about transit climate solutions.

Partner Organization	Partner Type(s)				Type	Description
	Utility	Energy	Climate	Community		
Duke Energy	x	x			Private	GTA's transition to BEBs has been aided by Duke Energy with grants to set up charging infrastructure for BEBs. The continuing transition will increase the demand for electricity and the consumption of it by the agency's facilities. A partnership with Duke Energy will enable the agency to work with the utility provider to manage demand during peak times, negotiate pricing, help set up and manage required infrastructure to support charging, or develop distributed energy resources such as solar projects.
City of Greensboro Chief Sustainability Officer, 336-373-2860, 300 W. Washington St. PO Box 3136 Greensboro, NC 27402-3136		x	x		Public	GTA may partner with other City departments to collaboratively develop solar or other distributed energy projects or to identify suitable City property for the location of distributed energy resources or charging infrastructure.
Community Sustainability Council Jeff Sovich 336-433-7264			x	x	Public	The Community Sustainability Council is an advisory group to the City Council. GTA may partner with the council in order to gauge public perception of changes to services and fares resulting from adoption of BEBs into the fleet. Such changes may include raise in fares to support further investments of the agency in infrastructure to transition to ZE and maintain quality of service.

Partner Organization	Partner Type(s)				Type	Description
	Utility	Energy	Climate	Community		
North Carolina Clean Energy Fund nccleanenergy@gmail.com		x	x	x	Private, Non-Profit	North Carolina Clean Energy Fund is a non-profit that invests in energy efficiency and renewable projects that benefit underserved populations in the state. GTA can explore entering into a partnership with NCCEF to generate capital for clean energy infrastructure and ZE buses that would serve underserved populations.
Greensboro City Water Resources Department 2602 S. Elm Eugene St. Greensboro, North Carolina 27406; 336-373-2489	x				Public	GTA may establish a partnership with Greensboro City Water Resources Department to better understand the best practices of water usage as it relates to the consumption in a transit agency. Apart from learning about the quality of water which is an issue of concern in the Greensboro area, the agency may implement practices that would promote conservation and recycling of water. If there is a requirement by the agency to ensure huge quantities of water for the purpose of hydrogen production, it may negotiate pricing and other terms of supply.
NC Clean Energy Technology Center 1575 Varsity Drive Raleigh, NC 27606 nccleantech@ncsu.edu		x	x	x	Public	The NC Clean Energy Technology Center provides services related to the development and adoption of clean energy technologies. Founded in 1987 as the North Carolina Solar Center, it has expanded its scope and grown into a state agency and center of knowledge for clean energy.

Energy Considerations

GTA's fleet transition will occur in the context of broader energy and utility trends. Emissions associated with EV operations are dependent on the emissions profile of the electric supply. Key energy considerations include the transformation of the electrical grid, available grid capacity, potential water demand, and the specific charging needs of GTA's future BEV fleet.

GRID TRANSFORMATION

A study completed by the REPEAT Project out of Princeton University's Zero Lab has estimated that the GHG reduction benefits associated with the Inflation Reduction Act depends on "more than doubling the historical pace of electricity transmission expansion over the last decade in order to interconnect new renewable resources at sufficient pace and meet growing demand from EVs , heat pumps, and other electrification." Rapid electrification of transit fleets as well as other medium- and heavy-duty vehicle (MHDV) fleets, private vehicles, and building electrification will mean that utilities, such as Duke Energy, will need to increase overall grid capacity and may need to add additional substations and feeder lines. Duke and other stakeholders will need to consider GTA's charging demand, as assessed in the ZEFTP, within the context of growing electric demands on the grid within Greensboro and throughout the region.

The growing electric demand may affect electricity costs over time. Duke Energy's Carolinas Carbon Plan (2023) outlines several possible portfolios varying in pace and scope for their energy transition (ranging from a rapid increase in solar resources to a slower increase in solar resources with more reliance on natural gas resources), with the more rapid emissions reduction portfolios anticipated to have greater impacts on customer costs. All portfolios include retirement of coal plants and a mixture of solar, wind, nuclear, and natural gas resources. The Plan includes cost management strategies including least cost planning principles, but notes that cost impacts will change over time as market conditions and policies evolve.

GRID CAPACITY

Available grid capacity will affect GTA's ability to meet electricity demand, described in the Modeled BEV Charging Demand section of the ZEFTP. Grid capacity is also dependent on regional growth data and factors that may affect demand, such as widespread ZEV adoption. This information will inform future coordination with utility providers and help GTA develop a process for effective coordination of future grid connections to support expanded charging infrastructure.

In its recent Carbon Plan Integrated Resource Plan (CPIRP), Duke is estimating that energy demand in the Carolinas is projected to grow by 35,000 gigawatt-hours (GWh) over the next 15 years. This has challenging implications for Duke as it aims to increase capacity and meet this demand while also transitioning away from fossil fuels. GTA will need to work closely with Duke Energy to understand energy demand and to fine-tune timing of BEB and charging infrastructure deployment, as well as implications for GHG impacts based on the pace of Duke's clean energy transition. For context, the most recent plan includes the following as part of its transition away from coal, but it should be noted that this near-term plan does not yet fully decarbonize Duke's energy supply:

- Solar – 6,000 MW by 2031
- Battery storage – 2,700 MW by 2031
- Hydrogen-capable natural gas – 5,800 MW by 2032, which includes replacing coal retirements at Roxboro (Person County) and Marshall (Catawba County)
- Wind – 1,200 MW onshore by 2033; preserve option of 1,600 MW offshore for 2033 or later
- Pumped storage hydro – 1,700 MW by 2034 at Bad Creek Hydro in Oconee County, S.C., serving both states
- Advanced nuclear – 600 MW by 2035, partially replacing coal retirements at Belews Creek (Stokes County) and one other existing plant location to be determined.

Duke Energy is working to meet the rising demand as well as reducing carbon emissions and controlling costs. Strategies to limit cost increases include applying least cost approaches and seeking cost-effective programs to reduce energy and modify load; however, costs are expected to increase over time, with the rate of increase peaking in 2030.

POTENTIAL WATER DEMAND

Water consumption and withdrawals are an important consideration for electrification of GTA's bus system. Research at a national scale utilizing national average electric supply resource mix has indicated that water consumption and withdrawal can be estimated at 0.24 gal H2O/mile and 7.8 gal H2O/mile, respectively. Additionally, water consumption rates can be two to five times greater in EVs than for gasoline or diesel fueled vehicles. However, it is important to contextualize this for NC and Duke Energy's electric grid supply. Duke Energy has already claimed a reduction of water withdrawals of 0.28 trillion gallons from 2016 to 2022 and aims to further reduce this by 1 trillion gallons by 2030. The utility also anticipates "further water savings as our coal and older natural gas plants are retired and replaced with newer, eventually hydrogen capable, natural gas combined-cycle plants utilizing more efficient closed-cycle cooling systems." Additionally, renewable energy sources such as solar and wind require no water consumption or withdrawals, further emphasizing the need to pair electrification with transitioning the supply to renewable energy sources. As this transition happens, water consumption and withdrawal rates will only improve.

MODELED BEV CHARGING DEMAND – BASE SCENARIO AND EXISTING OPERATIONS + TECHNOLOGY IMPACTS SCENARIOS

The ZEFTP provides an assessment of the anticipated electrical load associated with BEBs over time. This information can support more detailed discussions of GTA's needs with utility providers.

The load profile analysis provides the daily energy load profile resulting from the fleet charging needs at a specific charging rate, and the size of the transformer needed to support fleet charging, under unmanaged and managed charging conditions.

EVOPT® allows users to calculate two load profiles: 1) unmanaged, e.g., load generated by buses charging at full rated power until the battery is fully charged; and 2) managed, e.g., optimized charging scenario during which vehicles charge at a lower power rating and for longer time as allowed by the vehicle schedule to maintain uptime; this optimization can be achieved through a dedicated charging software.

Figure 5-1 is an example of the EVOPT® load profile calculation outputs and shows the unmanaged charging (black) and of the the managed charging (blue) load profiles for the existing transit BEBs covering the 22 ‘feasible’ blocks and charging at 60 kW in the maintenance facility. The unmanaged charging scenario (black) has a peak power demand of 540 kW, while the managed charging scenario (blue) has a peak power demand of 313 kW, fully leveraging the overnight hours that are available for charging vehicles thus yielding lower peak power draws.

* With managed charging only applying to the transit fleet of BEBs, under the conservative assumption that 19.2 kW chargers cannot be managed.

Figure 5-1: Energy analysis for Maintenance Center Existing BEBs

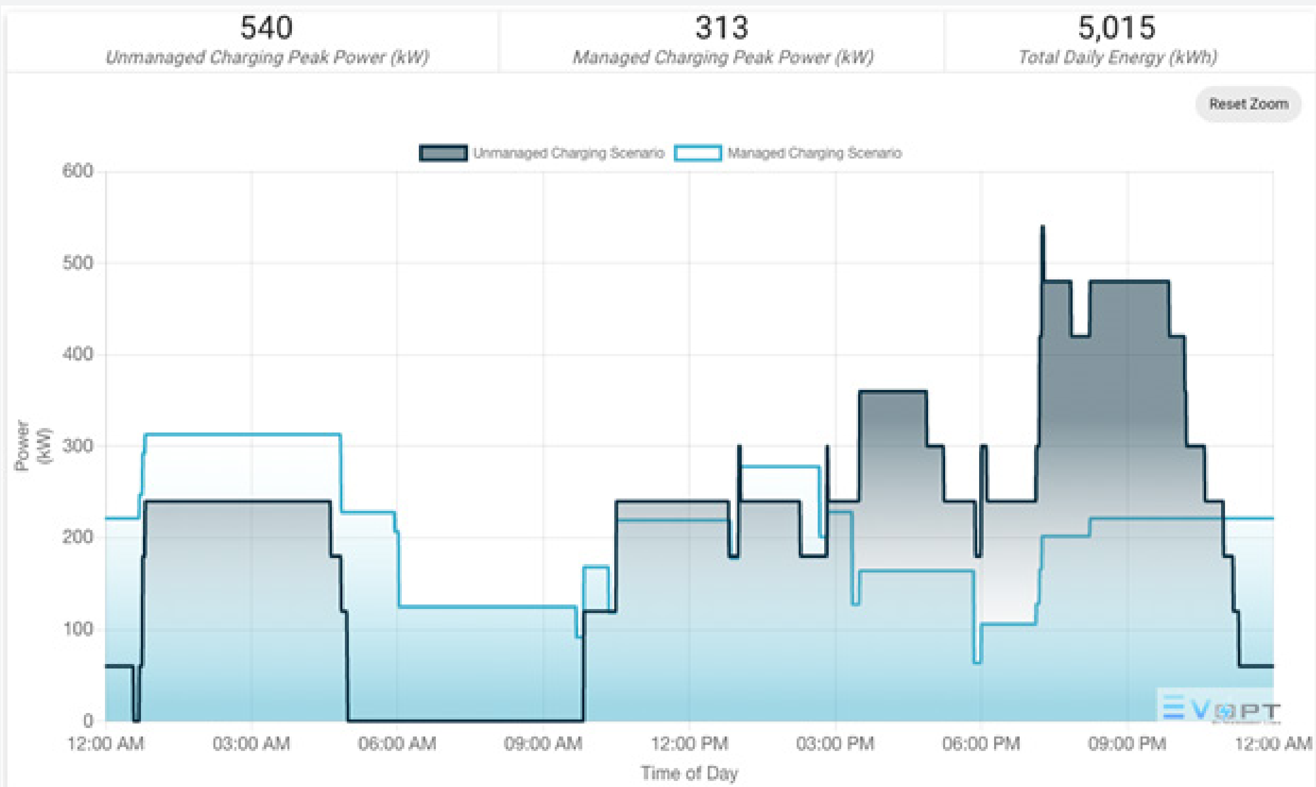


Figure 5-2 shows the load profile at the Maintenance Center for the combined fleet of the existing BEBs with the future BEBs and the paratransit ZEVs for a 100% electrification scenario. The unmanaged charging scenario (black) has a peak power demand of 6,214 kW, while the managed charging scenario (blue) has a peak power demand of 2,947 kW, fully leveraging the overnight hours that are available for charging vehicles thus yielding lower peak power draws.

Figure 5-2: Load Profile for 100% Electric Fleet

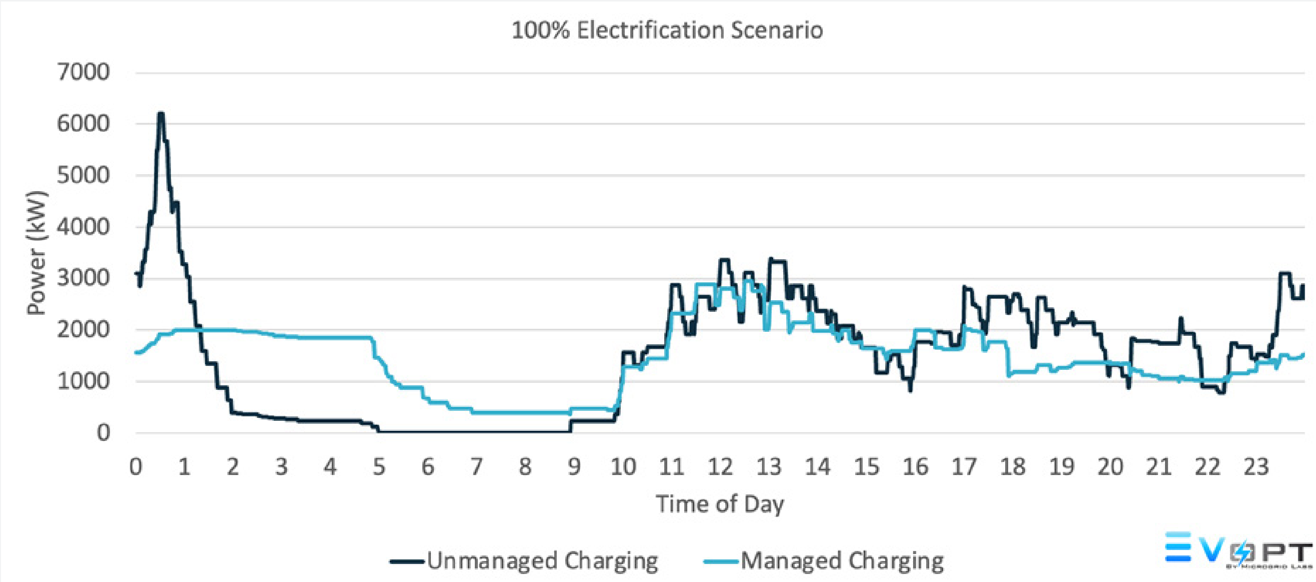
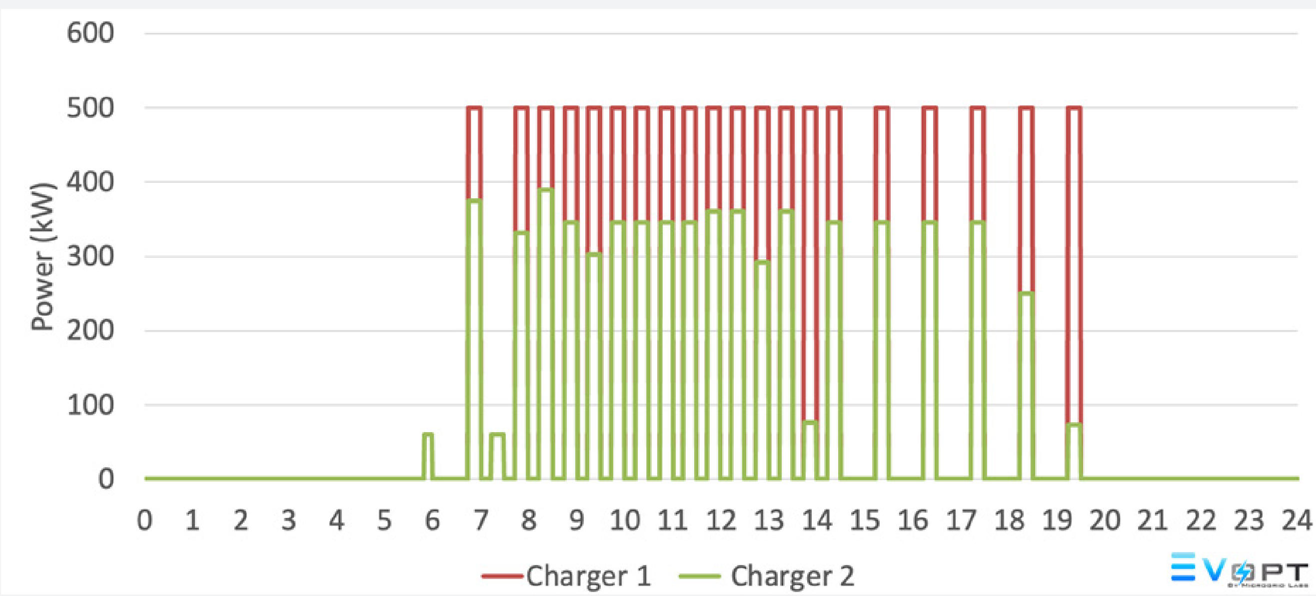


Figure 5-3 shows the load profile for charging at the Depot utilizing the two 500 kW chargers (Charger 1 and Charger 2). The depot has a daily energy demand of 4,395 kWh with a peak power of 500 kW.

Figure 5-3: Daily Load Profile at Depot



Figures 5-4 and 5-5 show the load profile for the endpoint charging at the end of Routes 2 and 10, respectively. There is only one 180 kW charger at each endpoint, so peak power for both locations is 180 kW. The Four Seasons Mall (Route 2) has a daily load of 979 kWh while GTCC Wendover Campus (Route 10) has a daily load of 992 kWh.

Figure 5-4: Daily Power Profile at Four Seasons Mall

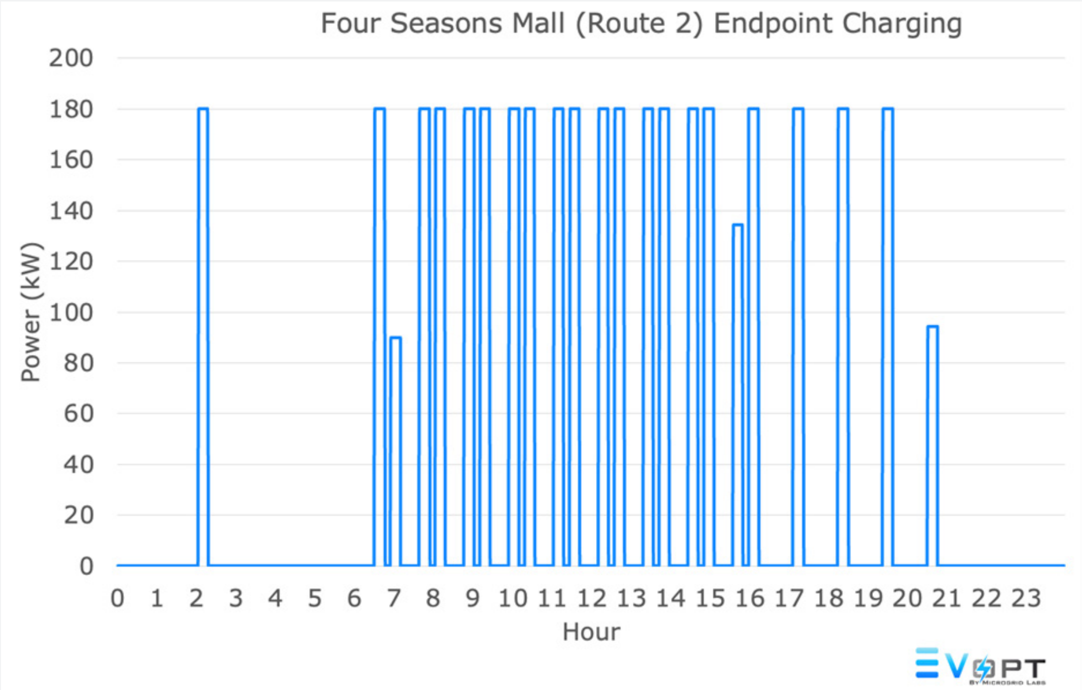


Figure 5-4: Daily Power Profile at GTCC Wendover Campus

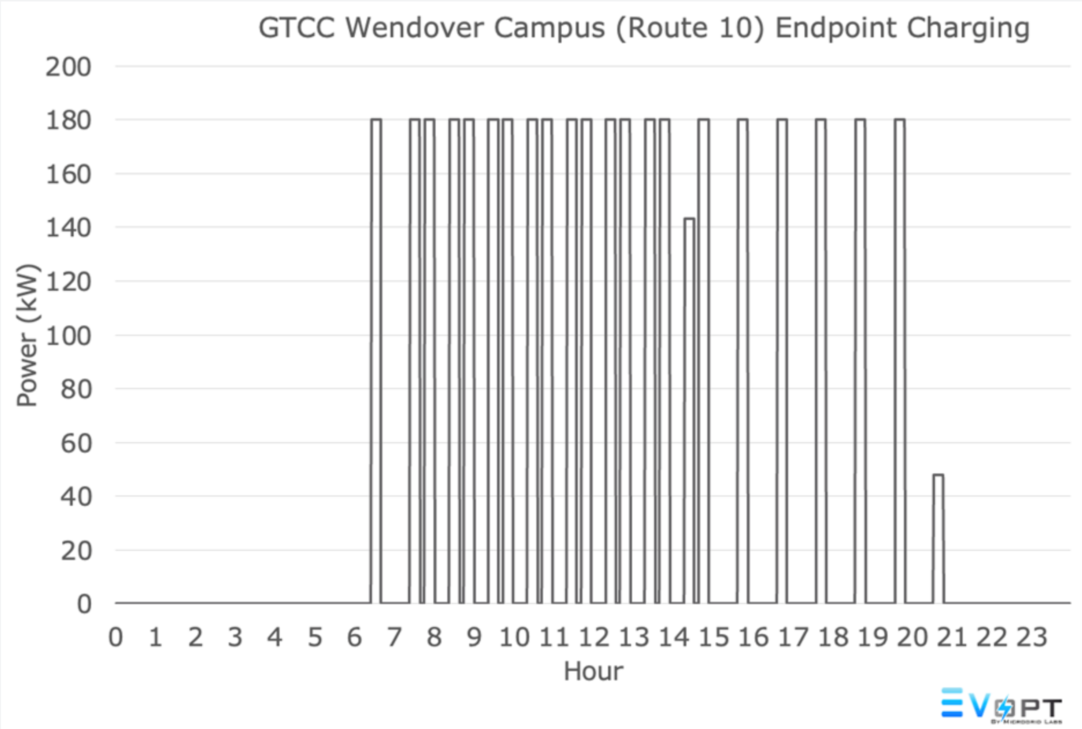


Table 5-2 shows the projected peak power demands and associated transformer size needed for the 22 new transit blocks served by the existing 16 BEBs and 31 paratransit vehicles and the 100% electrification scenario for the transit and paratransit fleet. The calculations are performed under the assumption that all transit blocks and paratransit vehicles charge in the maintenance facility only. Managed charging was only applied to the transit fleet (this is a conservative approach that guarantees a safer infrastructure sizing given that not all 19.2 kW chargers might be able to perform managed charging). GTA has a 1500 kVA transformer installed at their yard where overnight maintenance facility charging will occur, which suffices for the existing 16 BEBs and 31 paratransit ZEVs, however with a 100% electric fleet, the transformer will need to be upgraded, or an additional transformer can be added to increase redundancy and resiliency of the system.

Table 5-2- Results of energy analysis for the maintenance facility under the first phased-in electrification scenario.

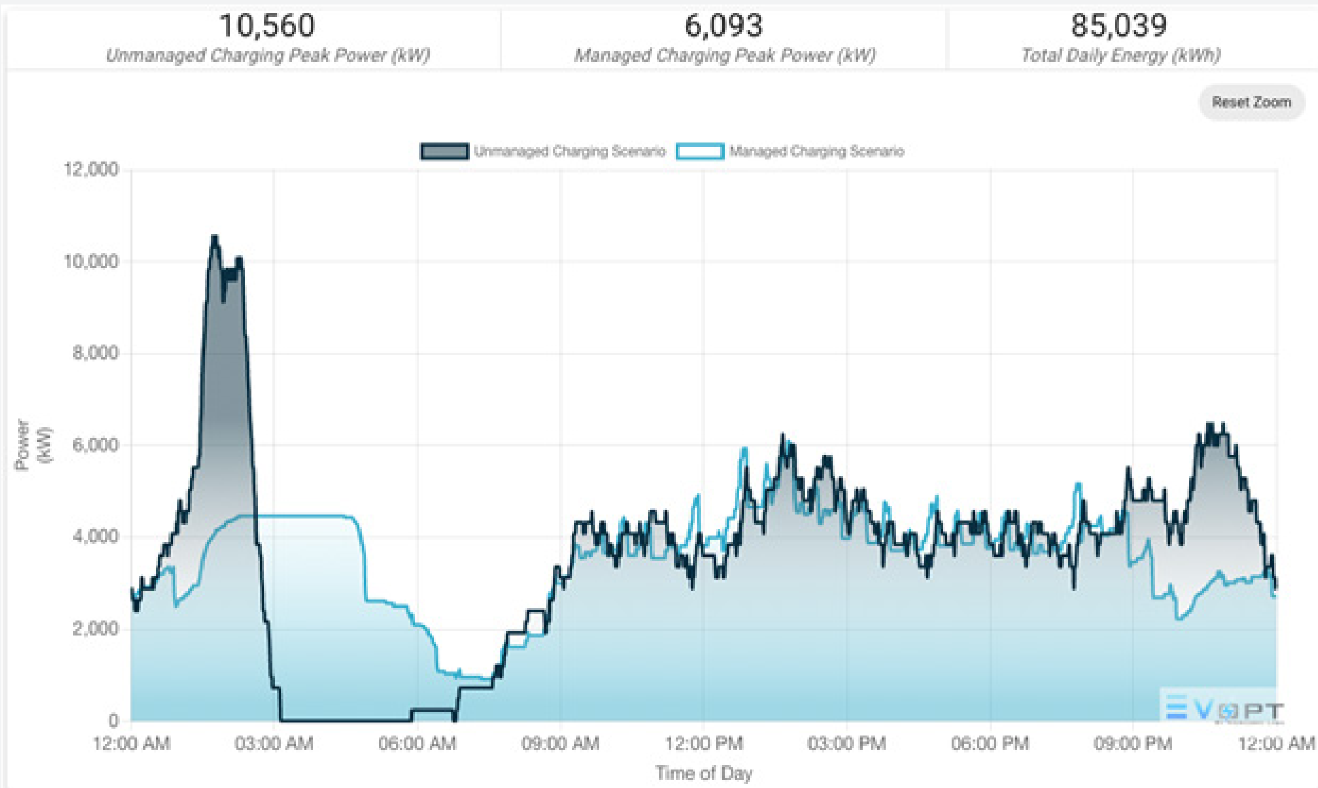
Phased-In Electrification %	Fleet Composition (Maintenance facility charging only	Peak Power (Unmanaged)	Minimum Transformer Size (Unmanaged)	Peak Power (Partially Managed)	Minimum Transfomer Size (Partially Managed
20%	16 existing transit BEBs, 33 paratransit ZEVs	771 kW	1,050 kVA	548 kW	750 kVA
100%	65 transit BEBs, 31 paratransit ZEVs	6,214 kW	8,350 kVA	2,947 kW	3,800 kVA

MODELED BEV CHARGING DEMAND – FUTURE MOBILITY PLAN COVERAGE SCENARIO

The load profiles calculated for the scenario utilizing 240-kW charging ports indicates that charging the full fleet of 107 BEBs at 240kW at the Maintenance Center utilizing unmanaged charging would result in a daily peak power of 10,560 kW, requiring a 14,700 kVA transformer. Managed charging would result in a daily peak power of 6,093 kW, requiring a 8,500 kVA transformer. The total daily energy need for the Future Mobility Plan Coverage Scenario with endpoint charging at the Maintenance Center is 85,039 kWh independent of charger rating (Figure 5-6).

The cumulative layover energy usage for endpoint charging (not shown) is 7,253 kWh/day.

Figure 5-6: Daily load profile at the Maintenance Center for Future Mobility Plan Coverage Scenario

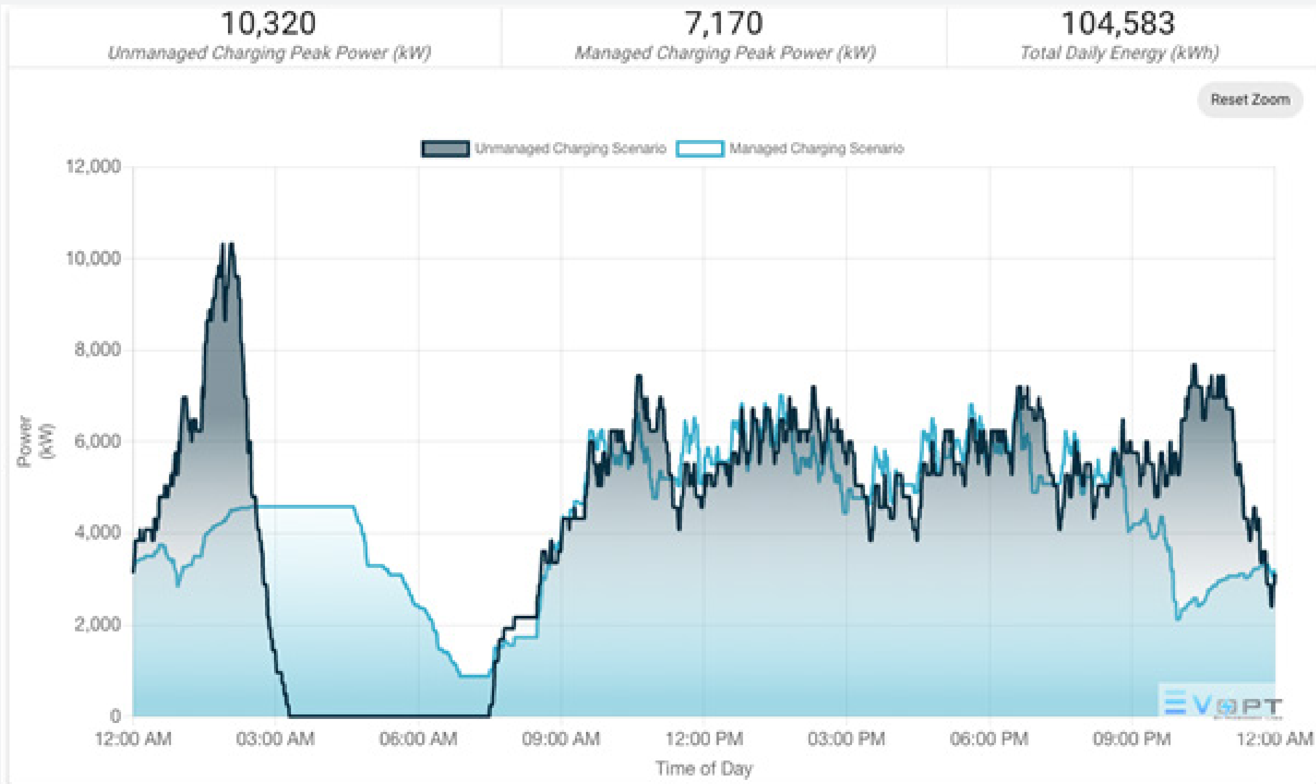


MODELED BEV CHARGING DEMAND – FUTURE MOBILITY PLAN RIDERSHIP SCENARIO

The load profiles calculated for the Future Mobility Plan Ridership scenario utilizing 240-kW chargers and charging 114 BEBs at 240kW at the Maintenance Center utilizing unmanaged charging would result in a daily peak power of 10,320 kW, requiring a 14,350 kVA transformer. Managed charging would result in a daily peak power of 7,170 kW, requiring a 10,000 kVA transformer. The total daily energy need for the Future Mobility Plan Ridership Scenario with endpoint charging is 104,583 kWh, independent of charger rating (Figure 5-7).

For the Future Mobility Plan Coverage Scenario, the cumulative layover energy usage for endpoint charging (not shown) is 3,603 kWh/day.

Figure 5-7: Daily load profile at the Maintenance Center for Future Mobility Plan Ridership Scenario with Maintenance Center and endpoint charging



Key Findings

- The deployment of the 16 existing transit BEBs charging at 60 kW charging at the maintenance facility will require 5,015 kWh daily.
- The deployment of the 49 future BEBs charging at 240 kW at the Maintenance Center will require 28,182 kWh daily.
- The deployment of the 31 paratransit ZEVs charging at 19.2 kW will require 2,256 kWh daily.
- A fully electric transit fleet, including paratransit, will have a peak power of 2,946 kW with managed charging and require a 3,800 kVA transformer at the Maintenance Center.

Recommendations

- GTA can use the results of the energy load profile to discuss the pathway for incremental fleet electrification with the local utility to assess what infrastructure is needed at each stage and plan the timing and costs of upgrades accordingly without causing service disruption.
- The energy load analysis should be refined over time for both the transit and paratransit fleets to reflect changes in vehicle battery technologies that might affect future procurement and operational decisions in terms of charging in the maintenance facility vs. on-route, and the potential for splitting blocks.

FTA Element 6: Human Resources Analysis

6

FTA ELEMENT 6:

Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers of the applicant to operate and maintain zero emission vehicles and related infrastructure and avoid displacement of the existing workforce.

Successful implementation of ZEFTP requires that GTA's workforce has the knowledge, skills, and capacity to support the new vehicles and equipment. This section compares the skills, training, and credentials needed to the worker skills and knowledge that already exist to identify skills gaps and recommend a training plan to address the gaps. This section also identifies strategies to protect and engage GTA's existing workforce and meet future staffing needs.

Skills, Training, And Credentials Needed

This section identifies the skills, training and credentials required to maintain and operate the proposed fleet and associated infrastructure.

NOTE: The elements may be vehicle-specific, and some may not be potentially determined until the Transit Vehicle Manufacturer (TVM) is selected. Consultation with the utility provider may also be appropriate during this step.

SKILLS IDENTIFICATION

Identifying the skills needed for technicians to safely repair and maintain ZEBs is a first step to transitioning from more traditional buses. Mastering basic electrical/electronic (E/E) skills becomes a foundation for all other ZEB skills to follow. The learning objectives contained in the American Public Transportation Association's (APTA) recommended training practice titled Training Syllabus to Instruct/Prepare for the Automotive Service Excellence (ASE) Transit Bus Electrical/Electronics Test represents an industry consensus for those basic but essential E/E skills. For example, before technicians can work on the high-voltage (HV) aspects of ZEBs that are upwards of 800 volts, they must first acquire the skills associated with aspects of 12 and 24 volts.

Foundational skills include:

- The ability to read basic wiring diagrams
- Safely handle low-voltage batteries
- Troubleshoot and repair basic circuit faults
- Inspect and test relays
- Demonstrate proficient use of digital multi-meters (DMM)
- Repair wiring and terminals among other tasks

Once basic electrical skills have been mastered, the next set of skills address the basic aspects of multiplexing, a more advanced and streamlined structure that essentially controls the vehicle's electrical system, replacing an extensive system of electrical hard wiring.

Multiplexing skills include the ability to:

- Read and interpret ladder logic diagrams
- Use LED indicator lights to troubleshoot the system
- Identify symbols used for input and output electrical signals

The next set of skills pertain to electronics, the branch of physics that deals with solid state devices using transistors, microchips, and other such components. Virtually, every bus system is now controlled by electronic devices, the usage of which has increased significantly with the introduction of ZEBs.

Electronic skills include:

- The ability to inspect and test capacitors, diodes, and other electronic modules
- Differentiate between analog and digital signals
- The ability to describe the purpose of data communication protocols CAN/SAE J1939 and SAE J1708
- Differentiate between direct current (DC) and alternating current (AC)
- Demonstrate use of an oscilloscope and a graphing multimeter
- Inspect and troubleshoot gateway modules

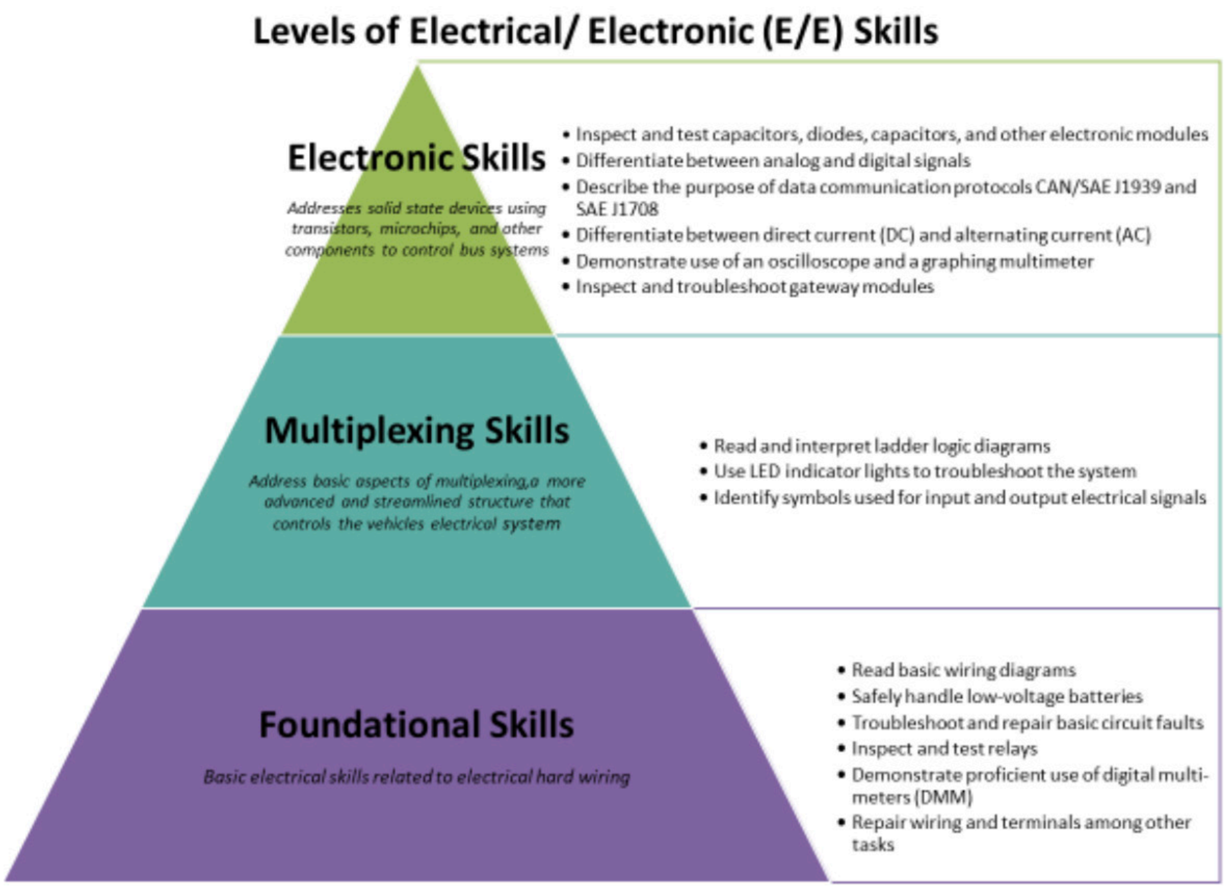


Figure 6-1: Levels of EE Skills

Again, the full range of foundational E/E skills are clearly identified in APTA's training standard mentioned above. This training standard and all others in the APTA series were developed on a joint labor-management basis.

Once foundational E/E have been acquired, the next step in the skills identification process is to become familiar with ZEBs in general, including the overall architecture of BEBs as well as FCBs, and their major components and functionality. Introductory training should also include preventive maintenance requirements, purpose and use of personal protective equipment (PPE), and the various approaches to propulsion. Next are skills pertaining to the specific HV aspects of ZEBs including all related subsystems. Identifying these more advanced skills is not straight-forward and the Transit Workforce Center (TWC) and APTA are just now working to establish a national training standard for ZEBs. However, there are three resources that can be extremely helpful in identifying ZEB skills in the absence of a ZEB national standard currently in development.

- The first resource used in identifying ZEB skills should be the original equipment manufacturers (OEMs), the companies that produced the vehicles, as they are the most specific.
- A second resource is the APTA Training Syllabus to Instruct Bus Technicians on Hybrid Drive Systems Operations and Maintenance. Since hybrids use a combination of combustion engine and HV battery propulsion, there are several skills contained in that training standard that also apply to ZEBs. Skills include demonstrating the ability to identify safe levels of voltage, explaining the significance of orange (HV) cables, using specialized tools for HV testing, using insulated tools, and identifying and demonstrating the use of PPE when working on HV applications.
- A third resource for identifying skills needed to maintain and repair ZEBs are the learning outcomes (also referred to as learning objectives) identified in the Electrified Transportation Pro+ Training and Certification program developed in part with the Society of Automotive Engineers (SAE) for Evs in general. Skills include the ability to demonstrate the general sequential steps in performing the disabling of a high voltage system on a live vehicle, identify components of a powertrain transmission or drive unit system, and others.

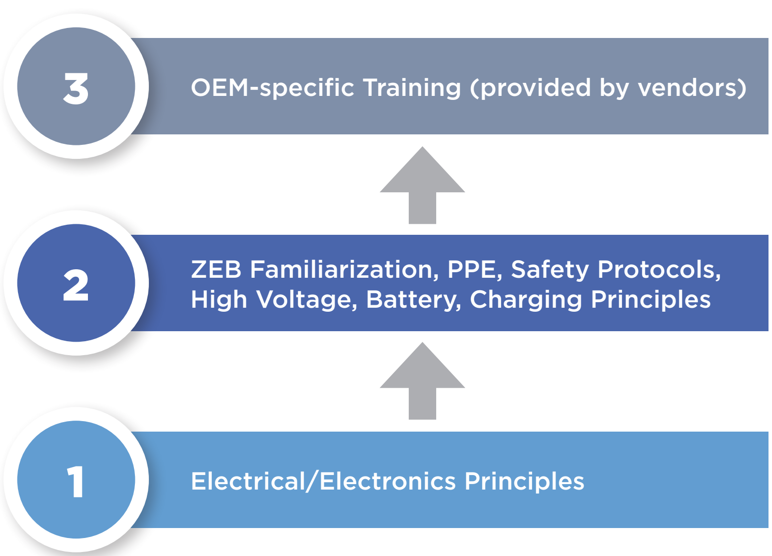


Figure 6-2: Resources to Identify ZEB Skills

TRAINING

Identification of ZEB training should follow the skills identified above. In other words, the training provided to technicians needs to be effective at producing the skills needed to safely and effectively maintain and repair these highly complex vehicles. Figure 6-2 below shows the potential training progression for ZEBs, starting with training that achieves basic E/E skills, provides foundational knowledge of how ZEBs operate, allows technicians to properly use PPE, understand HV safety, and become familiar with ZEB preventive maintenance requirements and the various approaches to propulsion battery charging. All of this training prepares technicians to be in a better position to then receive product-specific training from the OEMs.

When identifying training requirements, GTA should also consider apprenticeship, a time-tested training program for developing technical skills. Although classroom training plays an important part in apprenticeships, the majority of training is provided through on-the-job learning (OJL), primarily through experienced mentors who work with apprentices to perform actual job tasks. The transit industry has a fully developed Bus Maintenance Apprenticeship Framework, approved by the Department of Labor (DOL). It is based in large part on learning objectives included in the Automotive Service Excellence (ASE) task list and APTA training standards. The apprenticeship framework includes learning objectives in all bus areas, including propulsion, steering and suspension. Of interest to ZEBs are Job Function #2, Electrical & Electronics, and Job Function #4, and Propulsion, especially the sections on hybrid propulsion and electric propulsion, all of which are contained in the Apprenticeship Framework.

When identifying training, GTA should also consider some of the more advanced training delivery technologies effective at engaging students to learn. Frequent use of computer-based programs, training aids, and mock-ups, combined with OJL and other forms of teaching, allow students to become engaged in the learning process. For example, instead of learning how to use a DMM on a live (powered) electrical circuit, students can learn on a computer-based program that simulates operation where a mistake will not damage equipment or cause personal injury. Although not yet widely available, GTA should also become aware of augmented reality (AR) and virtual reality (VR) training platforms. APTA will release the Recommended Practice for Zero Emission Bus Maintenance Training in November 2023. This guide will outline a complete curriculum for training programs targeted at upskilling transit bus maintenance technicians to safely and effectively work on ZEBs and can be used to indentify the skills necessary for the technology of GTA's choosing.

CREDENTIAL REQUIREMENTS

As of now, there are no national credentialing requirements for ZEBs. Preliminary discussions are being had with Automotive Service Excellence (ASE), the organization responsible for developing a certification program for bus maintenance technicians, about including ZEBs. If ASE decides to incorporate ZEBs into their transit bus series, this could serve as one credentialing opportunity. Some agencies have confidence in the ASE process while others contend that the testing series first needs to be supported by adequate training, and that successfully passing a written test does not always translate into a technician's ability to perform job tasks. Any ZEB certification program should be done on a joint labor-management basis where both sides agree to the certification protocols and application, where adequate training is provided to allow technicians to achieve the certification, and where technicians are not disciplined for not passing the required testing. Instead, they should be given whatever training is needed to achieve certification.

In the absence of a formal ZEB certification, GTA could require ZEB OEMs, as part of the procurement process, to produce standard operating procedures (SOPs) for critical safety-related ZEB tasks such as proper use of PPE, HV insulated tools, working on ZEB roofs that house HV equipment, and de-energizing BEBs so technicians can work on them knowing the HV has been safely isolated. SOPs contain step-by-step procedures that must be followed properly and safely to perform given job tasks. Once the OEMs have established these SOPs, GTA could then have the OEMs or agency subject matter experts (SMEs) confirm that the SOPs are properly being followed by technicians. The SOPs could also be used as a training aid and made readily available to ZEB technicians as an on-the-job reference when needed.

For basic E/E certification, GTA could utilize the ASE Electrical/Electronic Systems (H6) test. As noted earlier, technicians should only be required to take this ASE test if first provided with the comprehensive training, and if both labor and management agree to the process. Since the ASE test is a written one, GTA should also consider working on a joint labor-management basis to develop hands-on assessments, either in place of or as a supplement to, the ASE test to confirm basic E/E competency.

Assessment of Existing Worker Skills

This section describes how the skills of existing workers will be assessed and identifies the estimated number and percentage of workers who may be impacted by this transition as a result of new skills requirements. The assessment includes both transit technicians and bus and rail operators.

ASSESSING BASELINE SKILLS/CREDENTIALS

To assess the baseline skills of existing technicians, GTA should first consider technicians' proficiency at diagnosing and repairing E/E faults found on more traditional buses with 12- and 24-volts electrical systems. Technicians will not be able to effectively transition to the skills needed for ZEBs with upwards of 800 volts unless they first acquire foundational E/E skills, understanding that these are among the most difficult to obtain. Mastering E/E related tasks are far more difficult than learning more traditional job tasks. Whereas mechanical related faults are easier to diagnose, an oil leak for example can be detected visually. Finding electrical faults are more difficult because electrons moving through wires cannot be seen. Furthermore, diagnosing these faults typically requires special tools and instruments.

One basic way to measure baseline E/E skills is to interview the shop floor supervisors, those who typically assign workers to jobs. Every maintenance workshop has workers who excel at diagnosing and repairing electrical faults, so-called "go-to" technicians, and shop supervisors and foremen certainly know who they are. Supervisors/foremen can estimate to some level of certainty the percentage of technicians proficient at using a DMM and other instruments to diagnose and repair electrical faults. Although not scientific, it does provide a starting point for assessing these essential foundational skills.

Another more quantifiable method is to determine those technicians that hold ASE transit bus certifications for Electrical/Electronic Systems (H6). Technicians with similar ASE electrical certifications from the automobile and heavy-truck sector should also be included and classified. ASE certifications are tests that confirm a technician's ability to correctly answer a series of written questions related to job tasks. Many contend that this method of testing accurately reflects technical skills in specific job areas. Others maintain that passing a written test does not necessarily guarantee that a technician can actually do the work. Regardless, ASE certifications are widely regarded in the ground transportation industry as a standardized way to classify those with requisite job skills. In addition to ASE certifications, E/E training provided by the agency, vendors, technical schools and community colleges, previous employers, and third-party training providers should be included in the skills assessment mix.

Once technicians' baseline E/E skills are assessed, GTA can move on to assessing technician knowledge and skills in specific ZEB related technologies.

ESTIMATED NUMBER OF WORKERS IMPACTED

Based on whether technicians will be specialized or not, the first step in this process is to determine the total number of technicians that GTA expects will work on ZEBs. As mentioned earlier, the pool of these workers should first be expected to have a solid set of prerequisite E/E skills as determined by skill gap survey results, ASE electrical certification, and/or recognized by shop supervisors/trainers/leads as possessing these skills. Labor and management should then jointly develop the criteria for establishing acceptable levels of foundational E/E skills. Those expected to work on ZEBs who do not yet have the requisite skills will require additional training to bring their skills to an acceptable level, and therefore will be impacted by the transition.

Given that the demand for ZEBs will increase, GTA should consider bringing all technicians to an acceptable level of foundational E/E skills. Doing so will not only help with transition to ZEBs but will also help with the repair of traditional buses where virtually every system has an electrical element to it.

It is safe to assume that those technicians who meet the criteria for possessing baseline E/E skills will also be impacted by the transition in that they will need some level of ZEB training to acquire needed skills. Those with existing hybrid-electric skills will need less training, as these buses already have electric propulsion; those without hybrids will need more. Regardless, all will need familiarization training, HV safety training, and training related to the unique features found on ZEBs.

Agencies may want to consider estimating the number of workers impacted by the transition by classifying them by the following training requirement areas:

- Basic E/E Training
- Multiplex Training
- Advanced E/E Training
- Basic ZEB Training (Familiarization, Preventative Maintenance, etc.)
- Advanced ZEB Training (Diagnostic Troubleshooting, etc.)

In summary, it is expected that all technicians may be impacted by the transition to ZEBs. All may need some level of E/E training to bring them up to an acceptable E/E level of proficiency or will require training related specifically to ZEBs. These training demands will decrease over time as skills are developed, but in the near term, it is expected that all technicians will need some form of training to become proficient at maintaining and repairing ZEBs. Using the results of skill gap analyses to categorize training needs by the classifications identified above will help quantify the impact.

160
Operators and Operator Supervisors affected

18
Technicians and Maintenance Supervisors affected

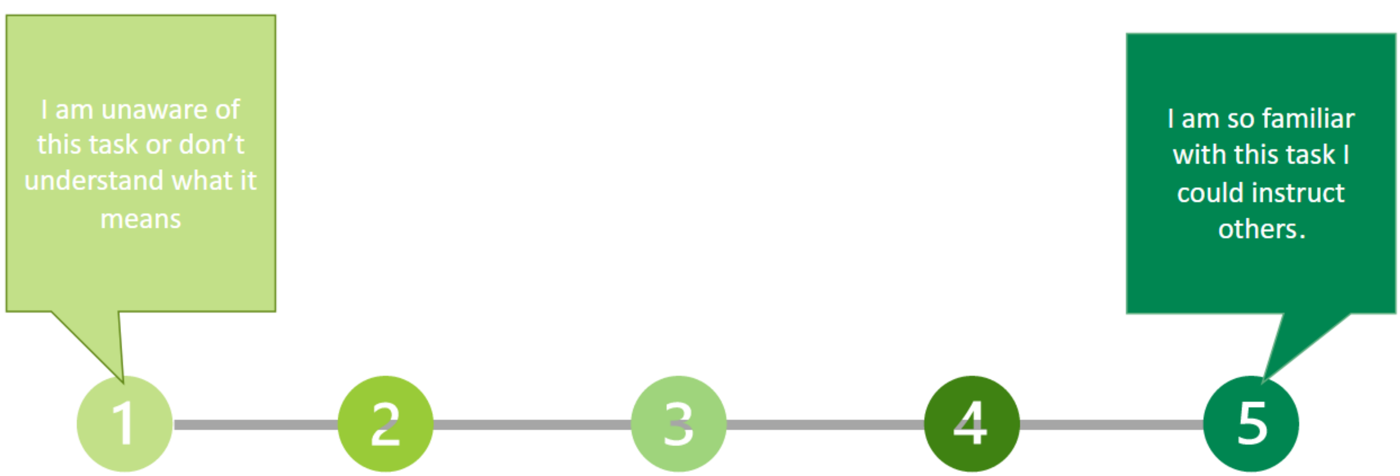
7
Management affected (introductory training)

SKILLS GAP

This section assesses and identifies any current or anticipated gaps between necessary workforce skills identified above and the existing baseline skills/credential requirements of the current workforce.

There are several ways to assess the gap between baseline skills and those skills required to maintain and repair ZEBs. One comprehensive method to assess E/E skills is to administer skills gap surveys, questionnaires that ask technicians to rate their own abilities. In those, technicians are asked to grade their own ability to perform job tasks on a scale from 5-1 where 5 is an indication that "You are so familiar with this task that you could instruct others," (highest skill level) and 1, an indication that "You are unaware of this task, or don't understand what it means" (lowest skill level). Other responses, 4 through 2, denote various skill levels in between.

Figure 6-3: Ability Scale 5-1



The numbering system allows agencies to identify each technician's skill level overall. It also identifies proficiencies in specific tasks making weak areas easy to identify. The higher the average score, the higher the skill level. The tasks used to establish skill levels for each subject area (e.g., brakes, engine, and E/E) come from the industry-recognized APTA training standards (also referred to as recommended practices) established for bus technicians on a joint labor-management basis to pass ASE certification testing.

In developing a skills gap survey to establish baseline E/E skills, GTA may use all or some of the job tasks identified in the APTA standard/recommended practice established specifically for E/E. Job tasks listed in this standard can then be turned into a skills gap survey. GTA may choose to insert all of the E/E tasks into the survey to assess the full range of a technician's E/E skills. However, the APTA standard is comprehensive and contains nine pages of tasks, so GTA may opt to pick those that best reflect a technician's skill level in a more abbreviated manner. A skills gap survey example is provided as a resource here that GTA can use as a starting point to develop their own survey. It contains an abbreviated list of electrical/electronics and ZEB specific tasks. In any case, labor and management should jointly develop the skills gap survey as a way to assess baseline E/E skills. Based on interviews with GTA staff, no concrete data was available to support understanding the skillset of the workforce, which is currently based on anecdotal evidence. GTA will likely need support to perform a skills gap analysis.

Additionally, any application of skills gap surveys should be done on a joint labor-management basis. First, it should be communicated to technicians that the sole purpose of the survey is to assess skills so training can be provided to enhance those skills. The survey results should not be used to discipline technicians or affect them negatively in any manner. Low scores, whether individually or in a group, should only be viewed as technicians needing additional training.

The surveys can be applied in one of two ways. One is to keep the skills gap survey anonymous. Doing so gives a generalized overview of skills but does not identify skill gaps for individual technicians. Agencies have found that anonymity helps to ensure that respondents will answer honestly. The other method is to include technicians' names so specific deficiencies for each technician can be identified and training tailored to fill those gaps. With either survey method, it is recommended that surveys be developed and administered on a joint labor-management basis as described above. In addition to not using the results of the survey to discipline technicians, survey results should not be shared outside a group of individuals jointly agreed upon and by both labor and management.

Once foundational E/E skills have been assessed, GTA has a tool by which to identify strengths and weaknesses in specific subject areas. Those with strong overall E/E skills could then become the primary candidates to be trained on ZEBs. They could also serve as mentors in an apprenticeship or other training program to transfer both basic E/E skills and more advanced ZEB skills to others lacking those skills.

Another skills gap survey could then be used to assess skills specific to ZEBs. Of major importance are those skills pertaining to HV safety where technicians not properly trained could find themselves victims of serious injury or death. Technicians with prior hybrid-electric bus experience will have an easier time closing the skills gap because they already have similar experience. Those without hybrid-electric bus experience will need comprehensive HV electrical training to ensure their safety. Until ZEB learning objectives are established through the industry vetting process, a process that is nearing completion, GTA should partner with OEMs to develop a more comprehensive ZEB skills gap survey.

Without exception, for obvious and significant safety reasons, technicians should not work on ZEBs until they have undergone asssessment and established the required competencies on HV safety. ASE has recently released their xEV certification that is focused mainly on battery-electric vehicles, and certifying that the technicians working in and around the HV systems are able to do so safely. While the majority of the focus is on the automotive industry, many of these concepts have crossover with transit. It may be beneficial to seek certifications for GTA's maintenance staff working on BEBs.

TRAINING PLAN

This section describes the training plan, including strategies and partners that will be deployed and resourced to help the agency transition existing workers to meet new skills requirements. The training plan may include in-house training, "train the trainer", registered apprenticeship, third-party training or similar. Identify any additional staff that will need to be recruited and hired.

The purpose of developing a training transition plan is to establish a pathway that will provide technicians with the skills needed to keep ZEBs, valued at about one million dollars each, working on a consistent basis to deliver passenger service and generate the environmental benefits they were constructed to achieve. The success of ZEBs is dependent in large part on a qualified staff of technicians achieved by first identifying their existing skill levels, establishing skills needed to make them proficient for maintaining ZEBs, and then providing training that will close any skills gaps.

While the steps needed to close the skills gap can be accomplished using a variety of scenarios, the very first step in this process should be to establish and engage a team of labor and management subject matter experts (SMEs) (L-M Team) committed to that goal. Participation by labor SMEs is essential for several reasons. A cooperative approach will likely cause technicians to be more accepting of and accurate in assessing their own skills when completing the skills gap survey. As recipients of training, technicians can also provide valuable feedback regarding training content and delivery methods effective at developing needed skills. Benefits to management include getting a workforce that is better prepared at keeping ZEBs operational and maximizing taxpayer investments.

The following is a sequence of steps that can be taken once the labor management team has been established. One such step should involve the joint labor-management team offering input into the technical specifications, especially the training requirements, and be taken prior to procuring ZEBs. This report on recommended procurement language contains a suggested list of courses, related hours, requirements for PPE, and other training that GTA can adopt.

When it comes to providing the actual training, OEMs can be a good source if steps are taken as part of the request for proposal (RFP) process to ensure that the training is effective and will produce the desired results. Under BIL, recipients of funding are to set aside five percent of funding for ZEB projects in the Buses and Bus Facilities and Low or No Emission competitive programs for workforce development, unless the recipient certifies a smaller percentage is necessary to carry out the training. The labor-management team should play a key role in determining how best to use those monies to acquire ZEB training that best accomplishes the goal of closing the skills gap with the understanding that in addition to the OEMs, other training providers and approaches identified below could supplement OEM training.

When establishing an effective training approach, the labor-management team should be aware that adult learning studies consistently show that about 70 percent of technical skills are best transferred by engaging students in the learning process through a combination of on-the-job exercises, computer simulations, training mockups, and advanced training delivery methods.

Apprenticeship programs are ideal in that the framework in association with DOL is based on the 70 percent learn-by-doing model. Apprentices need classroom instruction to learn underlying theory and principles. In classroom settings, instructors can and should use interactive learning and hands-on exercises as much as possible. Classroom instruction supports the majority of the time spent in the apprenticeship through on-the-job learning, where experienced technicians who are chosen to work as trainers and mentors transfer their knowledge and skills to the apprentice.

As described in Skills Gap, developing a skills gap survey on a joint labor-management basis becomes an important tool in assessing technician skills. Working together, the L-M Team should consider jointly developing two surveys, one to assess foundational E/E skills, and another for ZEBs. Those that excel in specific job tasks can be considered as mentors, and using information found in The Mentoring Guidebook, GTA can establish mentoring as a training method with guidance, suggestions, and examples.

Classifying technicians by their strengths and weaknesses in specific job areas allows GTA to target training as needed, thereby maximizing training resources.

Once training needs have been identified for specific technicians in specific skill areas, determining which training sources to use and how to prioritize the training is the next step. Given that there will be an immediate need for qualified ZEB technicians to be ready when these vehicles arrive, training should first be focused on those technicians that scored the highest on the E/E and ZEB surveys, have electrical ASE certifications, have hybrid bus experience if applicable, and have ZEB experience if applicable. Next would be to direct training to those technicians that scored in the midrange of the ZEB skills gap survey followed by those scoring midrange in the E/E survey.

A number of agencies have developed productive training partnerships with local community colleges, vocational schools, and technical colleges. These partnerships work most effectively when the colleges/schools and labor-management experts work together closely to ensure that the instructors understand the work, classroom components of the training cover areas directly useful for technicians, and the classroom work is integrated with OJL, and a range of interactive teaching methods and tools. In addition, GTA should contact the TWC by email at twc@transportcenter.com or on The Transportation Workforce Center webpage to request BEB Familiarization course material, to be directed to agencies known to have E/E materials available to the industry, or who have developed community college partnerships. Additionally, reference materials are available to help technicians correctly use a DMM. Fluke, a major supplier of DMMs, offers training on their website. Computer-based E/E troubleshooting training is available from Simutec, and hands-on electrical system training aids are available from Veejer.

SELECTION OF TRAINING PROGRAMS AND PARTNERS

This section identifies the process by which training programs and partners will be identified and selected.

Before writing up procurement specifications, consider involving the operators and technicians who will be directly affected by the introduction of the ZEBs. Their perspectives may influence many aspects of how to transition from current operations to the new technology. Hearing directly from the frontline workers about what is relevant for training will help inform what training specifications are needed in RFPs.

The vendors supplying the ZEBs and major related systems will have expertise in training needed for their specific equipment. In buying the bus, agency procurement officials should consider whether to also buy the needed training.

As mentioned elsewhere, two major areas of training may merit particular attention:

- Basic electrical/electronic skills; and
- HV safety.

Each OEM will have its own HV safety protocols and related training. It makes sense to use that training as a resource. GTA should develop in-house policies and procedures of their own on high-voltage safety. Similarly, first responders from local fire departments or Emergency Medical Technicians (EMTs) will need to know about the ZEBs and develop their own safety practices. Working together can enhance safety for all.

The skills gap on E/E systems creates its own set of dilemmas. OEMs may not be equipped or able to remedy this long-standing gap. GTA should consider creative approaches to achieve rapid learning gains on E/E systems. In choosing partners for this particular need, GTA and the joint labor-management training committee should be as specific as possible about the training need. As noted in Training Plan, community colleges or local Career Technical Education (CTE) providers could be excellent partners. Any training provider needs to show evidence that it has experience in workplace education and can provide evidence of success in training incumbent workers. Classroom training should be integrated with significant opportunity for hands-on practice.

In addition to these training partnerships, GTA should explore highly innovative training technology that allows workers to learn through gamification, virtual or augmented reality. The ability to train workers virtually on the use of DMMs allows for making and learning from mistakes with very low risk.

In the end, the best learning outcome derived from training is a technician's ability to properly and safely perform job tasks. Those tasks could be defined by a series of SOPs, step-by-step instructions for carrying out job tasks, developed by the OEMs or by GTA from established recommended practices. The key measure of any effective training program is its ability to convert instruction into actionable job tasks. Knowing how regenerative braking is used to help charge propulsion batteries is one thing, knowing how to diagnose and repair a related fault is entirely another.

PROTECTION AND EXPANSION OF THE WORKFORCE

Indicate the role training resources will play in supporting the recruitment, training and development of new workers, and what steps are being taken to ensure non-displacement of the existing workforce.

It is well-documented that the transit maintenance workforce is older than the general working population. Agencies are and will be facing retirements and, therefore, will need to hire new workers during the transition to ZEBs. Several major and interrelated concerns should be addressed:

- Agencies should ensure that the new technology does not displace current workers.
- New workers should learn the new technology.
- Transit agencies should be perceived as a source for good, family-supporting jobs.
- Transit agencies should consider addressing diversity, equity, and inclusion, particularly in the ranks of skilled maintenance workers.

Regarding the first concern, training for current workers so that they become proficient on ZEBs provides the primary means for GTA to ensure that no displacement occurs. The methods for determining what training is needed, ideas on how to begin planning and implementing a training program for incumbent workers, best practice examples, and resources are covered extensively throughout this analysis.

The full transition to a ZEB fleet will take time. During that transition, GTA will continue to need to maintain a legacy fleet. For some technicians approaching retirement, servicing that legacy fleet may be their primary job. Even if that is the case, many of these technicians need extensive training on E/E systems that are pervasive on these older buses. The small group of electronic specialists that have routinely performed work on multiplexing and other advanced electronic systems is the most likely to be occupied with new ZEB fleets. All workers in the garages will also need training and orientation on HV safety.

As agencies across the country establish comprehensive workforce development plans and training materials for the incumbent workforce, it is also clear that effective outreach will be needed to fill positions created by retirements. This challenge creates opportunities to recruit directly from the communities' transit serves, especially among underrepresented and disadvantaged groups, and, in doing so, to improve and strengthen diversity, equity and inclusion in the transit workforce, especially among the ranks of skilled technicians. GTA should consider the importance of partnerships with local education institutions, such as CTE/STEM high schools and community colleges, along with community-based workforce development organizations and state and local Workforce Investment Boards.

In integrating targeted outreach into a workforce development plan, it is important to consider the current workforce itself as a central resource. A number of agencies have strengthened and diversified their technical workforce through programs offering in-house training programs for workers in other job categories who want to move into skilled technician positions. In addition, industry experience has demonstrated that some of the most effective recruiters are current workers who know the work and come from the communities that agencies are targeting.

WORKER ENGAGEMENT

This section explains how current workers were engaged in the development of these transition strategies and how they will be consulted in finalizing any plans and training to meet the needs of this transition.

To ensure a high-quality workforce transition plan, full and ongoing involvement of the frontline workforce in all decisions around the implementation of the new ZEB technology constitutes a critical underlying element of that plan and its implementation. Even though this question comes near the end of the series, the process of engaging stakeholders from the workforce should be part of the entire workforce transition process, from the earliest planning stages through each successive step.

The message that frontline worker involvement is necessary needs to come from the highest levels of management and be consistently communicated and implemented throughout the entire organization. In a unionized agency, the General Manager (GM) and the local union president need to meet directly and choose people trusted by both sides to form a top-level labor-management team. That labor-management team then needs to develop effective mechanisms to engage workers, managers, and supervisors in training partnerships and opportunities for input that reach to the shop floor, incorporating the experience and expertise of the workers who know the work and the training needs. The entire organization should receive regular communications signed by the agency GM and the local union president on the urgency of working jointly and on updates about the partnership's progress. The synthesis report contains examples of joint labor-management partnership best practices that can be accessed here.

In the critical area of strategies that support the current workforce and avoid displacement, the previously linked report on recommended procurement language includes example language that would require the vendor to provide more training and training more in line with the need to raise the skill levels of the transit workforce to the challenge of working on a fully electric bus. GTA can consider bringing the trainers and expert technicians into the process of meeting with the vendors, asking questions, and writing and/or reviewing the training specifications in the RFPs. These steps provide a voice for those who will be directly affected by introduction of this new technology in how they adapt to and learn the new technology.

ZEB technology provides many technical challenges. This is a learning process for all involved, including the OEMs. For some period, GTA may want to rely on a warranty from the OEM to maintain the equipment. That is standard process (or practices) in most procurements, even in purchases with fewer technical challenges. Transit workers may resist the reliance on warranty work for good reasons; with labor-management and vendor collaboration on training, work at the agency can be performed by the incumbent workforce. Getting the existing workforce engaged in these repairs as early as possible is important because the warranty period eventually ends, and technicians must be prepared with needed skills to take over. It is recommended that GTA institute a policy that whenever possible, a technician be assigned to an OEM field service representative performing warranty or diagnostic work.

Here again is where there are significant advantages and opportunities in involving the union and the frontline workers directly and early. If there is a clear understanding that the agency does not intend to rely on extended warranties, management, labor, and the OEMs can work together on skills transfer. Experts doing work onsite can take the time to explain what they are doing and to instruct agency technicians on how it is done. While there will be some differences among OEMs, many of the firms creating the ZEB technology feel challenged by the pace of change. The rising demand for their products puts pressure on them for more production. It inevitably happens that as the new buses have difficulties, OEM staff are stretched thin and, at times, unavailable when needed, to meet competing demands from different agencies. There is significant opportunity for OEM's, knowledgeable agency technical staff, and frontline technicians to work collaboratively on solutions that meet everyone's needs.

With ZEBs and high-voltage electricity, transit agencies and their workers face new safety challenges. Another provision in BIL requires FTA recipients of funding under 49 U.S.C. 5307 that serve urbanized areas with populations of 200,000 or more to form safety committees comprised of representatives of frontline employees and management. The purpose of these committees is to identify and recommend mitigations or strategies to reduce the likelihood and severity of safety risks. GTA should consider involving safety experts from the local union in evaluating and purchasing the necessary PPE, and should evaluate the feasibility of using the same safety experts to run classes on the necessary and proper use of PPE.

TRAINING RESOURCES

This section identifies how training needs will be paid for.

In approaching the question of how to pay for the needed training in the workforce transition plan, GTA should establish a reasonable estimate of how much the ZEB transition training will cost. For in-house training, considerations should be given to at least the following items:

- Classroom training hours
- Instructor hours (instruction and prep)
- Instructor hourly wages and benefits
- Instructor costs per class
- Instructor cost per trainee
- OJL training hours
- Mentor hours
- Mentor hourly cost
- Mentor cost per trainee
- Facilities cost
- Training materials/mock-ups/software/simulation cost

For example, assuming an electrical and ZEB fundamentals training program consists of 120 hours of classroom instruction and 950 hours of OJL, the cost to locally train one bus technician is in the ballpark of $10,000, factoring in only instructor wages and benefits and mentor pay. Based on the skills gap analysis, GTA would be able to estimate the number of bus technicians that need to go through the program.

Considering GTA’s limited capacity for in-house training programs, contacting other locations with more experience on ZEBs is a suitable option. APTA’s Zero Emission Bus Committee and Workforce Development Committee, Community Transportation Association of America (CTAA), Zero Emission Bus Resource Alliance (ZEBRA), West Coast Center of Excellence, Midwest Hydrogen Center of Excellence, and Washington State Transit Association’s Maintenance & Facilities Committee are all great starting points to connect with other agencies. In reaching out to locations that have more ZEBs operating, a number of questions should be asked.

- How much did their training cost?
- How well did it work?
- Did the bus manufacturer provide the quality of training expected and needed?
- Did the agency engage any third-party trainer or consultant on the training?

- Are there training modules developed that can be shared?
- From the lessons learned to date in the implementation, what would trainers advise for an agency starting now?

Once the estimated costs are established, GTA can take advantage of some potential funding built into BIL to pay for the training. Federal public transportation law permits FTA recipients to use up to 0.5 percent of grant funds received under the urbanized area program, state of good repair program, and bus and bus facilities program for workforce development activities eligible under 49 U.S.C. 5314(b), including on-the-job training, labor-management partnership training, and registered apprenticeships, and an additional 0.5 percent for costs associated with training at the National Transit Institute.

BIL also amended 49 U.S.C. 5339 to require that applicants for competitive Bus and Bus Facilities Program or Low and No Emissions Program funding for projects related to ZEVs must use five percent of the Federal award for workforce development to retrain the existing workforce and develop the workforce of the future, including registered apprenticeships and other joint labor-management training programs, unless the recipient certifies via the application that less funding is needed to carry out the plan.

Additional funds for training may be available through state or local agencies. State and local workforce investment boards can fund training incumbent workers; those same boards regularly fund training programs that result in well-paying jobs for displaced workers or economically disadvantaged youth or adults. During interviews, GTA managerial staff indicated that funding is available for training programs, but the funding has not been used due to a lack of training programs and partners. Some of this funding may be best used towards bolstering GTA’s internal training program and dedicating some staffing resources for a training coordinator position who’s responsibility it would be to build training partnerships with educational institutions, coordinate available training and track progress of staff throughout the training program.

Key Findings

- GTA has already received several BEBs and therefore has an advantage in their ability to upskill their workforce.

  Technicians have received BEB training from Proterra, and although GTA has indicated that the training needs supplementary information, it does accomplish the task of introducing the workforce to the subsystems of the vehicle.

  Operators have received training from the OEM on safe and efficient operations, allowing for maximized range.

- Estimated Number of Workers Impacted

  Operators and Operator Supervisors affected: 160

  Technicians and Maintenance Supervisors affected: 18

  Management affected (introductory training): 7

- Resources are available throughout the industry to supplement GTA's current program , and many transit agencies have begun to open their ZEB programs to all transit agencies throughout North America. AC Transit and King County Metro are two examples who may be leveraged should the need arise.
- Apprenticeship programs can offer a method of further supplementing the workforce training program
- North Carolina has multiple transit agencies with ZEBs deployed, and training programs either in progress, or being developed.

Recommendations

- In the GTA's next procurement, language should be included that focuses on the specific areas that have been described as lacking.
- As of November 1, 2023, APTA will have made public the Recommended Practice for Zero-Emission Bus Maintenance Training. This guide outlines the complete curriculum for training programs targeted at upskilling transit bus maintenance technicians to safely and effectively work on ZEBs. This guide can be used to identify the skills necessary for the technology of GTA's choosing.
- A recent skills gap analysis needs to be performed to understand where GTA's workforce is lacking in specific skill sets associated with BEBs.
  - GTA should plan to issue an RFP for support on performing this skills gap analysis as staff have indicated that they do not have the capacity or experience to perform one internally.
  - During interviews of management, maintenance, and operator staff, it was clear that the understanding of the skillset of the workforce was anecdotal at best. No concrete data was used to support what was perceived by managerial staff. Within the RFP, a provision for establishing a method to continue to validate skillsets of the workforce should be established. In this way, GTA will be able to continue to compare the skillsets of their employees and validate against what is needed in the future.

Key Findings (cont.)

- Technical schools, community colleges, and engineering universities are also reliable sources of supplemental training programs, and with the curriculum outlined in the Recommended Practice for Zero-Emission Bus Maintenance Training, GTA can pursue a partnership that creates a pipeline of future employees.
- While GTA has enough staff to supply for instructor-led training courses, their workforce would still benefit from a blended approach. Using new, emerging training technologies such as augmented reality, virtual reality, artificial intelligence, adaptive learning, and proven e-learning courseware will bridge gaps more efficiently.
- Apprenticeship programs may offer additional funding opportunities through the DOL or DOT, depending on the state requirements.
- Considering that GTA's experience with the Proterra training fell short of expectations, all manufacturers used in the future should be engaged early to determine their ability to deliver on training needed to close skills gaps. Where manufacturers are not able to provide adequate training, partnerships with colleges, for-profit institutions, or other agencies may become necessary.

Recommendations (cont.)

- GTA should explicitly communicate to their workforce that the skills gap analysis is not intended to discipline or penalize any individual or group, but rather to identify areas where training needs to be targeted.
- The ITLC is able to supply an example of an appropriate skills gap analysis for GTA's use.
- GTA can continuously collect skills gap analysis data throughout the training process to assess the effectiveness of the training being delivered, and make changes to the program as needed.
- Consider seeking certifications through ASE xEV certification program for GTA maintenance staff.
- Technicians and Operators should be involved in the process of choosing training partners, and defining the amount of training needed for each job category. Doing so will require the creation and empowerment of multiple joint committees. Establishing these committees, meeting with them at a regular cadence, and empowering them to make certain decisions or issue specific guidance has proven to be successful.
- GTA may consider requesting training program overviews or outlines from manufacturers during the RFP process.
- GTA may consider the opportunity of a training partnership with one or more of the other transit agencies in NC implementing ZEBs. transition to fully zero emission.

Key Findings (cont.)

- While GTA has enough staff to supply for instructor-led training courses, their workforce would still benefit from a blended approach. Using new, emerging training technologies such as augmented reality, virtual reality, artificial intelligence, adaptive learning, and proven e-learning courseware will bridge gaps more efficiently.
- FTA has included an additional 5% for frontline workforce development in all Low-No grants, and GTA should anticipate receiving the full funding for their training needs.
- FTA has included an additional 5% for frontline workforce development in all Low-No grants, and GTA should anticipate receiving the full funding for their training needs.
- Apprenticeship programs may offer additional funding opportunities through the DOL or DOT, depending on the state requirements.
- GTA investing in its workforce becomes a recruitment tool on its own. Building a structured approach that incentivizes employees to continue to learn and grow means that GTA's workforce will be better positioned to perform their duties, and that the workforce will have the desire to advance in their career.
- During interviews, GTA managerial staff indicated that funding is available for training programs, but the funding has not been used due to a lack of training programs and partners.

Recommendations (cont.)

- GTA should engage with NCWorks Commission or similar local workforce development boards to aid in targeted outreach during the transition to fully zero emission.
- Establishing a zero emission transition committee is highly recommended for GTA. The committee should consist of an even number of frontline workforce representatives and agency management. The committee should convene regularly and discuss operations, maintenance, safety, and any issues that may affect the entire agency or its customers.
- Some of the available training program funding may be best used towards bolstering GTA's internal training program and dedicating some staffing resources for a training coordinator position who's responsibility it would be to build training partnerships with educational institutions, coordinate available training and track progress of staff throughout the training program.

Key Findings (cont.)

- GTA's workforce plan strategies include:
  - Continue to involve frontline workforce in ongoing ZEB technology implementation decisions at every stage
  - Recommended Maintenance and Operator training courses - 18 technicians and supervisors, 160 operators and supervisors; apprenticeship training
  - Labor-management team to engage workers, managers and supervisors for input and training opportunities, and regular workforce communications
  - Procurements requiring vendors to provide training to meet workforce needs

Recommended Training Courses

Below are the recommended number of training hours to successfully transition the GTA workforce personnel to operating and maintaining ZEVs. Note that while the costs for training may vary based on location, an estimate of $65/learner/hour of training can be applied to calculate total cost.

Figure 6-1: Recommended Training Hours for GTA Workforce Training

Course	Description	Target Audience	Length (Hours)
Operator Orientation	Class should cover driver familiarity, operation of all vehicle systems including the wheelchair ramp, and Commercial Driver's License (CDL) pre-trip requirements for the safe operation of battery electric powered vehicles. This orientation should also cover familiarity of vehicle for safe operation and specific procedures that can be used to train First Responders.	Maintenance Personnel, Operations Personnel (Operators, Supervisors, Managers, etc.), First Responders	6 hours
Maintenance General Orientation	Climate Reality Project is a non-profit that works on training and educating people about climate solutions and energy transition around the world. The organization is working on major steps towards zero emissions. GTA may partner with the organization to enable knowledge sharing and best practices on reducing community and municipal emissions and to help staff and commuters learn about transit climate solutions.	Maintenance Personnel and Operations Personnel, if applicable	8 hours
Electrical and Multiplexing	Class should cover the non-propulsion electrical system and multiplex system. Class should cover the inspection, location, troubleshooting/diagnostics, maintenance and repair of voltage monitors, battery, equalizer, battery maintenance, print reading, CAN system, ladder logic, wiring color coding, harnesses, connectors, plugs, and schematics.	Maintenance Personnel	24 hours

Course	Description	Target Audience	Length (Hours)
Energy Storage & Management Systems	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance (preventive and corrective) and repair of the high voltage energy storage system, battery management system, and any related components, controllers, etc. The class should provide safety procedures for handling and working with a high voltage system, and power down procedures; general construction and principles of operation and troubleshooting; battery thermal management system, pumps/piping diagnostics, lock-out/tag-out, and assembly and disassembly procedures.	Maintenance Personnel	12 hours
Fuel Cell Systems	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance (preventive and corrective) and repair of the Fuel Cell, battery system, and any related components, controllers, etc. The class should provide safety; general construction, principles of operation and troubleshooting; battery thermal management system, lock-out/tag-out, and assembly and disassembly procedures.	Maintenance Personnel	12 hours
Propulsion System Familiarization/HV Safety	Class should cover fluid types, fluid quantities, fluid level checks inspection and maintenance of fluid types, (manual and electronic), fill ports and basic servicing of bus to include PM schedules and all related safety precautions. procedures for charging buses for quick or slow charge and cover all hazards, safety procedures, and PPE related to both types of charging.	Maintenance Personnel	16 hours

Course	Description	Target Audience	Length (Hours)
Charging System and/or H2 Fueling Equipment	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance (preventive and corrective) and repair of all aspects of the charging and/or H2 equipment.	Maintenance Personnel or Facilities Maintenance Personnel (Contractors, if applicable).	8 hours
HVAC System	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance (preventive and corrective) and repair of the HVAC system for both the vehicle itself and propulsion system to include: compressor, evaporator/condenser fans, motor drivers, recovery/recycling refrigerants, system operation, diagnostic software, bus interface electrical and mechanical drawings.	Maintenance Personnel	12 hours
Brake and Air Systems	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance and repair of air lines, valves, compressor, air dryer, tanks, plumbing diagrams, electrical interface, kneeling system and air suspension, inspection, location, troubleshooting, maintenance and troubleshooting, maintenance and repair of regenerative braking and foundation braking.	Maintenance Personnel	16 hours
Steering, Suspension and Axle Systems	Class should cover the inspection, location, troubleshooting/diagnostics, maintenance and repair of steering, suspension, and axle systems.	Maintenance Personnel	16 hours
Wheelchair Ramp System	Class should cover the inspection, location, troubleshooting/ diagnostics, maintenance (preventive and corrective) and repair of the wheelchair ramp system including automatic and manual operation.	Maintenance Personnel	4 hours

Course	Description	Target Audience	Length (Hours)
Entrance & Exit Doors	Class shall cover the inspection, location, troubleshooting/diagnostics, maintenance (preventive and corrective) and repair of coach assembly, door adjustments, fasteners, repairs, major repairs, windows, seat adjustments, interiors, doors, under-floor heater boxes, etc.	Maintenance Personnel	8 hours
Operator Staff Totals			**6-14 Hours** **$390 -$910 per participant**
Maintenance Staff Totals			**116-134 Hours** **$7,745 - $8,710 per participant**

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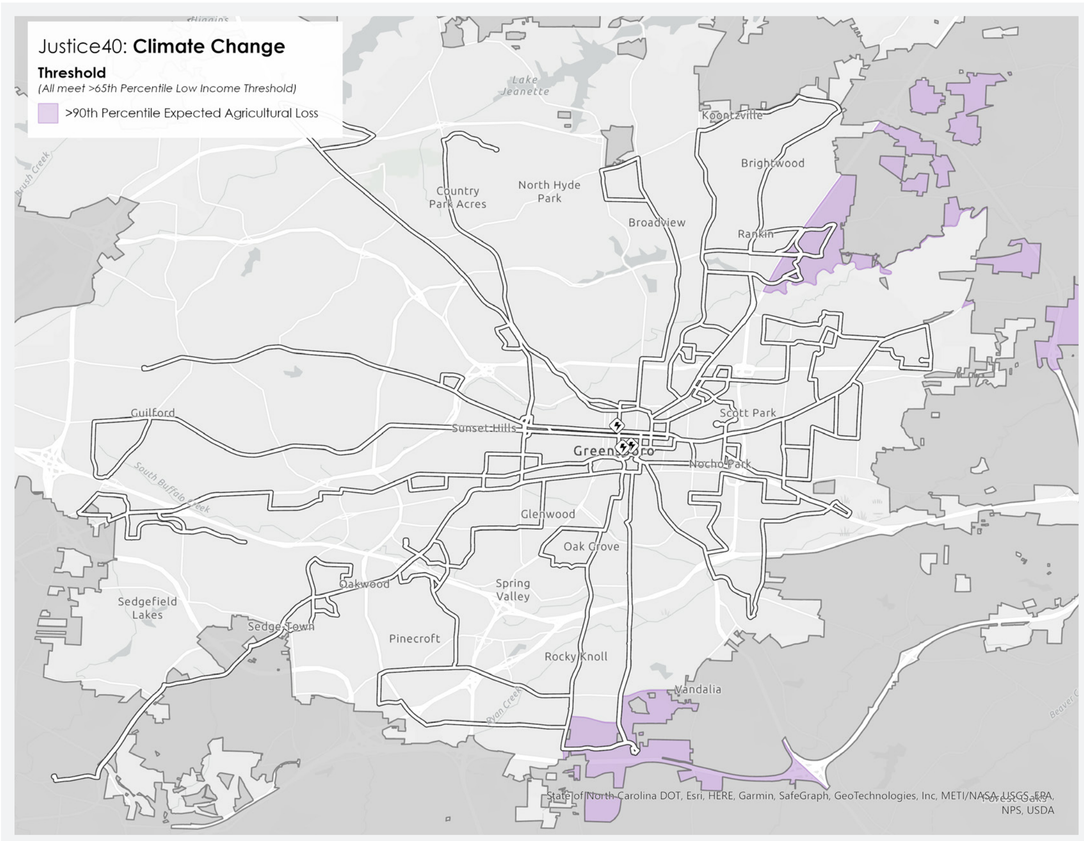
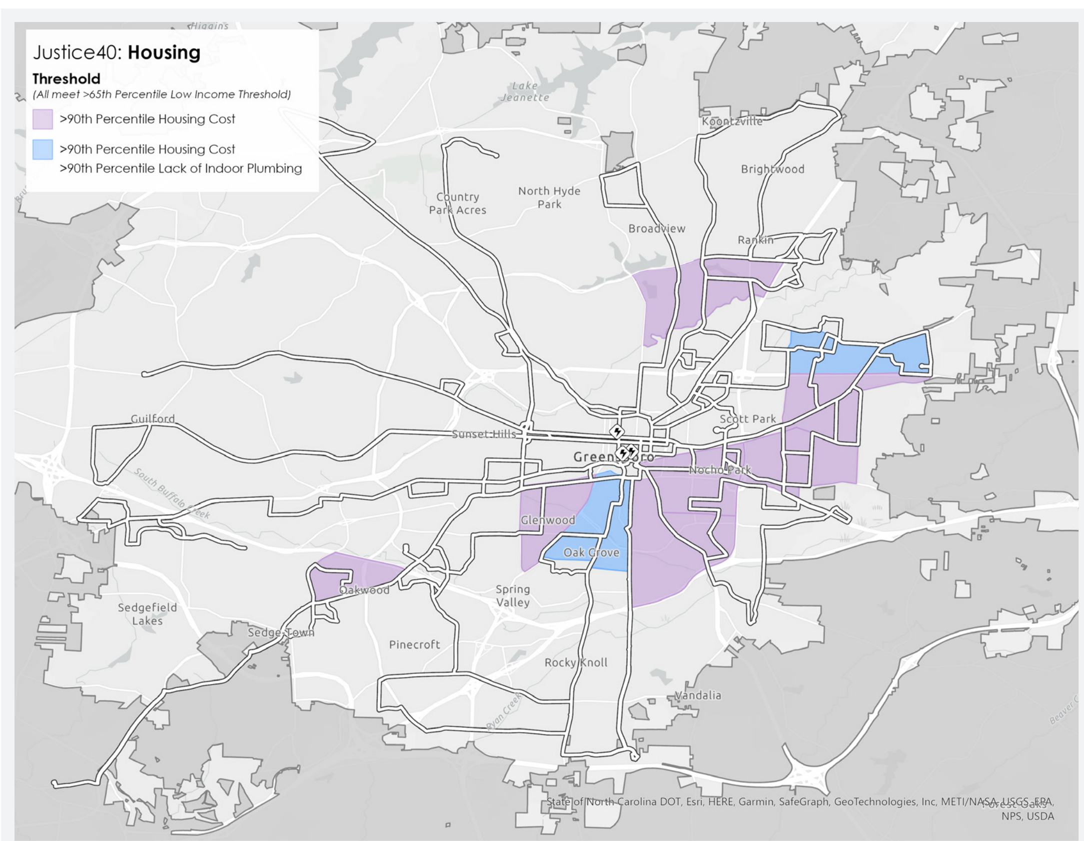
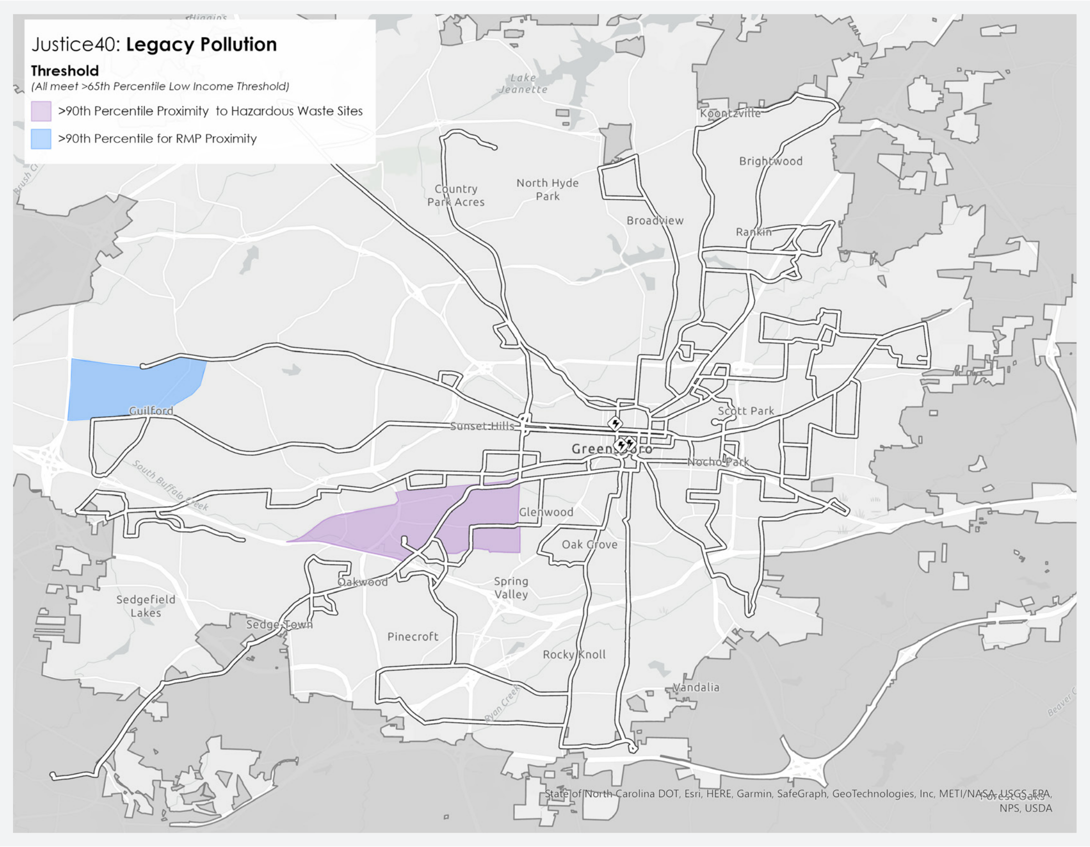
Deploying Battery Electric Buses at Scale: A Toolkit for New York State Transit Agencies (2021)

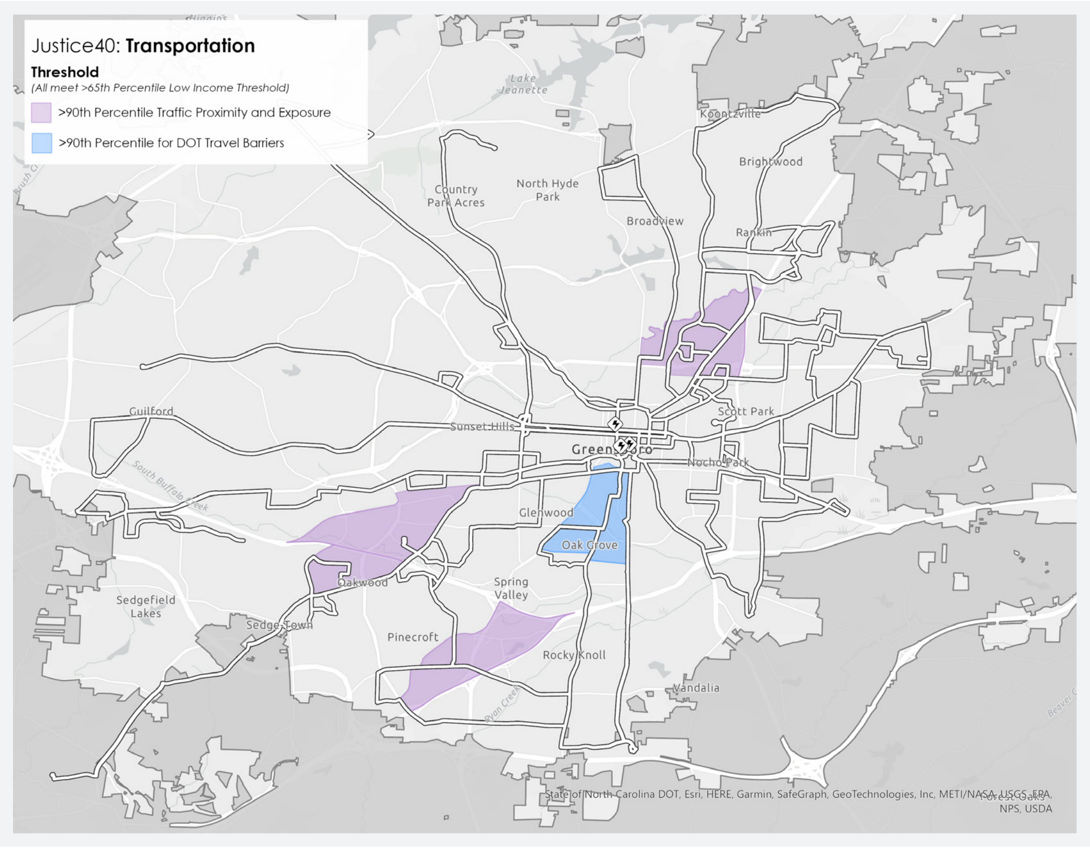
A study completed by the REPEAT Project out of Princeton University's Zero Lab

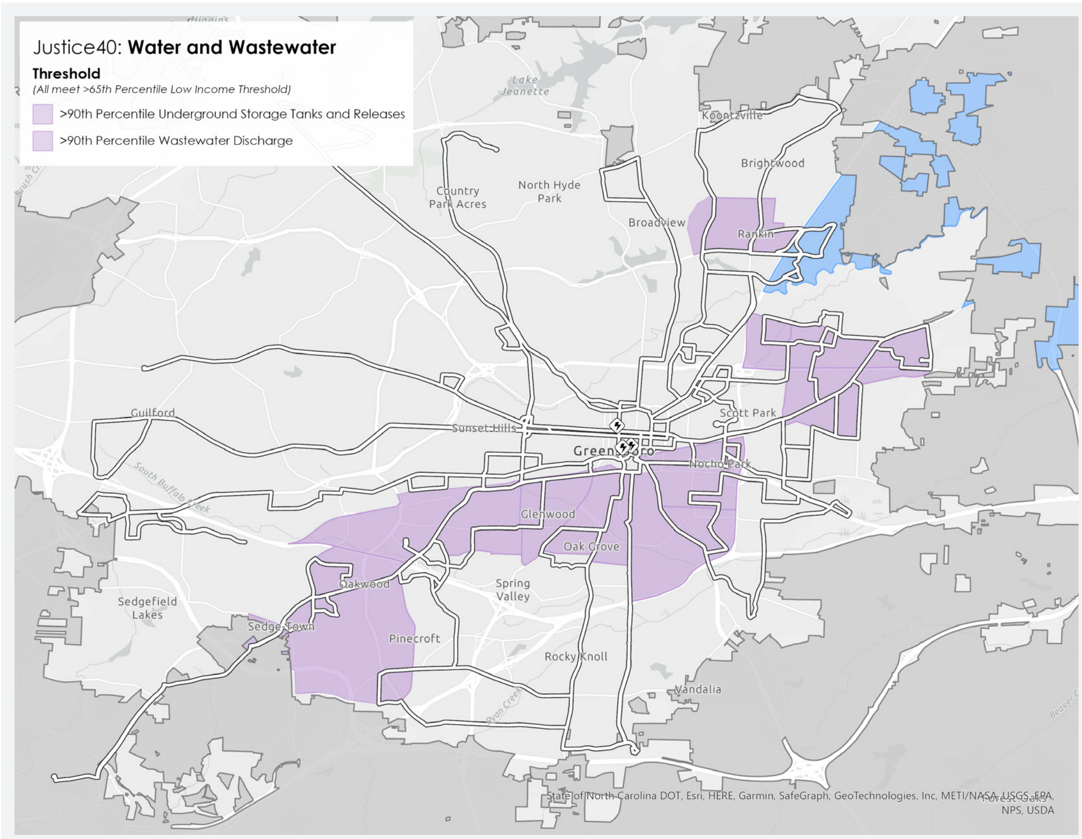
Appendix A: Justice 40 Screening






Justice40: **Legacy Pollution**
Threshold
(All meet >65th Percentile Low Income Threshold)
>90th Percentile Proximity to Hazardous Waste Sites
>90th Percentile for RMP Proximity
Lake Jeanette
Koontzville
Brightwood
Country Park Acres
North Hyde Park
Broadview
Rankin
Guilford
Sunset Hills
Scott Park
Greensboro
Nocho Park
South Buffalo Creek
Glenwood
Oak Grove
Oakwood
Spring Valley
Sedgefield Lakes
Sedge Town
Pinecroft
Rocky Knoll
Vandalia
State of North Carolina DOT, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA


Justice40: **Transportation**
Threshold
(All meet >65th Percentile Low Income Threshold)
>90th Percentile Traffic Proximity and Exposure
>90th Percentile for DOT Travel Barriers
Lake Jeanette
Koontzville
Brightwood
Country Park Acres
North Hyde Park
Broadview
Rankin
Guilford
Sunset Hills
Scott Park
Greensboro
Nocho Park
South Buffalo Creek
Glenwood
Oak Grove
Oakwood
Spring Valley
Sedgefield Lakes
Sedge Town
Pinecroft
Rocky Knoll
Vandalia
State of North Carolina DOT, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



Justice40: **Water and Wastewater**
Threshold
(All meet >65th Percentile Low Income Threshold)
>90th Percentile Underground Storage Tanks and Releases
>90th Percentile Wastewater Discharge
Lake Jeanette
Koontzville
Brightwood
Country Park Acres
North Hyde Park
Broadview
Rankin
Guilford
Sunset Hills
Scott Park
Nocho Park
South Buffalo Creek
Glenwood
Oak Grove
Oakwood
Spring Valley
Sedgefield Lakes
Sedge Town
Pinecroft
Rocky Knoll
Vandalia
State of North Carolina DOT, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

Table 12: Fleet Mix and Associated Lifecycle Costs | Business-as-usual Scenario (Costs in Thousands of Dollars, $2021)

Fleet Mix	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Totals
Diesel Buses in Fleet	71	60	40	37	37	22	22	14	14	5	2	0	0	0	0	0	0	0	0	0	0	324
Fuel Cost	$2,310	$1,830	$1,200	$1,090	$1,090	$560	$560	$290	$290	$110	$40	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,360
Emissions Cost	$430	$360	$240	$220	$220	$130	$130	$80	$80	$30	$10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,930
Purchase Cost (Annualized)	$3,340	$2,820	$1,880	$1,740	$1,740	$1,030	$1,030	$660	$660	$240	$90	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,230
Maintenance Cost	$2,490	$2,100	$1,400	$1,300	$1,300	$770	$770	$490	$490	$180	$70	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$11,340
Total Costs	**$8,560**	**$7,110**	**$4,720**	**$4,340**	**$4,340**	**$2,490**	**$2,490**	**$1,520**	**$1,520**	**$550**	**$220**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$37,860**
CNG Buses in Fleet	40	48	76	69	29	27	27	42	45	65	72	74	77	80	84	87	90	94	97	100	104	1,427
Fuel Cost	$520	$610	$920	$800	$310	$280	$280	$440	$470	$660	$740	$750	$770	$790	$820	$840	$870	$900	$920	$940	$970	$14,620
Emissions Cost	$210	$240	$380	$340	$140	$130	$130	$200	$220	$310	$340	$350	$360	$370	$380	$390	$400	$420	$430	$440	$450	$6,630
Purchase Cost (Annualized)	$1,920	$2,300	$3,650	$3,310	$1,390	$1,300	$1,300	$2,020	$2,160	$3,120	$3,460	$3,550	$3,700	$3,840	$4,030	$4,180	$4,320	$4,510	$4,660	$4,800	$4,990	$68,500
Maintenance Cost	$1,280	$1,530	$2,420	$2,200	$920	$860	$860	$1,340	$1,430	$2,070	$2,300	$2,360	$2,450	$2,550	$2,680	$2,770	$2,870	$3,000	$3,090	$3,190	$3,320	$45,490
Total Costs	**$3,920**	**$4,690**	**$7,370**	**$6,660**	**$2,770**	**$2,570**	**$2,570**	**$3,990**	**$4,280**	**$6,160**	**$6,830**	**$7,010**	**$7,280**	**$7,550**	**$7,910**	**$8,190**	**$8,460**	**$8,830**	**$9,100**	**$9,370**	**$9,730**	**$135,240**
RNG Buses in Fleet	0	0	0	10	50	75	75	75	75	75	74	74	74	74	74	74	74	74	74	74	73	1,248
Fuel Cost	$0	$0	$0	$10	$60	$80	$80	$80	$80	$80	$80	$80	$70	$70	$70	$70	$70	$70	$70	$70	$70	$1,270
Emissions Cost	$0	$0	$0	$40	$160	$220	$220	$220	$220	$220	$220	$200	$180	$180	$180	$180	$180	$180	$180	$180	$180	$3,350
Purchase Cost (Annualized)	$0	$0	$0	$480	$2,400	$3,600	$3,600	$3,600	$3,600	$3,600	$3,550	$3,550	$3,550	$3,550	$3,550	$3,550	$3,550	$3,550	$3,550	$3,550	$3,500	$59,900
Maintenance Cost	$0	$0	$0	$320	$1,590	$2,390	$2,390	$2,390	$2,390	$2,390	$2,360	$2,360	$2,360	$2,360	$2,360	$2,360	$2,360	$2,360	$2,360	$2,360	$2,330	$39,790
Total Costs	**$0**	**$0**	**$0**	**$860**	**$4,210**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,210**	**$6,180**	**$6,170**	**$6,170**	**$6,170**	**$6,160**	**$6,160**	**$6,160**	**$6,160**	**$6,160**	**$6,070**	**$104,300**
Battery Electric Buses in Fleet	0	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	100
Fuel Cost	$0	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$50	$40	$30	$30	$30	$30	$880
Emissions Cost	$0	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$10	$0	$0	$0	$0	$160
Purchase Cost (Annualized)	$0	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280	$5,510
Maintenance Cost	$0	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$70	$1,400
Total Costs	**$0**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$400**	**$390**	**$370**	**$370**	**$370**	**$370**	**$7,960**
Total Fleet	111	113	121	121	121	129	129	136	139	150	153	153	156	159	163	166	169	173	176	179	182	3,099
Fuel Cost	$2,830	$2,490	$2,170	$1,960	$1,510	$970	$970	$860	$890	$900	$910	$880	$890	$910	$940	$960	$980	$1,000	$1,020	$1,040	$1,070	$26,130
Emissions Cost	$640	$610	$630	$620	$530	$490	$490	$510	$530	$570	$580	$550	$550	$560	$570	$580	$590	$600	$610	$620	$630	$12,070
Purchase Cost (Annualized)	$5,260	$5,400	$5,800	$5,810	$5,810	$6,210	$6,210	$6,550	$6,690	$7,230	$7,380	$7,380	$7,520	$7,670	$7,860	$8,000	$8,150	$8,340	$8,480	$8,630	$8,770	$149,140
Maintenance Cost	$3,760	$3,700	$3,890	$3,880	$3,880	$4,090	$4,090	$4,290	$4,390	$4,710	$4,790	$4,790	$4,880	$4,980	$5,110	$5,200	$5,300	$5,430	$5,520	$5,620	$5,710	$98,020
Total Costs	**$12,490**	**$12,200**	**$12,490**	**$12,260**	**$11,730**	**$11,760**	**$11,760**	**$12,210**	**$12,490**	**$13,410**	**$13,660**	**$13,600**	**$13,850**	**$14,120**	**$14,480**	**$14,750**	**$15,020**	**$15,370**	**$15,630**	**$15,900**	**$16,180**	**$285,360**

Table 13: Fleet Mix and Associated Lifecycle Costs | RNG Focus Scenario (Costs in Thousands of Dollars, $2021)

Fleet Mix	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Totals
Diesel Buses in Fleet	71	60	40	37	37	22	22	14	14	5	2	0	0	0	0	0	0	0	0	0	0	324
Fuel Cost	$2,310	$1,830	$1,200	$1,090	$1,090	$560	$560	$290	$290	$110	$40	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,360
Emissions Cost	$430	$360	$240	$220	$220	$130	$130	$80	$80	$30	$10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,930
Purchase Cost (Annualized)	$3,340	$2,820	$1,880	$1,740	$1,740	$1,030	$1,030	$660	$660	$240	$90	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,230
Maintenance Cost	$2,490	$2,100	$1,400	$1,300	$1,300	$770	$770	$490	$490	$180	$70	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$11,340
Total Costs	**$8,560**	**$7,110**	**$4,720**	**$4,340**	**$4,340**	**$2,490**	**$2,490**	**$1,520**	**$1,520**	**$550**	**$220**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$37,860**
CNG Buses in Fleet	40	48	76	69	29	4	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	286
Fuel Cost	$520	$610	$920	$800	$310	$40	$40	$40	$40	$40	$40	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,420
Emissions Cost	$210	$240	$380	$340	$140	$20	$20	$20	$20	$20	$20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,430
Purchase Cost (Annualized)	$1,920	$2,300	$3,650	$3,310	$1,390	$190	$190	$190	$190	$190	$190	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,730
Maintenance Cost	$1,280	$1,530	$2,420	$2,200	$920	$130	$130	$130	$130	$130	$130	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,120
Total Costs	**$3,920**	**$4,690**	**$7,370**	**$6,660**	**$2,770**	**$380**	**$380**	**$380**	**$380**	**$380**	**$380**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$27,700**
RNG Buses in Fleet	0	0	0	10	50	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	74	1,259
Fuel Cost	$0	$0	$0	$10	$60	$80	$80	$80	$80	$80	$80	$80	$70	$70	$70	$70	$70	$70	$70	$60	$60	$1,250
Emissions Cost	$0	$0	$0	$40	$160	$220	$220	$220	$220	$220	$220	$200	$190	$180	$180	$180	$180	$180	$180	$180	$170	$3,340
Purchase Cost (Annualized)	$0	$0	$0	$480	$2,400	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,550	$60,430
Maintenance Cost	$0	$0	$0	$320	$1,590	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,360	$40,140
Total Costs	**$0**	**$0**	**$0**	**$860**	**$4,210**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,270**	**$6,250**	**$6,250**	**$6,240**	**$6,240**	**$6,240**	**$6,240**	**$6,240**	**$6,230**	**$6,150**	**$105,160**
Battery Electric Buses in Fleet	0	5	5	5	5	28	28	43	46	66	72	78	81	84	88	91	94	98	101	104	108	1,230
Fuel Cost	$0	$50	$50	$50	$50	$240	$240	$350	$370	$500	$540	$580	$600	$620	$640	$660	$660	$670	$690	$700	$720	$8,970
Emissions Cost	$0	$10	$10	$10	$10	$50	$50	$70	$80	$110	$120	$120	$130	$130	$130	$140	$140	$140	$140	$140	$150	$1,870
Purchase Cost (Annualized)	$0	$280	$280	$280	$280	$1,540	$1,540	$2,370	$2,540	$3,640	$3,970	$4,300	$4,470	$4,630	$4,850	$5,020	$5,180	$5,400	$5,570	$5,730	$5,950	$67,800
Maintenance Cost	$0	$70	$70	$70	$70	$390	$390	$600	$640	$920	$1,010	$1,090	$1,130	$1,180	$1,230	$1,270	$1,320	$1,370	$1,410	$1,460	$1,510	$17,220
Total Costs	**$0**	**$400**	**$400**	**$400**	**$400**	**$2,220**	**$2,220**	**$3,390**	**$3,630**	**$5,170**	**$5,640**	**$6,100**	**$6,330**	**$6,550**	**$6,860**	**$7,080**	**$7,300**	**$7,580**	**$7,810**	**$8,030**	**$8,330**	**$95,860**
Total Fleet	111	113	121	121	121	129	129	136	139	150	153	153	156	159	163	166	169	173	176	179	182	3,099
Fuel Cost	$2,830	$2,490	$2,170	$1,960	$1,510	$920	$920	$760	$780	$740	$710	$660	$670	$690	$710	$730	$730	$740	$750	$760	$780	$23,000
Emissions Cost	$640	$610	$630	$620	$530	$420	$420	$390	$400	$370	$370	$320	$310	$310	$320	$320	$320	$320	$320	$320	$320	$8,570
Purchase Cost (Annualized)	$5,260	$5,400	$5,800	$5,810	$5,810	$6,370	$6,370	$6,820	$6,990	$7,670	$7,860	$7,900	$8,070	$8,230	$8,450	$8,620	$8,780	$9,000	$9,170	$9,330	$9,510	$157,190
Maintenance Cost	$3,760	$3,700	$3,890	$3,880	$3,880	$3,680	$3,680	$3,610	$3,650	$3,620	$3,600	$3,480	$3,530	$3,570	$3,620	$3,670	$3,710	$3,760	$3,810	$3,850	$3,870	$77,810
Total Costs	**$12,490**	**$12,200**	**$12,490**	**$12,260**	**$11,730**	**$11,380**	**$11,380**	**$11,580**	**$11,820**	**$12,390**	**$12,530**	**$12,360**	**$12,580**	**$12,800**	**$13,100**	**$13,330**	**$13,540**	**$13,820**	**$14,040**	**$14,260**	**$14,480**	**$266,570**

Table 14: Fleet Mix and Associated Lifecycle Costs | Electric Focus Scenario (Costs in Thousands of Dollars, $2021)

Fleet Mix	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	Totals
Diesel Buses in Fleet	71	60	40	37	37	22	22	14	14	5	2	0	0	0	0	0	0	0	0	0	0	324
Fuel Cost	$2,310	$1,830	$1,200	$1,090	$1,090	$560	$560	$290	$290	$110	$40	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,360
Emissions Cost	$430	$360	$240	$220	$220	$130	$130	$80	$80	$30	$10	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,930
Purchase Cost (Annualized)	$3,340	$2,820	$1,880	$1,740	$1,740	$1,030	$1,030	$660	$660	$240	$90	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$15,230
Maintenance Cost	$2,490	$2,100	$1,400	$1,300	$1,300	$770	$770	$490	$490	$180	$70	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$11,340
Total Costs	**$8,560**	**$7,110**	**$4,720**	**$4,340**	**$4,340**	**$2,490**	**$2,490**	**$1,520**	**$1,520**	**$550**	**$220**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$37,860**
CNG Buses in Fleet	40	48	76	69	29	4	4	4	4	4	4	0	0	0	0	0	0	0	0	0	0	286
Fuel Cost	$520	$610	$920	$800	$310	$40	$40	$40	$40	$40	$40	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$3,420
Emissions Cost	$210	$240	$380	$340	$140	$20	$20	$20	$20	$20	$20	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1,430
Purchase Cost (Annualized)	$1,920	$2,300	$3,650	$3,310	$1,390	$190	$190	$190	$190	$190	$190	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$13,730
Maintenance Cost	$1,280	$1,530	$2,420	$2,200	$920	$130	$130	$130	$130	$130	$130	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$9,120
Total Costs	**$3,920**	**$4,690**	**$7,370**	**$6,660**	**$2,770**	**$380**	**$380**	**$380**	**$380**	**$380**	**$380**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$27,700**
RNG Buses in Fleet	0	0	0	10	50	75	75	75	75	75	75	68	60	52	45	37	31	27	18	11	3	862
Fuel Cost	$0	$0	$0	$10	$60	$80	$80	$80	$80	$80	$80	$70	$60	$50	$40	$40	$30	$30	$20	$10	$0	$910
Emissions Cost	$0	$0	$0	$40	$160	$220	$220	$220	$220	$220	$220	$180	$150	$130	$110	$90	$80	$70	$40	$30	$10	$2,410
Purchase Cost (Annualized)	$0	$0	$0	$480	$2,400	$3,600	$3,600	$3,600	$3,600	$3,600	$3,600	$3,260	$2,880	$2,500	$2,160	$1,780	$1,490	$1,300	$860	$530	$140	$41,380
Maintenance Cost	$0	$0	$0	$320	$1,590	$2,390	$2,390	$2,390	$2,390	$2,390	$2,390	$2,170	$1,910	$1,660	$1,430	$1,180	$990	$860	$570	$350	$100	$27,480
Total Costs	**$0**	**$0**	**$0**	**$860**	**$4,210**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$6,290**	**$5,680**	**$5,000**	**$4,340**	**$3,750**	**$3,080**	**$2,580**	**$2,250**	**$1,500**	**$920**	**$250**	**$72,180**
Battery Electric Buses in Fleet	0	5	5	5	5	28	28	43	46	66	72	85	96	107	118	129	138	146	157	168	179	1,626
Fuel Cost	$0	$50	$50	$50	$50	$240	$240	$350	$370	$500	$540	$630	$690	$760	$820	$880	$920	$950	$1,000	$1,050	$1,110	$11,240
Emissions Cost	$0	$10	$10	$10	$10	$50	$50	$70	$80	$110	$120	$130	$150	$160	$170	$180	$190	$190	$200	$210	$210	$2,290
Purchase Cost (Annualized)	$0	$280	$280	$280	$280	$1,540	$1,540	$2,370	$2,540	$3,640	$3,970	$4,690	$5,290	$5,900	$6,500	$7,110	$7,610	$8,050	$8,650	$9,260	$9,870	$89,630
Maintenance Cost	$0	$70	$70	$70	$70	$390	$390	$600	$640	$920	$1,010	$1,190	$1,340	$1,500	$1,650	$1,810	$1,930	$2,040	$2,200	$2,350	$2,510	$22,760
Total Costs	**$0**	**$400**	**$400**	**$400**	**$400**	**$2,220**	**$2,220**	**$3,390**	**$3,630**	**$5,170**	**$5,640**	**$6,630**	**$7,470**	**$8,310**	**$9,150**	**$9,980**	**$10,650**	**$11,230**	**$12,050**	**$12,870**	**$13,690**	**$125,930**
Total Fleet	111	113	121	121	121	129	129	136	139	150	153	153	156	159	163	166	169	173	175	179	182	3,098
Fuel Cost	$2,830	$2,490	$2,170	$1,960	$1,510	$920	$920	$760	$780	$740	$710	$700	$750	$810	$870	$920	$950	$970	$1,020	$1,060	$1,110	$24,930
Emissions Cost	$640	$610	$630	$620	$530	$420	$420	$390	$400	$370	$370	$310	$300	$290	$280	$270	$260	$260	$240	$230	$220	$8,060
Purchase Cost (Annualized)	$5,260	$5,400	$5,800	$5,810	$5,810	$6,370	$6,370	$6,820	$6,990	$7,670	$7,860	$7,950	$8,170	$8,390	$8,660	$8,890	$9,100	$9,340	$9,520	$9,790	$10,010	$159,970
Maintenance Cost	$3,760	$3,700	$3,890	$3,880	$3,880	$3,680	$3,680	$3,610	$3,650	$3,620	$3,600	$3,360	$3,260	$3,160	$3,090	$2,990	$2,920	$2,900	$2,770	$2,700	$2,600	$70,700
Total Costs	**$12,490**	**$12,200**	**$12,490**	**$12,260**	**$11,730**	**$11,380**	**$11,380**	**$11,580**	**$11,820**	**$12,390**	**$12,530**	**$12,320**	**$12,480**	**$12,650**	**$12,900**	**$13,060**	**$13,230**	**$13,480**	**$13,550**	**$13,790**	**$13,940**	**$263,660**

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