Battery Electric Bus Master Plan & Roadmap

Charleston Area Regional Transportation Authority Battery Electric Bus Master Plan

Final Draft Report

CARTA

March 2022

Stantec

Battery Electric Bus Master Plan and Roadmap

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CARTA

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BATTERY ELECTRIC BUS MASTER PLAN AND ROADMAP

Release Version

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0	Draft Report Issued to CARTA	03/31/2022
	Comments received	
1	Revised Report Issued to CARTA	
2	Final Report Issued to CARTA	

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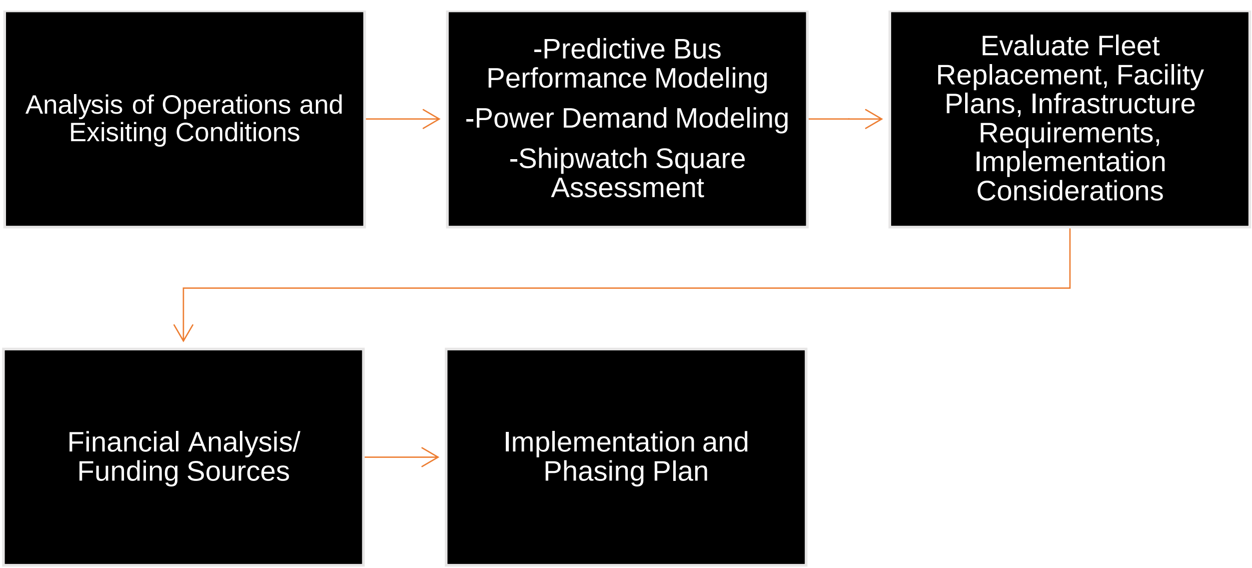
EXECUTIVE SUMMARY

The Charleston Area Regional Transportation Authority (CARTA) provides public transportation services to the residents and visitors of Charleston County via a combination of local fixed routes, express commuter routes extending service to Berkeley and Dorchester counties, and Downtown Area Shuttle (DASH) routes. In 2014, CARTA identified a need for a large capital effort to replace its aging rolling stock. As part of its Fleet Modernization Project, CARTA has developed a strategy to gradually transition to a battery-electric bus (BEB) fleet. CARTA received its first BEB in 2019, and currently operates six BEBs in revenue service, with 27 more scheduled for delivery in early 2022.

As part of its Fleet Modernization Project (as defined in Section 1.0) and to support regional sustainability goals, CARTA has committed to an eventual transition to a 100% battery-electric fleet for its fixed route services. Stantec has been retained by CARTA to help develop this comprehensive Battery Electric Bus Master Plan and Roadmap (BEB Master Plan), which includes assessing the existing conditions, performing predictive modeling of bus performance, determining the power, energy, and charging required to support the immediate and future BEB fleet, assessing route optimization and the fleet replacement plan as well as required infrastructure modifications and other implementation considerations and then conducting financial analysis and creating an implementation and phasing plan.

The figure below presents an overview of the BEB planning process that was used to develop a BEB Master Plan based on CARTA's operating conditions.



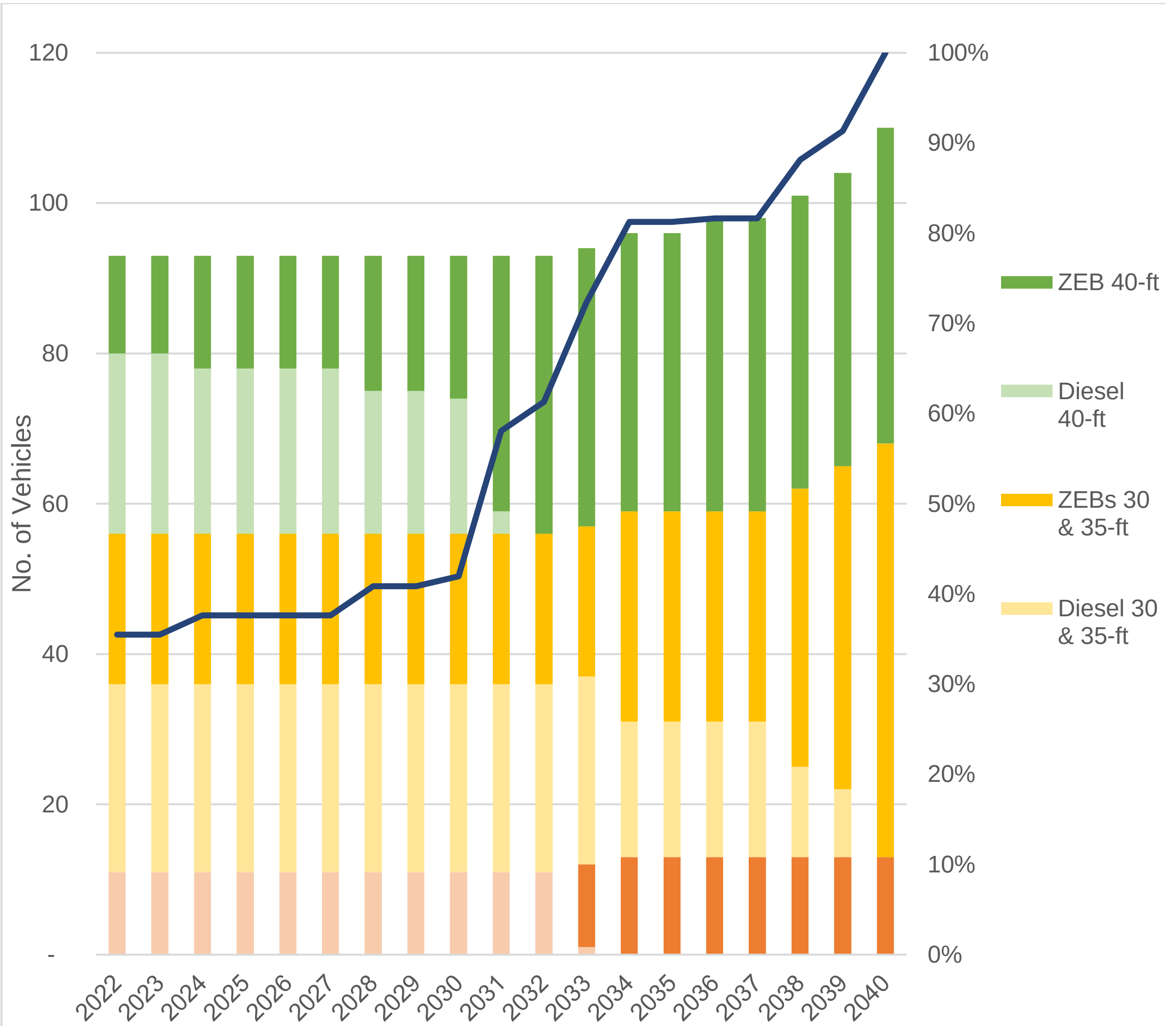
Stantec worked closely with CARTA's staff to first assess current conditions to understand the challenges, opportunities and needs around converting CARTA's operations to 100% BEB. A number of elements were assessed as part of the current conditions including (1) CARTA's existing in-service BEBs and their performance, (2) the infrastructure already installed at the facility, (3) the ongoing acquisition of BEBs and planning of associated charging infrastructure, and (4) how these existing and planned assets will fit into the BEB Master Plan.

The next step involved BEB route modeling and bus simulation of CARTA's service to understand both the feasibility and challenges to the electrification of service. The modeling revealed that while a minority of CARTA's service could be electrified in a one-to-one manner from diesel buses to BEBs, there are other strategies that CARTA needs to leverage to successfully electrify its services. These strategies include adjusting the vehicle blockingor rescheduling services to limit the mileage a BEB operates in a day, as well as using on-route or opportunity charging to recharge BEBs in-service to ensure that they have enough energy to complete their service. In that vein, Stantec also analyzed on-route charging at CARTA's in-design, future transit hub at Shipwatch Square, where several bus routes will converge. The analysis confirmed that Shipwatch Square provides a good opportunity to deploy on-route charging.

Together with CARTA staff, Stantec developed a phasing program as provided in the table below.

Phase Name	Description
Phase I	
Phase I – A	Operating the current fleet of six BEBs and of the upcoming twenty-seven (27) BEBs for a total fleet of thirty-three (33) at the end of 2022. These will be charged using only the existing six single plug-in chargers. No on-route charging will be available at Shipwatch square in this phase. Therefore, to maintain scheduled service, it will be necessary to have strategic adjustments to the vehicle and swapping out during the day of depleted BEBs with either diesel buses or charged BEBs (relief vehicle).
Phase I – B	Operations of thirty-three (33) BEBs with overnight charging using one new centralized charging units and forty (40) new plug-in dispensers. No on-route charging will be available at Shipwatch Square so strategic reblocking and relief of BEBs will be necessary to complete service.
Phase I – C	Operations of thirty-three (33) BEBs with overnight charging using two new centralized charging units and using on-route charging at Shipwatch Square to provided extended driving range to failing blocks.
Phase II	
Phase II	Operations of an 100% battery electric fleet that has incorporated a 20% vehicle growth to accommodate increase in service for a total fleet size of 100 vehicles. Considers the expansion of depot-charging equipment for the entire fleet and the use of on-route charging at Shipwatch Square and a second on-route location.

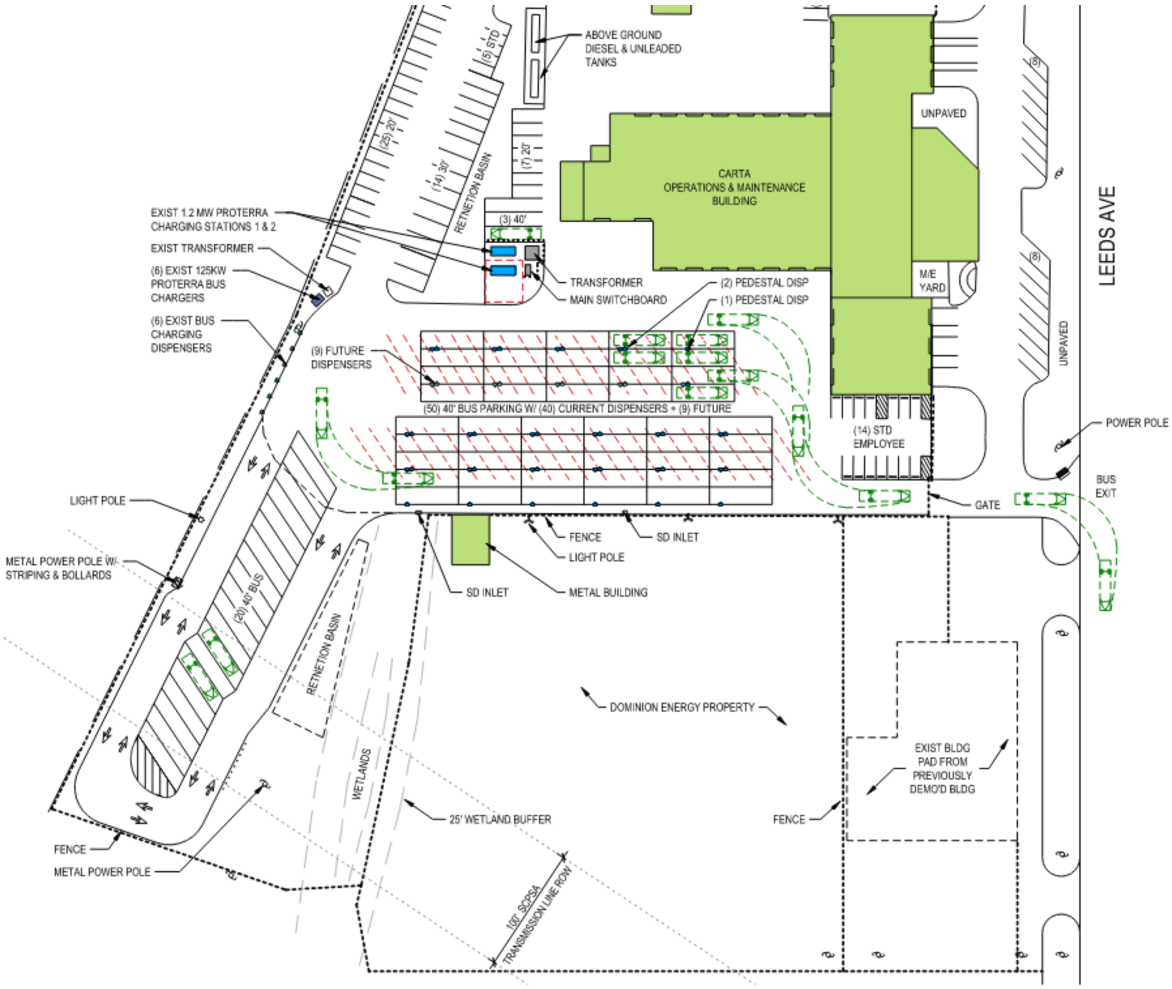
Further, Stantec developed a phasing plan for acquiring BEBs to replace diesel buses to a achieve a 100% BEB fleet in 2040, as shown in the graph below.



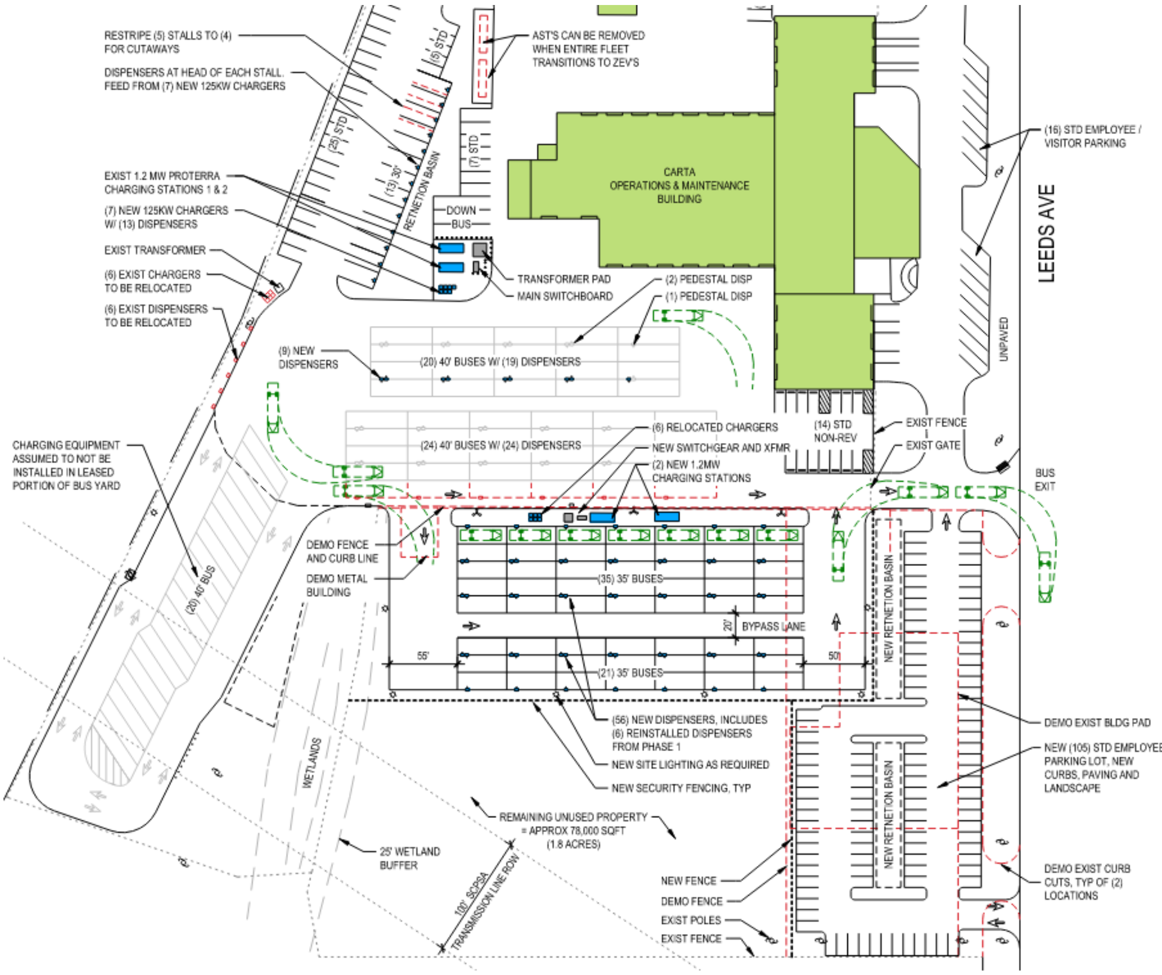
Furthermore, supporting infrastructure to accommodate a total power need of 5.75 MW at full build capacity is proposed with the phasing in the table below:

	Infrastructure				
	2021	**2022**	**2030**	**2033**	**2039**
Power Electronics No. of Units (125 kW)	**6**		**7**		
Cumulative	6	6	13	13	13
Centralized Units (1.2 MW)		**2**		**1**	**1**
Cumulative		2	2	3	4
Cumulative Plug-in Dispensers	**6**	**46**	**60**	**80**	**100**
Min. Power Requirement (kW)	750	1,800		3,600	4,800
Max. Power per installed equipment (kW)	750	3,150	4,025	5,225	6,425
Required/Recommended Installed Capacity (kW)	**750**	**2750**	**5750**	**5750**	**5750**

Using this phasing plan, Stantec developed two conceptual site plans—for both Phase I and Phase II—as shown below. These site plans indicate the position of BEB parking, siting of chargers and dispensers, as well as supporting infrastructure like a backup generator. The site plan for Phase I is meant to only reflect the ongoing infrastructure improvements that will be completed at the end of 2022 and have not been altered of modified by Stantec. The site plans for Phase II build from the infrastructure that will be in place and outlines the required modifications to support a fleet of 110 BEBs (i.e., 100% electric fleet by 2040).



Phase I Site Plan



Phase II Site Plan

The site plans where the base of design to conduct a rough-order-of-magnitude cost estimate for the facility infrastructure improvements. Such infrastructure estimate, in combination with the vehicle phasing plan and insights into operations and fueling (i.e., charging), was used by Stantec to develop a financial analysis of two scenarios: 1) a “Base Case” scenario where CARTA does not acquire additional electric vehicles and 2) a “BEB Scenario” that captures the full transition to BEB (as well as 20% fleet growth to accommodate service expansion, improvement, etc.).

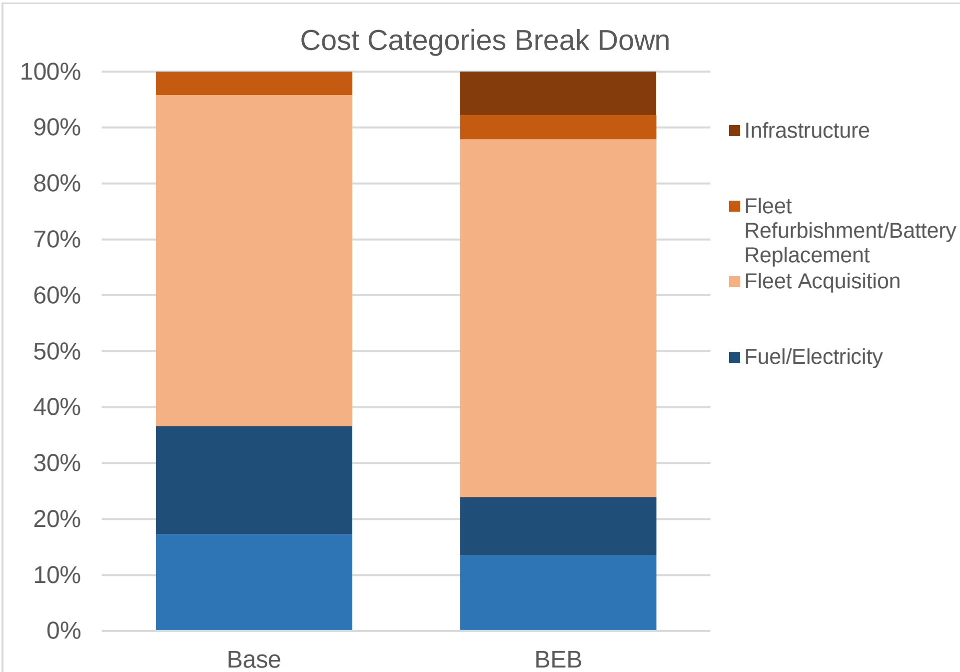
The cost comparison between the Base Case and the BEB Case transition scenario is presented in in the table below, incorporating both capital (orange) and operating (blue) expenses.

	Case (2023-2043)		
	Base	BEB	Savings
Fleet Acquisition	$106,530,000	$133,963,000	$(27,433,000)
Fleet Refurbishment/Battery Replacement	$7,565,000	$9,021,000	$(1,456,000)
Fleet Maintenance	$31,104,000	$28,443,000	$2,661,000
Fuel/Electricity	$34,698,000	$21,686,000	$13,012,000
Infrastructure	$-	$16,256,000	$(16,256,000)
Total	*$179,897,000*	*$209,369,000*	*$(29,472,000)*

The BEB Case has a total cumulative cost of $209,369,000 versus $179,897,000 for the Base Case, a difference of $29,472,000 or 16% increase over the Base Case. The financial assessment does not consider any potential rebates, grants, credits, or other alternative funding mechanisms available for BEB over internal combustion engines. Therefore, there may be several opportunities to offset the difference in the price between the two scenarios.

The graph below shows cash flows year-by-year of the scenarios and includes the percentage of electrification for the entire fleet, reaching a 100% BEB fleet in 2040. The spikes in costs for the BEB Case occur during the years that new modifications are made at the transit facility and/or when a procurement of BEBs is made (2031, 2033, 2034, 2039, and 2040).

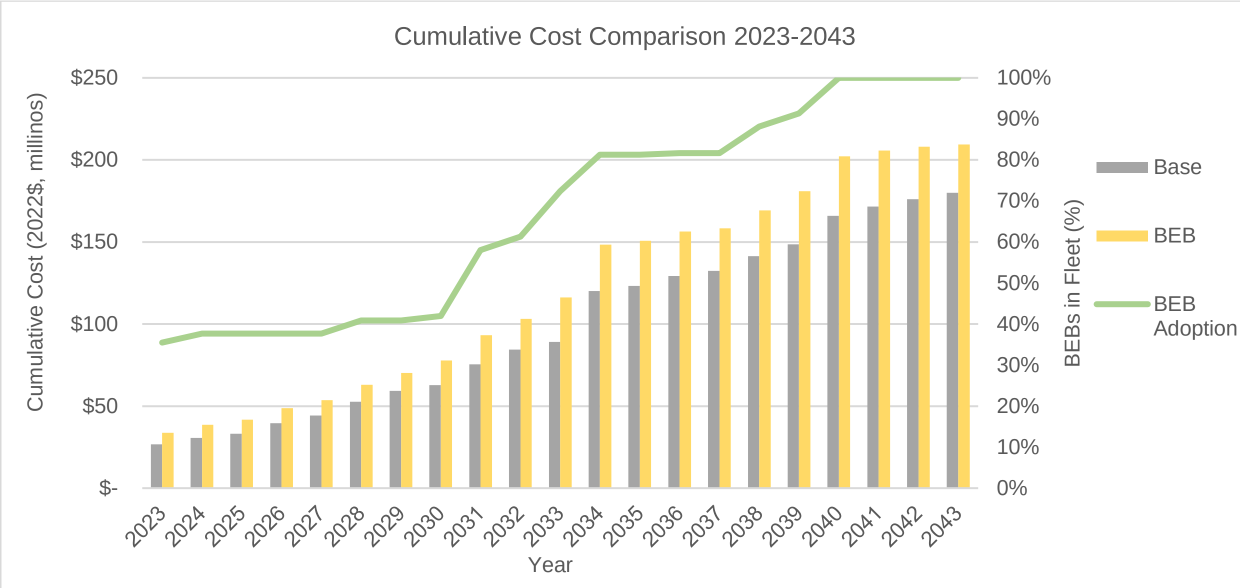
The graph below presents the cost categories for each case as a percentage of the total cost, demonstrating that in both cases, fleet acquisition constitutes the largest segment of the cost of BEB conversion.



The procurement of BEBs represents $27.5 million more in expenses due to the purchase price difference between BEBs and fossil fuel vehicles. The conversion and upgrades to the facility to install charging infrastructure resulted in an additional cost of $16.3 million. Capital costs associated with vehicle overhauls and battery replacements are relatively minor in comparison, although the simplicity of BEB propulsion systems means that these costs are lower for this technology compared to diesel engine components in the Base Case.

Furthermore, the use of electricity as a 'fuel' represents an economic benefit of $13 million when compared to the existing diesel and gasoline refueling, and the maintenance of BEBs also represents savings of $2.6 million. These savings are a direct reflection of the improved efficiency that BEBs have with respect to fossil fuel technologies, with the added benefit of eliminating emissions.

The table below shows the cumulative difference between the Base Case ($179,897,000) and the BEB Case ($209,369,000) is a difference of $29,472,000 or 16% increase over the Base Case.



Finally, the table below summarizes the phasing plan for CARTA's BEB rollout strategy.

CARTA BEB PHASING PLAN

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative, net of replacements)	Charging infrastructure equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2023		(20) 30 & 35-ft BEBs (13) 40-ft BEBs		(6) units (1) centralized units (46) plug-in dispensers Recommended Installed Capacity 2.75 MW	$0	$3,082,000	$3,082,000
FY2024	(2) 40-ft BEBs	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		Same as above	$1,801,000	$3,049,000	$4,850,000
FY2025		Same as above		Same as above	$0	$3,094,000	$3,094,000
FY2026	(10) gasoline 22-ft cutaways (6) 30 & 35-ft diesel buses	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		Same as above	$3,818,000	$3,121,000	$6,939,000
FY2027	(1) gasoline 22-ft cutaway (3) 30 & 35-ft diesel buses	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		Same as above	$1,890,000	$3,126,000	$5,016,000
FY2028	(9) 30 & 35-ft diesel buses (3) 40-ft BEBs	(20) 30 & 35-ft BEBs (18) 40-ft BEBs		Same as above	$6,392,000	$3,004,000	$9,396,000
FY2029		(20) 30 & 35-ft BEBs (18) 40-ft BEBs		Same as above	$4,073,000	$3,015,000	$7,088,000
FY2030	(1) 40-ft BEB	(20) 30 & 35-ft BEBs (19) 40-ft BEBs	Installation of (14) single-port plug-in dispensers Installation of (7) individual charging units 3.0 MW installed transformer power capacity	(13) units (2) centralized units (60) plug-in dispensers Recommended Installed Capacity - 5.75 MW	$4,547,000	$3,102,000	$7,649,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative, net of replacements)	Charging infrastructure equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2031	(15) 40-ft BEBs	(20) 30 & 35-ft BEBs (34) 40-ft BEBs		Same as above	$13,071,000	$2,341,000	$15,412,000
FY2032	(9) 40-ft BEBs	(20) 30 & 35-ft BEBs (37) 40-ft BEBs		Same as above	$7,822,000	$2,189,000	$10,011,000
FY2033	(11) 22-ft BE cutaways	(11) 22-ft BE cutaways (20) 30 & 35-ft BEBs (37) 40-ft BEBs	Installation of (1) Proterra centralized unit Installation of (20) single-port plug-in dispensers	(13) units (80) plug-in dispensers (3) centralized units Recommended Installed Capacity - 5.75 MW	$10,974,000	$2,064,000	$13,038,000
FY2034	(2) 22-ft BE cutaways (28) 30 & 35-ft BEBs (7) 40-ft BEBs	(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (37) 40-ft BEBs		Same as above	$30,392,000	$1,817,000	$32,209,000
FY2035		Same as above		Same as above	$431,000	$1,818,000	$2,249,000
FY2036	4 40-ft BEBs	(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (39) 40-ft BEBs		Same as above	$3,757,000	$1,857,000	$5,614,000
FY2037		Same as above		Same as above	$83,000	$1,859,000	$1,942,000
FY2038	(9) 30 & 35-ft BEBs	(13) 22-ft BE cutaways (37) 30 & 35-ft BEBs (39) 40-ft BEBs		Same as above	$9,227,000	$1,666,000	$10,893,000
FY2039	(6) 30 & 35-ft BEBs	(13) 22-ft BE cutaways (43) 30 & 35-ft BEBs (39) 40-ft BEBs	Installation of 1 Proterra centralized unit Installation of 20 single-port plug-in dispensers	(13) units (4) centralized units (100) plug-in dispensers Recommended Installed	$10,283,000	$1,581,000	$11,864,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative, net of replacements)	Charging infrastructure equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
				Capacity - 5.75 MW			
FY2040	(11) 22-ft BE cutaways (12) 30 & 35-ft BEBs (6) 40-ft BEBs	(13) 22-ft BE cutaways (55) 30 & 35-ft BEBs (42) 40-ft BEBs		Same as above	$19,752,000	$1,330,000	$21,082,000
FY2041		Same as above		Same as above	$2,286,000	$1,328,000	$3,614,000
FY2042		Same as above		Same as above	$984,000	$1,327,000	$2,311,000
FY2043		Same as above		Same as above	$0	$1,326,000	$1,326,000

Abbreviations

AHJ	Authorities Having Jurisdiction
BCDCOG	Berkeley-Charleston-Dorchester Council of Governments
BEB	Battery electric bus
BESS	Battery electric storage system
CARB	California Air Resources Board
CARTA	Charleston Area Regional Transportation Authority
DC	Direct current
DHEC	Department of Health and Environmental Control
DRIVE	Drive-cycle Raid Investigation Visualization, and Evaluation
NFPA	National Fire Protection Association
PV	Photovoltaic
TOU	Time of Use
ZE	Zero-emission
ZEB	Zero-emission bus
ZEV	Zero-emission vehicle

1.0 INTRODUCTION

The Charleston Area Regional Transportation Authority (CARTA) provides public transportation services to the residents and visitors of Charleston County via a combination of local fixed routes, express commuter routes extending service to Berkeley and Dorchester counties, and Downtown Area Shuttle (DASH) routes. In 2014, CARTA identified a need for a large capital effort to replace its aging rolling stock. As part of its Fleet Modernization Project[1], CARTA has developed a strategy to gradually transition to a battery-electric bus (BEB) fleet as part of this project. CARTA received its first BEB in 2019, and currently operates six BEBs in revenue service, with 27 more scheduled for delivery in early 2022.

As part of its Fleet Modernization Project and to support regional sustainability goals, CARTA has committed to an eventual transition to a 100% battery-electric fleet for its fixed route services. Stantec has been retained by CARTA to help develop a comprehensive electric bus master plan, which includes determining the power, energy, and charging requirements at CARTA's maintenance facility to support the immediate and future BEB fleet, charging strategy, and fleet management plan.

CARTA boasts a service area population of 548,404[2] and a fleet of 93 vehicles utilized for fixed-route services. CARTA has chosen to be a leader in the zero-emission space and is in the midst of transitioning its entire fleet to battery-electric buses (BEBs). This plan provides a strategic BEB transition plan for all of CARTA's vehicles used for fixed-route service delivery.

CARTA's maintenance facility is located on Leeds Avenue in North Charleston, with electrical service provided by Dominion Energy. Dominion Energy is a partner with CARTA to facilitate and service existing and future electrical charging infrastructure improvements to support BEBs. CARTA is in negotiations to acquire the land parcel immediately south of the Leeds Avenue facility, currently owned by Dominion Energy and used as a solar power farm. This parcel will be made available for future expansion of the facility, which may include a new operations and maintenance facility, expanded bus parking, and additional BEB charging dispensers.

As part of the CARTA Board of Directors' organizational goal of replacing all diesel and gasoline buses with a sustainable, ZE fleet, CARTA has already initiated its Fleet Modernization Project, and has taken steps to adopt BEB technology. Elements already completed or in progress include:

- Initial procurement of six Proterra 40-ft BEBs
- Installation of 6-unit charging cabinets (125 kW per unit) and six electrical charging dispensers

[1] CARTA's Fleet Modernization Project is an effort to replace its aging fixed route fleet with zero emission-battery electric vehicles.
[2] NTD 2019 agency profile

- Additional procurement of twenty-seven (27) additional BEBs (seven 40-ft New Flyer and twenty (20) 35-ft Proterra vehicles) to be complete in early 2022, bringing the full BEB fleet roster to thirty-three (33) vehicles.
- Procurement and installation of forty (40) Power Electronics charging dispensers and associated infrastructure (including two 1.2 MW charging solutions) at the Leeds Avenue maintenance facility to be completed in early 2022. This will allow for simultaneous charging of up to forty (40) BEBs, with the original six charging stations available as backup.

This document provides a plan of the technology, needs, and strategies that will help CARTA manage their current BEB fleet, and transition to a 100% BEB service in the future. To develop this transition plan, the steps were taken to determine the best ZEB strategy for CARTA include:

- A review of existing conditions to understand characteristics and constraints for CARTA's operations and service area. This included a primer on different ZEB technologies to provide a scan of the market and technologies associated with BEBs.
- Energy and power modeling to understand performance under different BEB technology options and their viability.
- A quantitative and qualitative assessment of modeling results to determine the preferred BEB fleet composition for CARTA.
- An analysis of the future bus transfer center at Shipwatch Square, to replace the current "SuperStop" located at the intersection of Rivers Avenue and Cosgrove Avenue including determining the most efficient rerouting for each bus route, and the electrical infrastructure requirements to provide on-route charging to the BEB fleet.
- Site master planning for the BEB transition at the Leeds Avenue facility, including cost estimation for the site improvements, facility modifications, and BEB-associated infrastructure.
- A financial analysis of the capital and operating elements of the BEB transition.

2.0 SUMMARY OF KEY EXISTING CONDITIONS

The major findings from the Overview of Battery-Electric Bus Technologies and Existing Conditions Review Report (January 2022) that will affect the BEB transition are summarized below.

- Overall, the majority of CARTA's service is within the mileage ranges of BEBs (generally 200 miles or less), though some blocks and vehicle assignments exceed current BEB range capacities (Figure 1 and Figure 2).

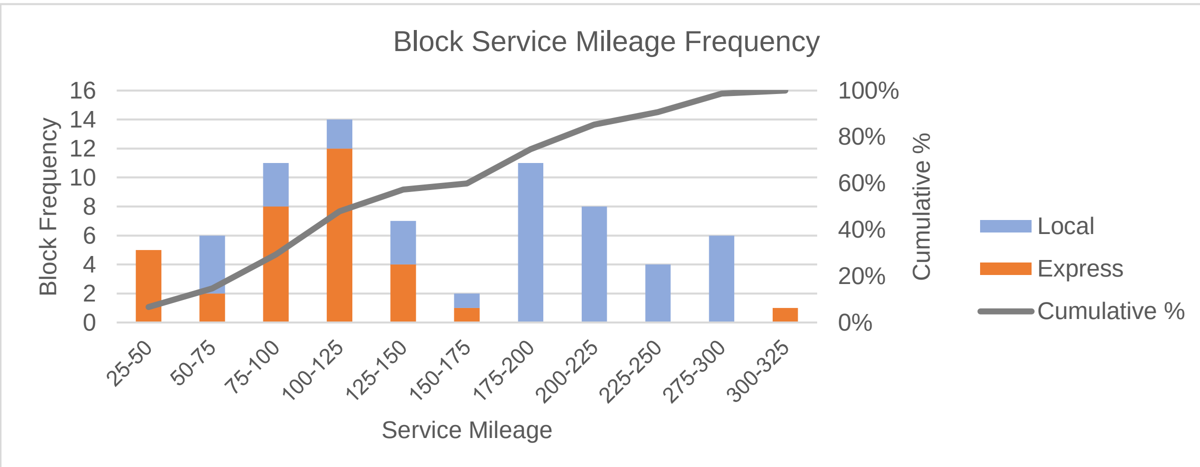


Figure 1: Block frequency by daily service miles (weekday)

- Figure 1 shows that block lengths average 148 miles, ranging from a minimum block length of 33 miles to a maximum of 315 miles. Nineteen (or 25%) of blocks travel over 200 miles, which is outside the range of current BEBs[3]. Other strategies, such as on-route/opportunity charging or strategic adjustment to vehicle blocking, can help mitigate these issues. It is also important to consider how CARTA assigns vehicles to blocks, how many vehicles are assigned to multiple blocks, and how many miles vehicles travel on an average day. Blocks have been combined at the vehicle assignment level in Figure 2.

[3] Range of 200 miles is assumed for 40-ft buses, smaller vehicles have smaller batteries and will yield shorter driving ranges.

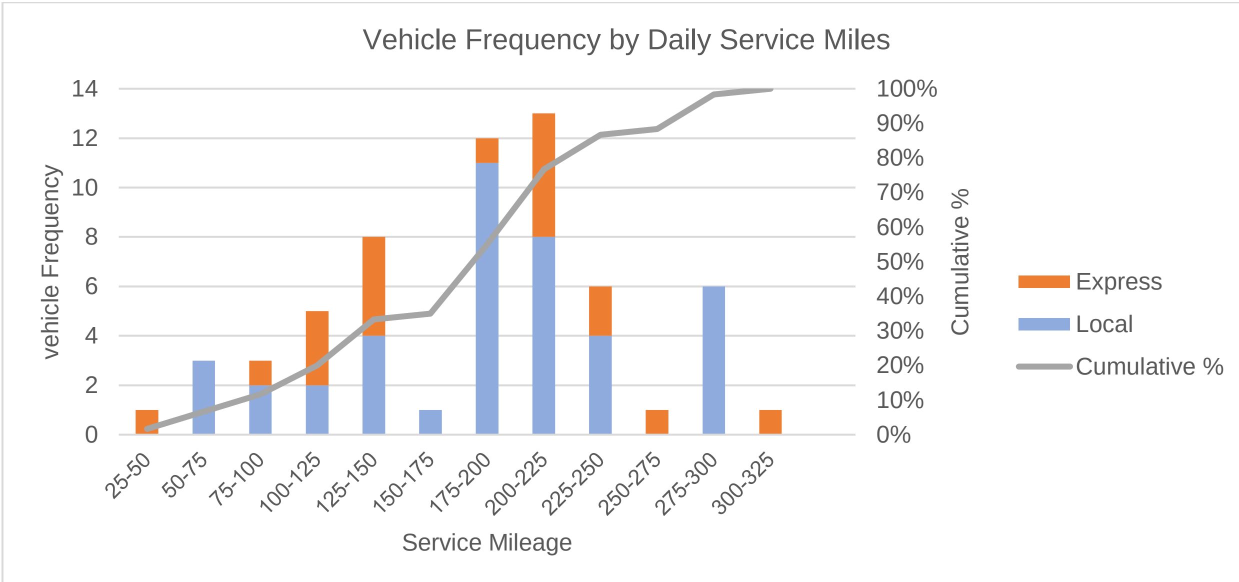


Figure 2: Vehicle frequency by daily service miles (weekday)

- Figure 2 shows that 25% of vehicles complete multiple blocks on an average weekday. Average distance increases from 148 miles (blocks) to 185 miles (vehicle assignments). Examining how many miles vehicles travel in an average day show that the majority of blocks and vehicle assignments should be straightforward to electrify, but there are some blocks and vehicle assignments that will be more challenging and require an alternate strategy, such as reblocking or on-route/opportunity charging (see Sections 4.0 and 6.0).

- CARTA operates a variety of different vehicle sizes to fit the needs of its different service types and diverse service area; this can add complexity to the BEB transition as different vehicle types have different BEB equivalents with different operating ranges. Given these issues it will be important to ensure that vehicles are scheduled on the correct block to avoid operational issues. Specifically, CARTA operates a combination of cutaway buses, 30-ft buses, 35-ft buses, and 40-ft buses for their fixed route service.

- As CARTA already has BEBs in operation, the operators and other staff are already familiar with this technology and the agency has real-world data on fuel efficiency and estimated operating range, which aids in comparing the results of the predictive power and energy modeling. Currently, CARTA's six BEBs are operating mostly on Route 10, operating between 120 and 130 miles each day, in service for seven hours a day.

- CARTA's operating base and maintenance facility is in good operating condition and fit the needs of CARTA (Figure 3). There are currently six bus parking spaces with charging dispensers (125 kW per unit) for charging CARTA's six BEBs. CARTA is currently working with Proterra and

Dominion Energy to install an additional forty (40) charging dispensers that would be supplied by two 1.2-MW charging stations.

Figure 3: Aerial view of site showing CARTA property bound in red and leased Dominion Energy property bound in green (source: Google Maps)

- Compared to peer agencies, between 2014 and 2019 CARTA's operating expenses increased at a much lower rate. The vast majority of CARTA's operating expenses are allocated to contractor expenses as the firm Transdev North America maintains and operates CARTA's services. To track the impacts of BEBs on costs, CARTA needs to monitor and compare BEB performance indicators like cost per mile and per hour to the conventional fleet.

3.0 PREDICTIVE BUS PERFORMANCE MODELING

ZEBDecide, Stantec's route modeling and bus simulation tool, was used to determine the feasibility of transitioning CARTA's fleet to BEBs, under CARTA's current operating conditions, in its current operating environment. The following sections outline the modeling methodology used and results of the modeling, showing what percentage of CARTA's fleet can be successfully electrified.

3.1 VEHICLE MODELING METHODOLOGY

ZEBDecide–Stantec's proprietary tool for the predictive modeling–uses several inputs, such as passenger loads, driving cycles (or duty cycles), topography, vehicle specifications, and ambient conditions subject to the environment in which the agency operates (schematic overview in Figure 4). To capture the real-life performance of the vehicles more accurately, CARTA vehicles were outfitted with GPS loggers that track the buses throughout the day, capturing many of the inputs outlined below (including driving cycles, ambient conditions, changes in topography and elevation, and passenger loads).

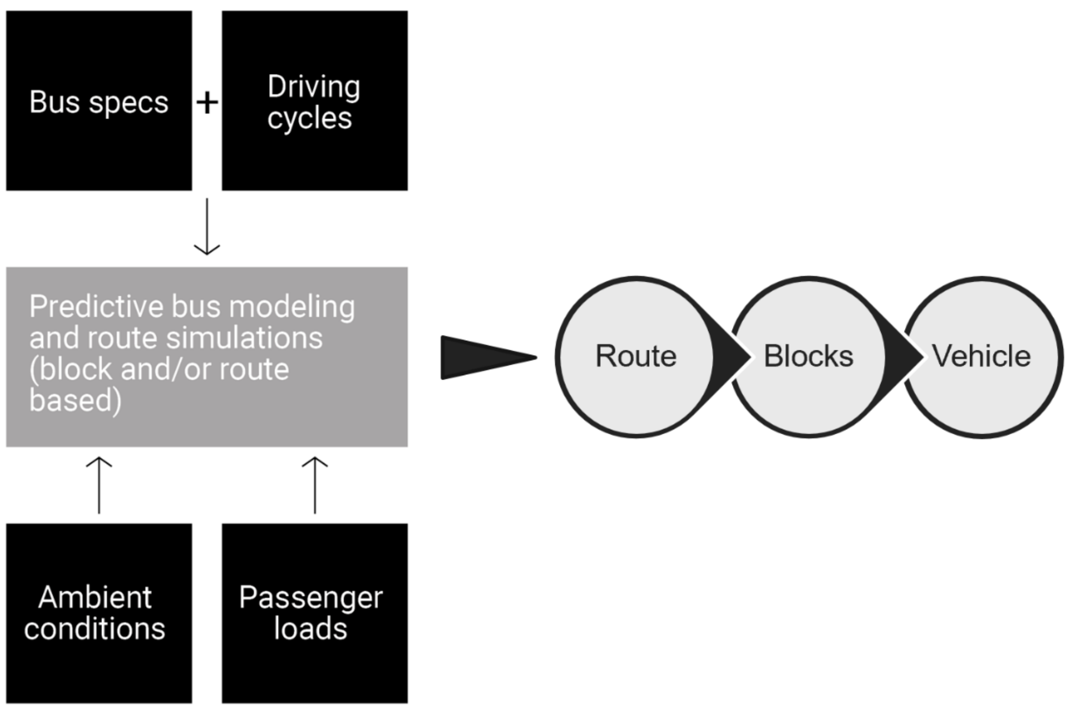


Figure 4: ZEBDecide modeling overview

3.1.1 Modeling Inputs

3.1.1.1 Bus Specifications

ZEBDecide's energy modeling process predicts BEB drivetrain power requirements specific to given acceleration profiles. One key component to the modeling is the bus design or bus specifications that include curb weight and frontal dimensions (factors needed to account for aerodynamic drag and rolling resistance coefficients), auxiliary power, and HVAC (Figure 5).

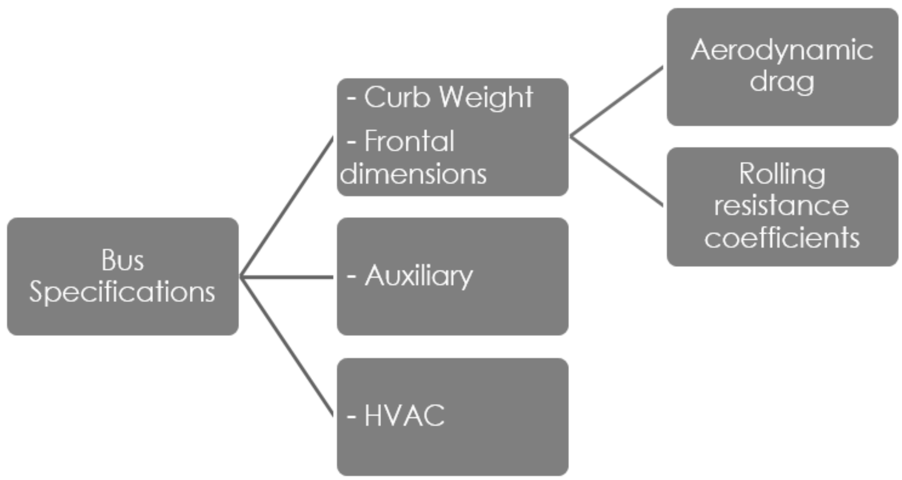


Figure 5: Detailed bus specification inputs

For CARTA, the key bus specification used in the modeling process for each vehicle size are detailed in Table 1.

Table 1: Bus specifications for modeling

BEB Model	Cutaway (25-ft and 30-ft)	Standard 35-ft Bus	Standard 40-ft Bus
Battery (kWh)	225	450	466
Curb Weight (lbs.)	25,000	30,000	34,000

3.1.1.2 Custom Driving Cycles

A driving cycle is a speed versus time profile that is used to simulate the vehicle performance, and consequently, the energy use. We captured actual driving cycles based on CARTA's operations with onboard loggers that tracked traveling speed, number of stops, and traffic levels.

We deployed fifteen (15) OBD-II GPS trackers (branded AccuTracking) to record operations of vehicles over the course of three days and it was needed to recapture the operations of certain routes over the course of another three days. During this time, the trackers recorded operations for vehicles operating on selected routes that were then used as representative to model the rest of the service. Figure 6 shows an example of the online dashboard that was used to track the loggers and download the data.

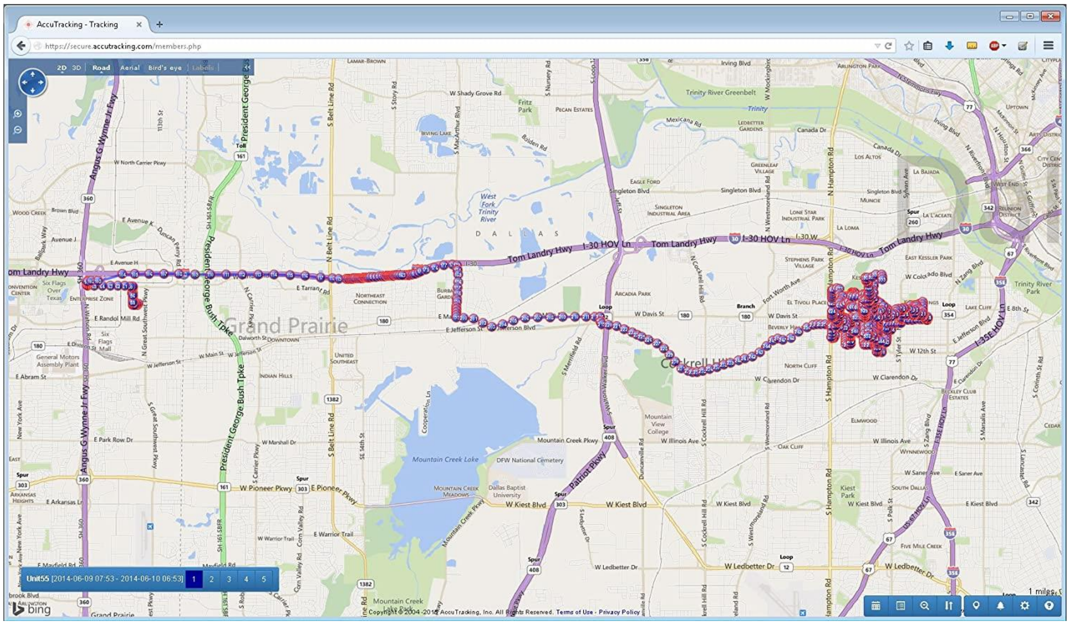


Figure 6: Example of dashboard interface for GPS trackers from AccuTracking

The data captured by the loggers was then transformed into custom driving cycles using a software tool developed by the National Renewable Energy Laboratory called DRIVE (Drive-cycle Raid Investigation Visualization, and Evaluation). The custom driving cycles outputted by the DRIVE software completes statistical analysis to create a representative driving cycle based on the raw vehicle data recorded by the loggers. An example of the original cycle compared to the representative cycle developed by the DRIVE software is presented in Figure 7.

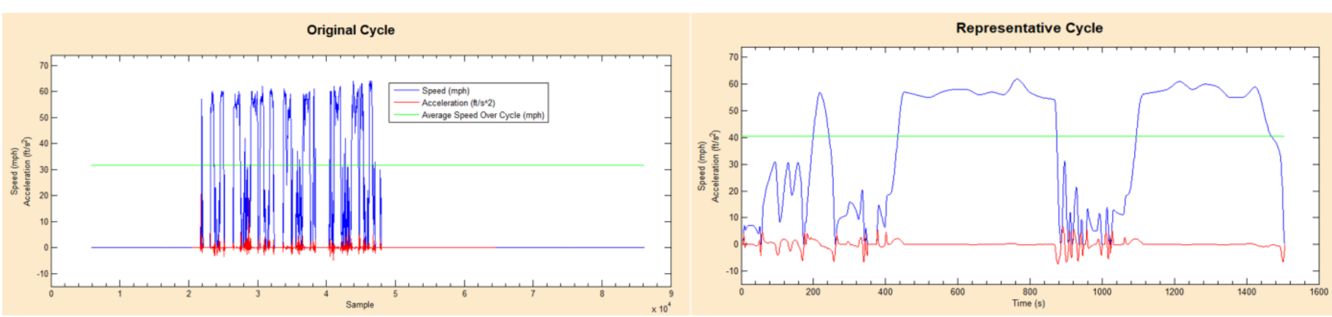


Figure 7: DRIVE software example; original cycle compared to representative cycle

3.1.1.3 Passenger Loads

To examine the impacts of passenger loads and their associated weight, Stantec considered two scenarios:

- A deadheading condition, which assumes no passengers onboard
- A more strenuous, extreme condition with passenger loads at 80% of the actual max vehicle capacity

The fuel efficiency under each condition was then assigned to the specific mileage that each block completes; meaning, the deadhead mileage driven by each block was modeled under the deadhead scenario and every other trip during regular service was modeled assuming the 80% passenger capacity to be conservative and account for a worst-case scenario.

3.1.2 Ambient Temperature

Stantec developed a correlation between ambient temperature and power requirements from the HVAC system. The power requirement for modeling purposes was set based on an annual average low temperature average of 38°F and an annual average high temperature of 91°F[4].

3.2 MODELING RESULTS

Using the inputs described above, the first step in modeling CARTA's service was obtaining route-level fuel economy and energy use based on the customized driving cycles derived from the DRIVE software. However, since some vehicles may operate more than one block in a day, it is also necessary to model the total daily duty of a vehicle. The process of modeling from route, to block, to vehicle assignment is outlined in Figure 8.

[4] US Climate Data https://www.usclimatedata.com/climate/charleston-afb/south-carolina/united-states/ussc0052

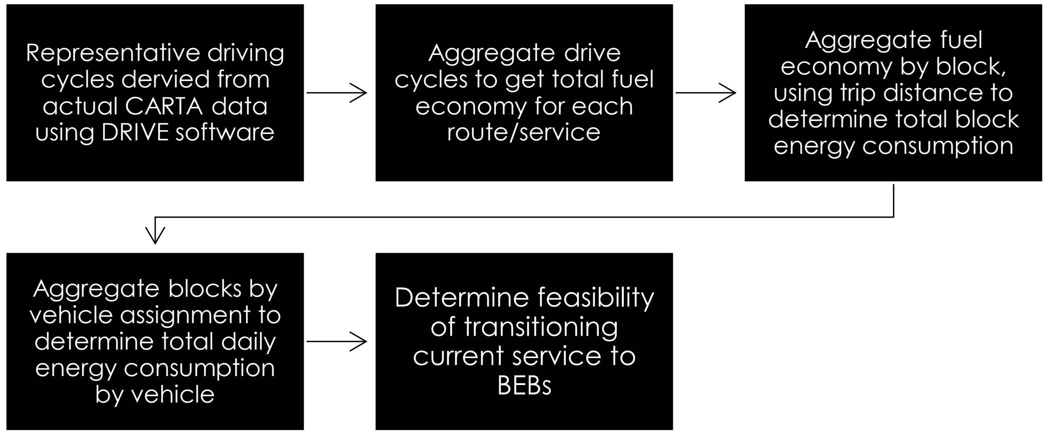


Figure 8: ZEBDecide energy modeling process

Modeling results for all blocks and vehicle assignments (including services that will be passing through Shipwatch Square) are presented in this section. For each service, the criteria for determining if a service can be successfully replaced by a BEB is whether the state of charge (SOC) of the battery remains ≥20% after completing its scheduled service[5]. The outputs of the modeling include the average fuel efficiency and driving range for each BEB equivalent.

The overall energy or fuel demand per block was obtained by aggregating the fuel consumption from each trip according to the route-level results. Then, all blocks completed by a vehicle were aggregated at the vehicle assignment-level to understand whether the daily service assigned to a vehicle can be completed with the BEB equivalent.

3.2.1 Depot-only Charging Results Electrification Results

3.2.1.1 Weekday Results

Figure 9 shows the electrification success for all fixed routes operating on a weekday relying only on overnight depot charging based on the vehicle specifications presented in Section 3.1.1. At the block level (left bar), only 60% of the blocks can successfully be completed by a BEB equivalent and the rate drops to 38% when the vehicles complete more than one block during the day (i.e., at the vehicle level).

[5] OEMs recommend that a BEB charge only to 90% of its total battery capacity and not drop below 10% SOC to preserve battery life; dipping below 10% can void the battery's warranty.

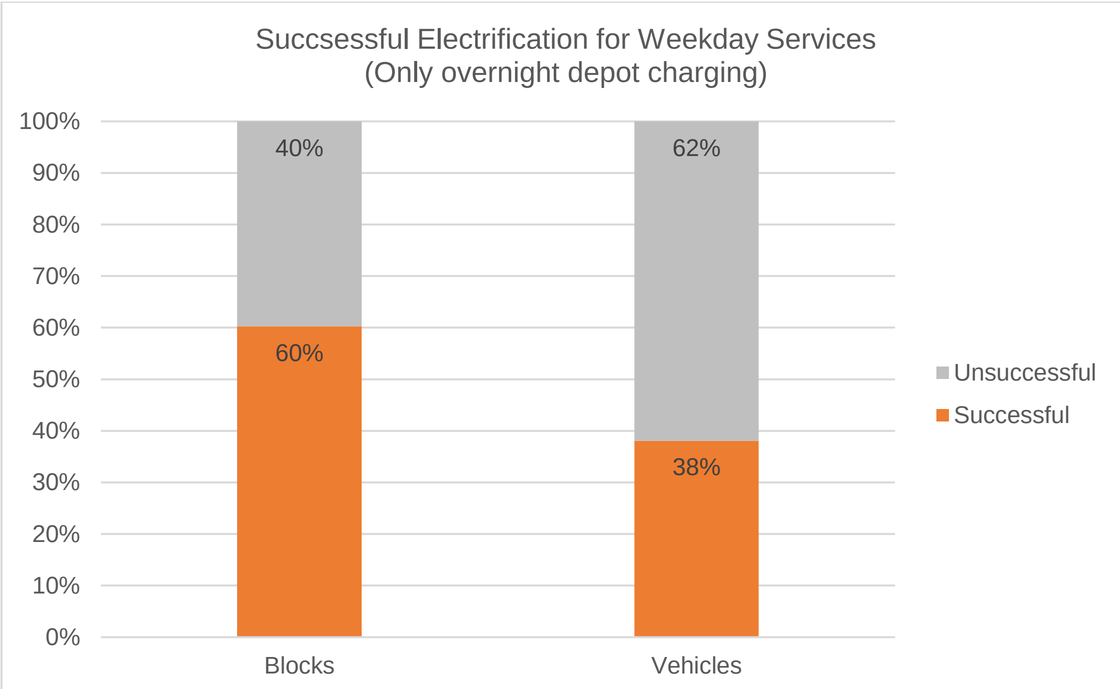


Figure 9: Successful electrification for weekdays with only overnight depot-charging

Given that not all the weekday services can successfully transition to a BEB equivalent based on overnight depot charging, on-route charging would be needed to 'top-up' the batteries to provide enough charge throughout the day and extend the operating range of the BEB. Given the ongoing plans to develop Shipwatch Square, this location was identified as the ideal hub for on-route charging in addition to a charging facility at a downtown location for the future. This approach for on-route charging infrastructure looks to centralize the locations where vehicles will be charging to minimize cost and maximize the equipment utilization.

3.2.1.2 Weekend Results

Weekend services were also examined to understand the feasibility for electrification. In contrast to weekday services when vehicles may be assigned multiple blocks, weekend service is operated such that a vehicle is assigned a single block for the day. While simpler in terms of scheduling, the outcome of that approach is that vehicles scheduled for weekend blocks—even though service levels are generally lower than weekdays—spend more continuous time in service. The result for BEBs is that service may exceed the vehicles' operating ranges.

Figure 14 shows the success rate of blocks when charging in-depot only. Compared to weekdays, the success rate for weekends with only in-depot charging is much lower than the weekday numbers, 37% in-depot only on weekends vs. 60% in-depot only on weekdays likely attributable to the mileage and duration of scheduled blocks.

Taken together, this analysis indicates that for successful electrification of CARTA's services, CARTA will need to employ strategic on-route charging, as well as redesign blocks to respect the operating limits of BEBs. In the future, with improved technology and battery densities, longer ranges may be achievable, but given current constraints, this approach is recommended to account for limited operating ranges.

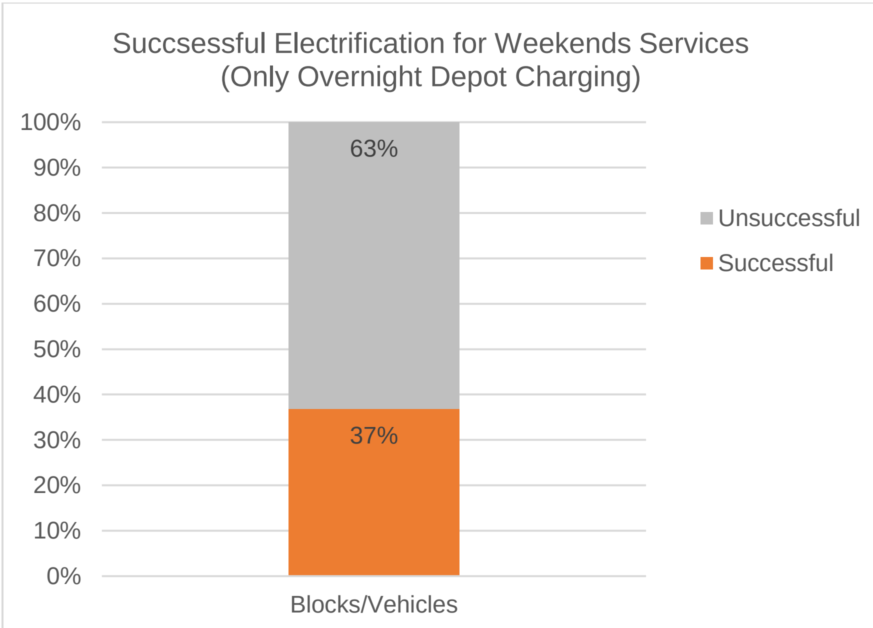


Figure 10: Successful electrification for weekends with only overnight depot-charging.

3.2.2 On-Route Charging Results

As described in the previous section, based on the low successful electrification rate at the blocks and vehicle level for depot-charging only, the use of on-route (also known as fast or opportunity) charging was added to the analysis to increase the driving range of the vehicles. On-route charging is usually provided by high-power rate chargers (>300 kW) that are overhead pantographs that lower onto charge rails mounted on the roof of the bus (see Figure 11). On-route charging effectively recharges or 'tops up' a bus in as fast as five minutes, providing additional driving range; subsequently, the BEB is able to complete additional trips before requiring additional recharging. Section 11.4 provides additional details on the requirements around on-route charging.

Figure 11: Overhead pantograph charger lowering onto a BEB for opportunity or on-route charging. (Metro, Los Angeles).

Given these higher power rate chargers are not only more expensive but involve logistical challenges in installation, the decision of where to deploy on-route charging equipment needs to be structured to minimize overlapping charging events that could delay service. Effective on-route charging strategies include taking advantage of long layovers to recharge the vehicles without affecting service. With these considerations in mind, it was ideal to assume the installation of fast-charging equipment at the new Shipwatch Square location. Many of the blocks whose routes exceeded the available charges in our analysis (failing vehicle blocks) will have longer layovers here; making it ideal to have several pantographs to allow the driving range to be increased. Further details on the charging for the Shipwatch Square location are presented in section 6.3.

To capture as many additional failing blocks as possible and increase the electrification success rate, it was necessary to evaluate on-route charging equipment at a location in addition to Shipwatch Square. Given the impact that overhead chargers may have on the built urban environment, right-of-way easements, and permitting constraints, a detailed assessment was conducted to identify a key second location for on-route charging. Downtown Charleston (Downtown) was identified as a strategic location to add on-route charging equipment as it will maximize the use of the chargers and increase the electrification success rate. Figure 12 shows the proposed location for the on-route charging in Downtown. Having fast chargers in this location will allow an increase in the driving range for all failing blocks that serve routes 4, 7, 31, 30, 33, 40, 41, 42, and 211. Specifics about the charging equipment and impacts to service from longer layovers is outside of the scope of this analysis and this approach has not been formally defined as the path forward for CARTA's electrification plan.

Figure 12: Downtown routing of existing CARTA routes. On-route chargers could be installed here in downtown to maximize the number of routes able to leverage on-route charging.

3.2.2.1 Weekday Results

Figure 13 shows the successful electrification rate for weekdays when considering buses will be able to charge on-route both at the Shipwatch Square and at Downtown locations. When incorporating this on-route charging, the left bar shows that the success rate for blocks increases from 60% to 92%, meaning that only 8% of the blocks would need a redesign to accommodate the use of BEBs. Reblocking will be necessary in some instances because the use of smaller vehicles doesn't allow for the use of on-route charging.

The right bar in Figure 13 shows that for the vehicle assignment, the success rate increase from 38% to 86% by incorporating on-route charging. A complete and successful electrification (i.e., 100% electrification rate) can be achieved if the unsuccessful blocks are restructured to accommodate BEB range limitations or if vehicles that are running low on battery SOC are exchanged with fully charged vehicles.

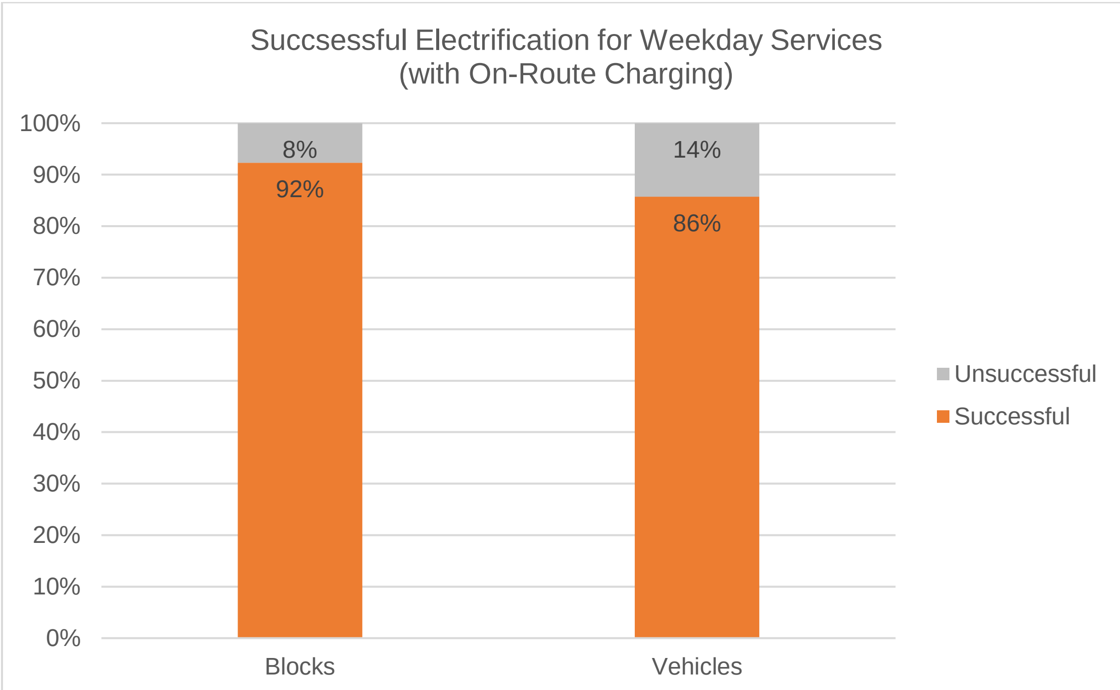


Figure 13: Successful electrification for Weekdays with on-route charging at Shipwatch Square and Downtown

3.2.2.2 Weekend Results

Weekend services were also examined to understand the feasibility for electrification. As previously described, for weekends vehicles are assigned to a single block for the day. Therefore, the electrification success level at the block and vehicle level is the same. Figure 14 shows the success rate of blocks and vehicles when implementing on-route charging. Compared to weekdays, the success rate for weekends with on-route charging drops from 86% to 81%. However, implementing on-route charging during weekends increased the electrification success from 37% to 81% versus only relying on depot-charging overnight.

Taken together, this analysis indicates that for successful electrification of CARTA's services, CARTA will need to employ strategic on-route charging, as well as redesign blocks to respect the operating limits of BEBs. In the future, with improved technology and battery densities, longer ranges may be achievable, but at the present time, this approach is recommended to account for limited operating ranges.

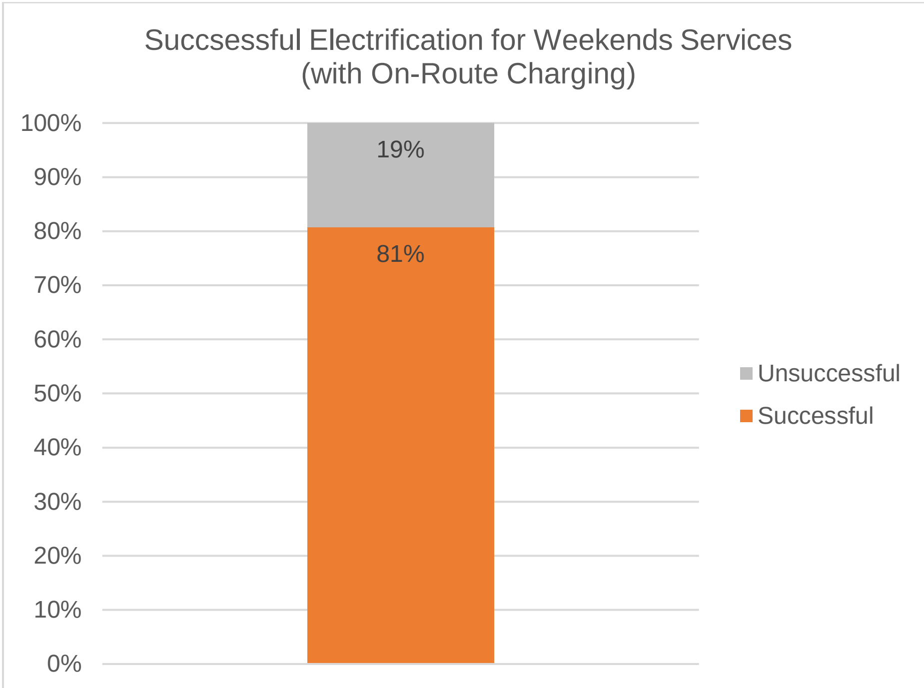


Figure 14: Successful electrification for Weekends with on-route charging at Shipwatch Square and Downtown

4.0 IMPLEMENTATION PHASES

CARTA has been an early adopter of BEBs in South Carolina, and as result, the implementation of an 100% electrification plan needs to incorporate the early efforts and ongoing projects that are under development. To provide relevant information that will inform the deployment of additional BEBs, the implementation phases presented in Table 2 are recommended.

Table 2: Recommended Implementation Phases for the Full Fleet Electrification

Phase Name	Description
Phase I	
Phase I – A	Operating the current fleet of six BEBs and of the upcoming twenty-seven (27) BEBs for a total fleet of thirty-three (33) at the end of 2022. These will be charged using only the existing six single plug-in chargers (each with a power rating of 125 kW). No on-route charging will be available at Shipwatch square so strategic reblocking and swapping out of depleted BEBs with either diesel buses or charged BEBs(relief buses) during the day at prescribed locations and times to maintain scheduled service is needed.
Phase I – B	Operations of thirty-three (33) BEBs with overnight charging using two new centralized charging units (each with a power capacity 1.2 MW) and forty (40) new plug-in dispensers. No on-route charging will be available at Shipwatch square so strategic reblocking and relief of BEBs during the day will be necessary to complete service.
Phase I – C	Operations of thirty-three (33) BEBs with overnight charging using two new centralized charging units from Proterra and using on-route charging at Shipwatch Square to provided extended driving range to failing blocks.
Phase II	
Phase II	Operations of an 100% battery electric fleet that has incorporated a 10% vehicle growth to accommodate increase in service for a total fleet size of 100 vehicles. Considers the expansion of depot-charging equipment for the entire fleet and the use of on-route charging at Shipwatch Square and at Downtown.

Given that the installed charging equipment has unique implications in the charging dynamic of the fleet, further details for each implementation phase are presented in this section and the power requirements for each phase are presented in the following section.

4.1 PHASE I-A

As of early 2022, the first phase of CARTA's Fleet Modernization Plan will be complete. The final steps are:

- Delivery of seven New Flyer Xcelsior 40-ft buses, with 450 kW battery packs. These vehicles will supplement the existing BEB fleet of six existing 40-ft Proterra buses.
- Delivery of twenty (20) Proterra ZX5 35-ft buses, with 450 kW battery packs.

The delivery of the twenty-seven (27) Proterra ZX5 buses will occur prior to the completion of the additional charging dispensers. Therefore, for a period of time in 2022, only the original six charging dispensers (each with a power rate of 125kW) will be available for supplying power to the full fleet of thirty-three (33) BEBs. Full deployment of all BEBs into the current service schedule may not be possible, due to the limitations of the number of available chargers, and reblocking of service will be necessary in addition to the relief of BEBs during the day to be replaced by diesel buses. The preliminary reblocked schedule provided by CARTA (Table 3 and Table 4) was used to plan the relief during the day to create a charging strategy relying on the six existing charging dispensers. Results on the charging profile and charging strategy are provided in Section 5.0.

Table 3: Proposed Re-Blocking of Weekdays and Vehicle Swap for Phase I-A

Block	Vehicle ID	Route	Shipwatch Service	Phase I Approach - Vehicle Swap at the following location	Relief Time for Vehicle Swaps
3101W	3414	31		Vehicle swap during driver relief (Mary St.)	1:20 PM
3102W	3430	31		Mary St.	2:05 PM
3302W	3435	33		Bees Ferry Lowes	12:55 PM
1302W	3405	13, 104	X	SuperStop	2:00 PM
1102W	3417	11	X	Mary St.	12:20 PM
1003W	3420	10	X	Mary St.	12:45 PM
1008W	3426	10	X	Trident Medical Center	1:05 PM
3002W	3428	30, 40		Citadel Mall	1:45 PM
1301W	3406	13, 104	X	SuperStop	1:15 PM
1202W	3431	12	X	SuperStop	2:10 PM
3301W	3432	33		Citadel Mall	12:15 PM
1005W	3412	10	X	Trident Medical Center	2:05 PM
1203W	3501	12	X	SuperStop	1:10 PM
1006W	3502	10	X	Mary St.	1:07 PM
1303W	3505	13, 104	X	Tanger Outlets	1:35 PM
1001W	3508	10	X	Mary St.	1:44 PM
1101W	3510	11	X	Mary St.	1:47 PM

Block	Vehicle ID	Route	Shipwatch Service	Phase I Approach - Vehicle Swap at the following location	Relief Time for Vehicle Swaps
4201W	3511	42		Hungry Neck Blvd. at Theatre Dr.	2:02 PM
1002W	4001	10	X	Trident Medical Center	1:00 PM
1201W	4503	12	X	SuperStop	12:12 PM
3003W	4505	30, 40		Mary St.	1:11 PM

Table 4: Proposed Re-Blocking of Weekends and Vehicle Swap for Phase I-A

Block	Route	Shipwatch Service	Phase I Approach - Vehicle Swap at the following location	Relief Time for Vehicle Swaps
1001S	10	X	Mary St.	3:40 PM
1002S	10	X	Mary St.	2:07 PM
1003S	10	X	Mary St.	2:50 PM
1004S	10	X	Trident Medical Center	3:34 PM
1001U	10	X	Trident Medical Center	4:00 PM
1003U	10	X	No Reblocking, monitor vehicle	-
1101U	11	X	Tanger Outlet	2:50 PM
1101S	11	X	Tanger Outlet	1:19 PM
1102S	11	X	Mary St.	3:41 PM
1201S	12, 102	X	SuperStop	1:55 PM
1202S	12, 102	X	SuperStop	2:55 PM
1203S	12, 102	X	SuperStop	12:55 PM
1204S	12, 102	X	Otranto	1:26 PM
3201S	32	X	SuperStop	13:55
1201U	12, 13, 32	X	Otranto Rd. Layover	3:32 PM
1202U	12, 13, 32	X	SuperStop	1:20 PM
3001S	30, 40		Citadel Mall	3:28 PM
3002S	30, 40		Mary St.	3:47 PM
3003S	30, 40		Mary St.	3:13 PM
3101S	31		Mary St.	1:50 PM
3102S	31		Mary St.	2:55 PM
3301S	33		Mary St.	4:25 PM
4201S	42		Hungry Neck Blvd. at Theatre Dr.	3:02 PM
3001U	30, 40, 42		Citadel Mall	11:28 AM
3002U	30, 40, 42		Mary St.	12:56 PM
3101U	31		No Reblocking, monitor vehicle	-
4201U	30,40, 42		No Reblocking, monitor vehicle	-

4.2 PHASE I-B

The difference between Phase I-A and I-B relates only to the available charging equipment at the Leeds Avenue facility. Both phases consider the operations of thirty-three (33) BEBs, but Phase I-B assumes that the construction of the additional charging equipment provided by Proterra will be completed at the bus yard. The charging equipment for Phase I-B consists of two Proterra centralized units, each with a power capacity of 1.2 MW and a total of forty (40) plug-in dispensers and a new bus parking site layout at the Leeds Avenue facility. Therefore, all vehicles will be able to have in-depot charging both overnight, and between block assignments during the day if necessary. After completion of construction for the forty (40) new dispensers, the original six dispensers will be “non-primary” charging options and be utilized only in overflow situations when the primary forty (40) dispensers are already in use or otherwise unavailable.

On-route charging however will not be possible until the completion of the Shipwatch Square transit center and the two overhead pantograph chargers slated for installation there. Construction is expected to be completed in 2024. Until that on-route charging option is available, the same vehicle swapping strategy will be applied as described in Phase I-A (Table 3 and Table 4), where the BEBs will be exchanged at the described location and time by diesel buses to continue the scheduled service.

4.3 PHASE I-C

Upon completion of the Shipwatch Square transit center, two overhead charging pantographs will be available for on-route charging of BEBs serving all routes intersecting at the transit center, with the exception of certain routes (10 and 11) to avoid unnecessary dwell times and schedule adjustments. Table 5 present the proposed strategy provided by CARTA for the utilization of on-route charging equipment at Shipwatch Square for weekdays and weekends, respectively.

Table 5: Proposed Re-Blocking of Weekdays and Vehicle Swap for Phase I-C

Block	Vehicle ID	Route	Shipwatch Service	Vehicle Swap at the following location	Phase I-C Approach
1302W	3405	13, 104	X	n/a	On-route at Shipwatch
1301W	3406	13, 104	X	n/a	On-route at Shipwatch
1202W	3431	12	X	n/a	On-route at Shipwatch
1203W	3501	12	X	n/a	On-route at Shipwatch
1201W	4503	12	X	n/a	On-route at Shipwatch
1003W	3420	10	X	Mary St.	Reblock
1102W	3417	11	X	Mary St.	Reblock
1008W	3426	10	X	Trident Medical Center	Reblock
1005W	3412	10	X	Trident Medical Center	Reblock

Block	Vehicle ID	Route	Shipwatch Service	Vehicle Swap at the following location	Phase I-C Approach
1006W	3502	10	X	Mary St.	Reblock
1001W	3508	10	X	Mary St.	Reblock
1101W	3510	11	X	Mary St.	Reblock
1002W	4001	10	X	Trident Medical Center	Reblock
1303W	3505	13, 104	X	Tanger Outlets	Reblock
3101W	3414	31		Mary St.	Reblock
3102W	3430	31		Mary St.	Reblock
3302W	3435	33		Bees Ferry Lowes	Reblock
3002W	3428	30, 40		Citadel Mall	Reblock
3301W	3432	33		Citadel Mall	Reblock
4201W	3511	42		Hungry Neck Blvd. at Theatre Dr.	Reblock
3003W	4505	30, 40		Mary St.	Reblock

Table 6: Proposed Re-Blocking of Weekends and Vehicle Swap for Phase I-C

Block	Route	Shipwatch Service	Vehicle Swap at the following location	Phase I-C Approach
1201S	12, 102	X	n/a	On-route at Shipwatch
1202S	12, 102	X	n/a	On-route at Shipwatch
1203S	12, 102	X	n/a	On-route at Shipwatch
1204S	12, 102	X	n/a	On-route at Shipwatch
3201S	32	X	n/a	On-route at Shipwatch
1201U	12, 13, 32	X	n/a	On-route at Shipwatch
1202U	12, 13, 32	X	n/a	On-route at Shipwatch
1001S	10	X	Mary St.	Reblock
1001U	10	X	Trident Medical Center	Reblock
1003U	10	X	No Reblocking, monitor vehicle	Reblock
1101U	11	X	Tanger	Reblock
1002S	10	X	Mary St.	Reblock
1003S	10	X	Mary St.	Reblock
1004S	10	X	Trident Medical Center	Reblock
1101S	11	X	Tanger	Reblock
1102S	11	X	Mary St.	Reblock
3001S	30, 40		Citadel Mall	Reblock
3002S	30, 40		Mary St.	Reblock
3003S	30, 40		Mary St.	Reblock
3101S	31		Mary St.	Reblock

Block	Route	Shipwatch Service	Vehicle Swap at the following location	Phase I-C Approach
3102S	31		Mary St.	Reblock
3301S	33		Mary St.	Reblock
4201S	42		Hungry Neck Blvd. at Theatre Dr.	Reblock
3001U	30, 40, 42		Citadel Mall	Reblock
3002U	30, 40, 42		Mary St.	Reblock
3101U	31		No Reblocking, monitor vehicle	Reblock
4201U	30,40, 42		No Reblocking, monitor vehicle	Reblock

4.4 PHASE II

Phase II considers a 100% BEB fleet to be fully operational by 2040 in fixed-route service. As the existing diesel fleet vehicles reach the end of their service lives, they can be replaced with BEB rolling stock on an orderly schedule (see details in Section 7). Beyond the straightforward replacement of diesel vehicles with BEBs, projected growth in CARTA's service over the 18-year period will result in the need for supplanting the fixed-route fleet with additional rolling stock beyond the current 92 vehicles. To model future service expansion, fleet size was calculated to have a 20% increase by the 2040 target year.

Fleet expansion of 20% more vehicles would result in a fleet total of 110

- CARTA has indicated that they expect expansion to be represented by higher frequencies and more service on current routes, rather than the establishment of new routes.
- If increases of service frequency are considered to apply to all routes and blocks equally, and the bus sizes are specifically tied to the routes they serve (CARTA operates in historic areas where street widths and turning ratios do not allow for full-sized 40-ft buses), then the 20% fleet expansion by 2040 would breakdown as follows:
    - Thirteen (13) 22-ft cutaways (eleven (11) replacement of diesel buses + two expansion BEBs)
    - Nineteen (19) 30-ft buses (sixteen (16) replacements of diesel buses + three expansion BEB)
    - Thirty-six (36) 35-ft buses (all replacements of diesel buses)
    - Forty-two (42) 40-ft buses (twenty-nine (29) replacements of 40-ft diesel buses + seven expansion replacing 35-ft buses + five expansion BEBs)
- 110 total vehicles (ninety-two (92) from current fleet + eighteen (18) expansion BEBs)

5.0 POWER DEMAND MODELING AND CHARGING PROFILE

After translating the modeling results into the phased BEB implementation approach described above, the subsequent step is to estimate the power capacity needed at the transit facility to meet the energy demand for each phase of implementation to provide the necessary information for any required utility upgrades.

5.1 MODELING APPROACH FOR CHARGING PROFILES

Several operational factors were incorporated as parameters for the power modeling, including:

- Charging/recharging time windows: Stantec assumed that when a vehicle is not in service it can charge, including between blocks, i.e., charging can occur during out-of-service times. This input is the service schedule of vehicle pull-out and pull-in times for a representative day as presented in the Existing Conditions Report.
    - Phase I-A and I-B: considers no on-route charging. Vehicles that were unsuccessful after modeling have been reblocked to end their service span earlier so that the vehicles can return to the depot to charge, and a new (non-BEB) vehicle is dispatched to complete the block.
    - Phase I-C: on-route charging occurs for vehicles at Shipwatch Square. Vehicles that were unsuccessful after the CARTA – directed modeling will not be receiving on-route charging at Shipwatch Square (route 10 and 11) and have been reblocked to end their service span earlier so that the vehicles can return to the depot to charge, and a new (non-BEB) vehicle is dispatched to complete the block.
    - Phase II: on-route charging occurs for vehicles at both Shipwatch Square and Downtown. Vehicles that were reblocked in earlier phases are not reblocked and it is assumed that through on-route charging, they can complete their daily scheduled service and return to the depot with 20% SOC.
- For Phase I-A, the depot is outfitted with six 125 kW chargers and dispensers (Charger Output in Equation 1).
- For Phases I-B and I-C, the depot is outfitted with forty-six (46) dispensers each receiving 60 kW of power (Charger Output in Equation 1).
- For Phase II, the depot is outfitted with 100 dispensers, each receiving 60 kW of power (Charger Output in Equation 1).
- A 90% charger efficiency (Eff. in Equation 1)

- A 25% contingency factor to account for limits of onboard charging equipment that limit the maximum power capacity from the chargers (Contingency in Equation 1)
- Minimize charging between 7am-12pm and 5pm-9pm in accordance with Dominion Energy rates for Large General Service time of use (TOU)
- Assumes a negligible time delay between when a bus enters the facility and is connected to a charger to start charging.

Using the technical specifications and assumptions from the charging equipment, the charging hours (hours of charging required per block) that are required based on the daily energy demand were calculated using Equation 1 for each phase of implementation.

Equation 1: Hours of charging needed to serve daily energy demand

$$Hrs.Charging = \left[\left(\frac{kWh}{day} * \frac{1}{Charger\ Output\ kW}\right) * \frac{1}{eff.}\right] * (1 + Contingency)$$

Equation 1 was applied to the daily energy demand calculated for all blocks and vehicle assignments. The total charge time per block per vehicle was then used to develop a vehicle charging schedule for CARTA’s depot (i.e., hours during the day that each bus needs to charge in order to have enough energy to go into service at the time specified by the service or dispatching schedule).

The number of hours each charger needs to be online provides the power requirement, and the cumulative number of connected chargers at a specified hour represents the total power required at each hour of the day for each phase. For example, if ten chargers with a maximum capacity of 150 kW are connected at the same time for one hour, the power demand during this hour is 1,500 kW.

The key aspect of calculating the power demand for each hour of the day is assigning the correct charging schedule to every bus serving a specific block. Assigning charging times to the vehicles was based on the following parameters:

- Charging buses as soon as they return to the depot.
- Charging buses during vehicle not-in-service hours based on block schedules.
- Charging occurs in between blocks for vehicles that complete multiple blocks throughout the day and return to the depot between blocks.
- Minimizing charging during peak hours as much as possible given the number of hours required to charge.
- Smart charging software will be implemented to optimize the charging times and guarantee all vehicles will be charged and ready for service.

5.2 RESULTS

The power modeling provides the following outputs for each phase:

- The minimum number of chargers that need to be connected at each hour of the day.
- Representative daily charging schedule.
- Minimum power requirements, from optimized charging model
- Maximum power requirements are driven by the total number of installed charging equipment. While not all chargers will be simultaneously active because a smart charging software will control the peak load; the utility company often requires equipment to be in place (e.g., transformers and switch boards) that can support the maximum power from the installed equipment to avoid damages or overloading the system.

A summary of the parameters used in the development of each charging profile for each phase along with the maximum daily power demand is presented in Table 7.

Table 7: Summary of each implementation phase and charging profile parameters

Phase No. and Description		No. Vehicles	Active Dispensers	Installed Dispensers	Min. Power (kW)	Max Power (kW)
Phase I-A	Buses charging with only six 125-kW chargers	33	6	6	750	750
Phase I-B	Buses charging with new (1.2 MW) centralized system	33	15	40+6 = 46	900	2x1,200 = 2,400
Phase I-C	Buses charging with new two (1.2 MW) system and fast charge at Shipwatch Square	33	27	40+6 = 46	1,800	3,150
Phase II	100% BEB fleet with four (1.2 MW) system and fast charging at Shipwatch Square and Downtown	110	53	80+6 = 86	3,800	6,500

Figure 15 through Figure 18 display the charging schedule and daily power requirements at CARTA’s depot for each implementation phase. Given that the delivery of the additional twenty-six (26) BEBs is scheduled for 2022, the implementation of Phase I-A will not allow for an increase to the current power capacity at the facility. Therefore, no contingency factor was added to the predicted load of 750 kW.

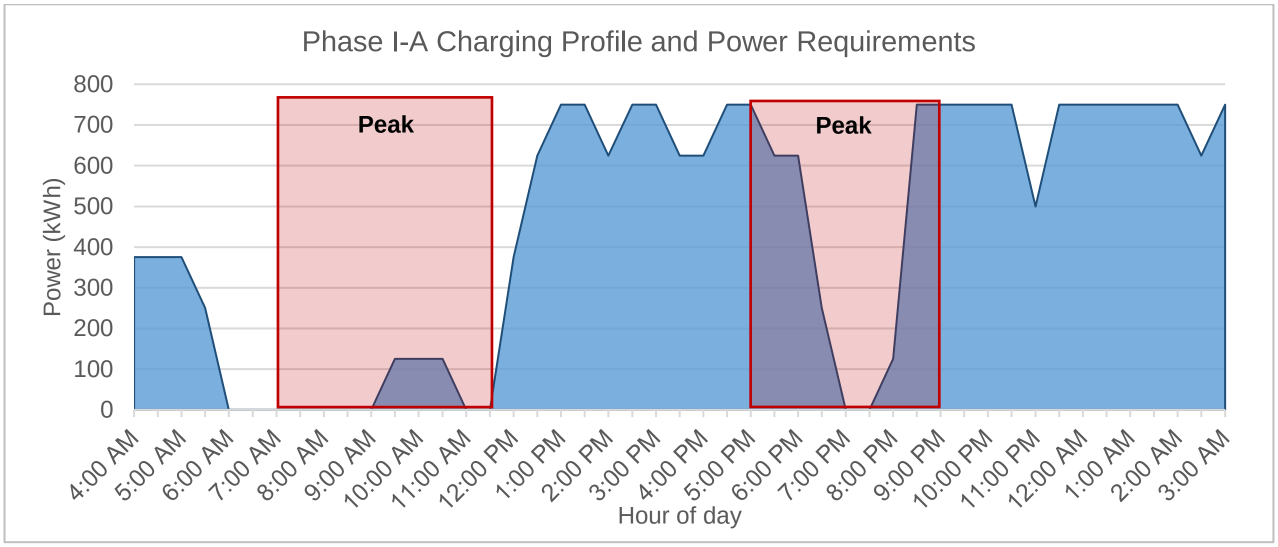


Figure 15: Phase I-A charging profile

For all phases, except phase I-A, a 10% contingency was added to the calculated power capacity that is shown in the charging profile graphs to account for additional chargers coming online or for any failures in the smart charging system.

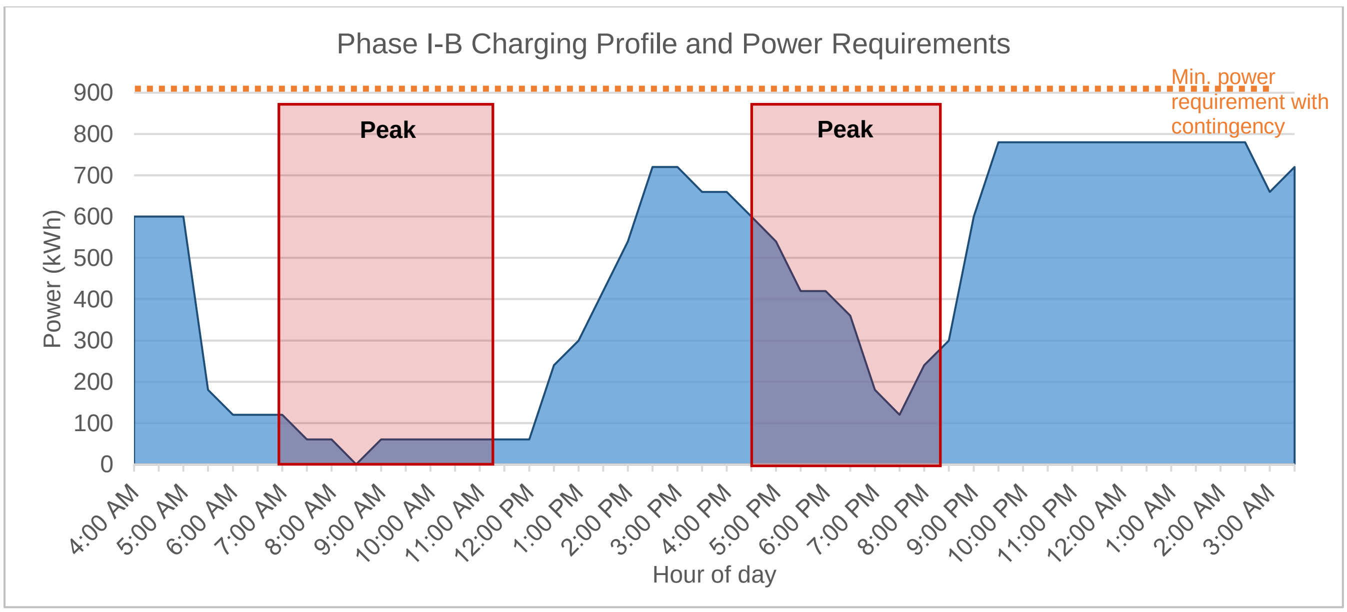


Figure 16: Phase I-B charging profile

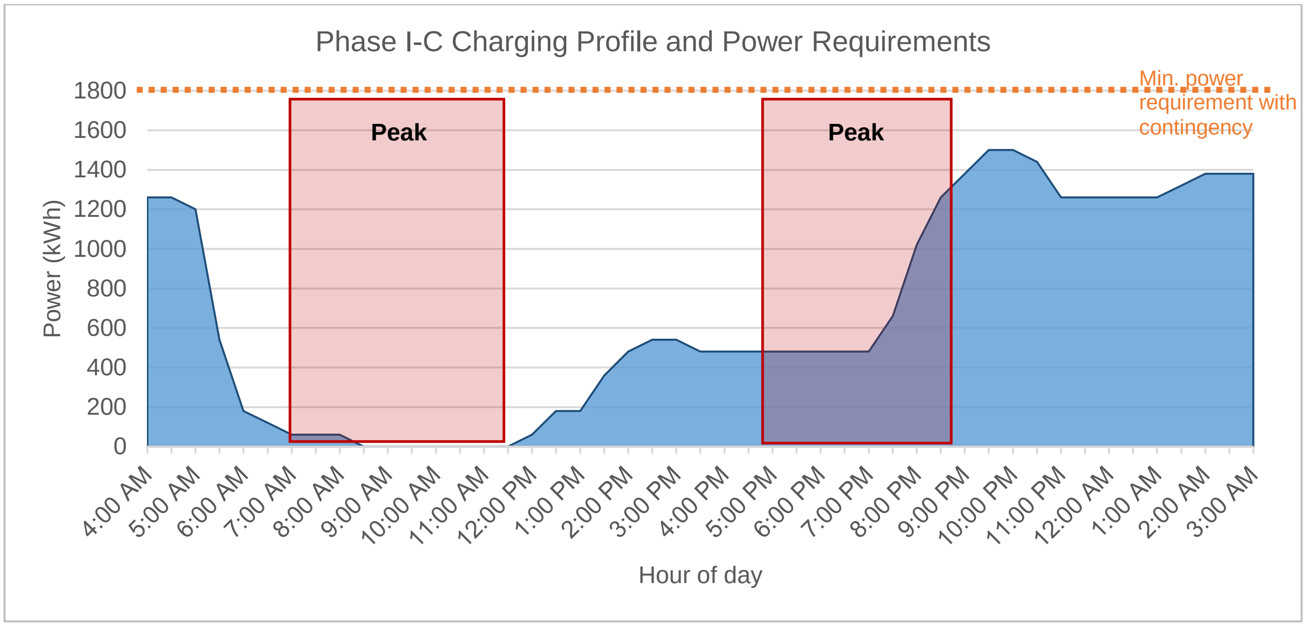


Figure 17: Phase I-C charging profile

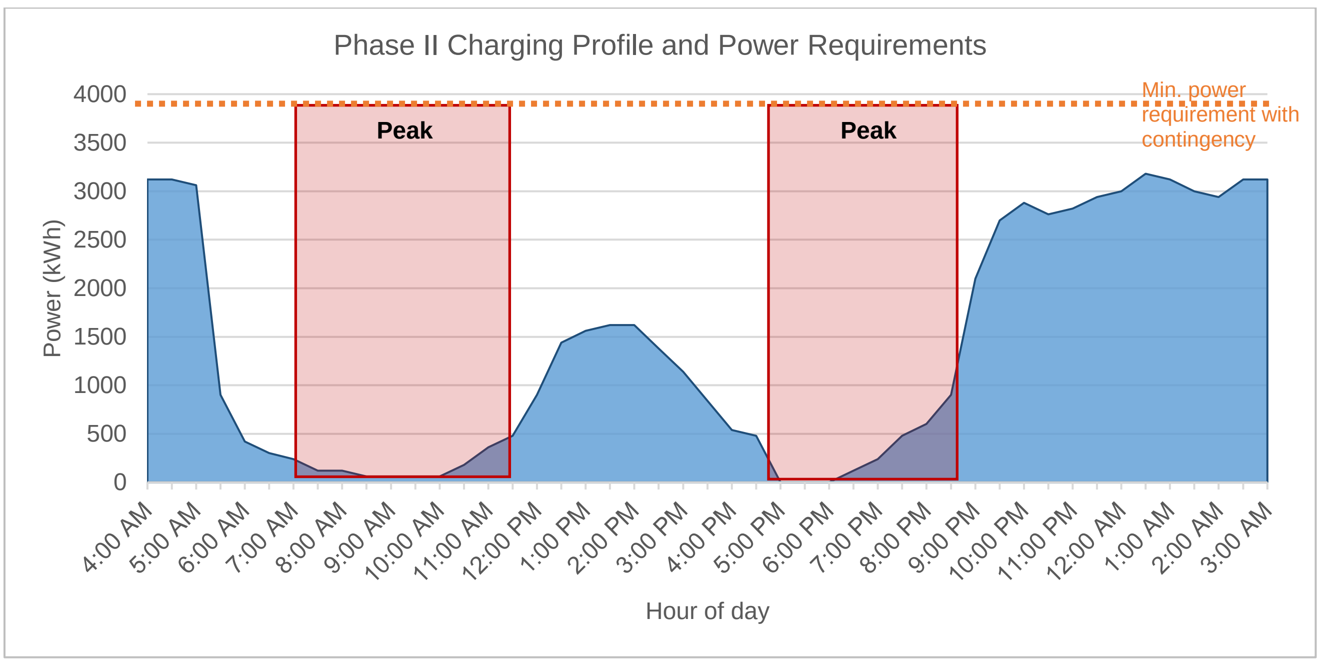


Figure 18: Phase II charging profile

The charging profile and total number of active chargers will vary if using smart charging management software, but the analysis shown here ensures that a high demand service day under Phase II for CARTA can be achieved under a minimum power demand of 3.8 MW. Nevertheless, the electrical equipment will likely be sized to power a maximum peak demand of 6.5 MW to comply with utility’s regulation.

6.0 SHIPWATCH SQUARE ASSESSMENT

As a transit agency committed to continuously providing better service, CARTA is also in the process of redeveloping and relocating its current SuperStop, a major transfer center where seven bus routes currently converge to Shipwatch Square. The current SuperStop is located at the intersection of Rivers Avenue and Cosgrove Avenue in North Charleston. Shipwatch Square, a new social services and transit center, is being constructed approximately 1/3 mile west of the current SuperStop location. All transit service will relocate to Shipwatch Square when it opens which is anticipated in 2024 (Figure 19).

Figure 19: Schematic of Shipwatch Square relative to current SuperStop

The current SuperStop has no room for growth and has outlived its functional life span. The move to Shipwatch Square will not only upgrade the passenger waiting experience and provide connections to the region’s future bus-rapid transit (BRT) line, but will also provide convenient access for CARTA riders to the multiple county social services organizations also relocating to Shipwatch Square. Furthermore, the new transit center construction allows CARTA to proactively plan for on-route charging of BEBs at Shipwatch.

As part of the BEB planning effort, Stantec examined the impacts that the relocation of Shipwatch Square will have on two areas:

- Bus operations and service planning for seven CARTA routes that currently terminate at the SuperStop
- Considerations for on-route charging infrastructure and bus operations at the new Shipwatch Square

Community outreach and engagement was conducted to understand the potential impacts the move would have on riders currently using the SuperStop, the surrounding community, and the social services agencies that will be relocating to Shipwatch Square. This was accomplished through meetings with representatives from two social services agencies, with an in-person pop-up outreach event at the current SuperStop to solicit feedback on the new transit center, and with an online survey asking respondents how the relocation of transit service to Shipwatch Square will impact riders' travel and mobility.

6.1 CONTEXT

The I-26ALT study conducted in 2016 for the future BRT line identified a hub or station for the BRT alignment in the vicinity of the intersection of Rivers Avenue and Dorchester Road. Since 2018, CARTA, BCDCOG, and partner agencies have been in the planning and development process for the new transit center at Shipwatch Square.

The project site is approximately 1 million square feet and is located about 1/3 mile west of the current SuperStop at Rivers Avenue and Cosgrove Avenue at this site, the County Hub and Library are already under construction, and while Shipwatch Square is currently in the planning stages, an area within the County Hub and Library has been set aside for the Shipwatch Square transit center. The adjacent social services hub (orange in Figure 20) will include a substance abuse prevention, intervention, education and treatment center; Department of Social Services; Department of Health and Human Services; Guardian Ad Litem; and South Carolina Department of Health and Environmental Control (DHEC) Administration, Clinics and Vital Records. A county library is also planned (red in Figure 20). By providing a bus transfer center (light blue in Figure 20) adjacent to these important destinations, CARTA is ensuring that bus customers will have easy access to these valued opportunities.

The transit center is slated to have ten sawtooth bus bays. Early concepts include having dynamic assignments for bus route for bays to facilitate transfers and eventually BEB charging. One key constraint of the current bus bay layout is that the two bays noted in purple in Figure 20 are unable to accommodate vehicles larger than 35-ft length turning right from Dorchester Road, because of the greater-than-90-degree turn required and limits of the turning radii of larger vehicles.

Figure 20: Bus bays limited by size of vehicle at Shipwatch Square

The figure below demonstrates ingress and egress points for CARTA vehicles (Figure 21). The blue arrows indicate access from the east from Dorchester Road. This access and egress would likely be the main points of entry and exit, although vehicles larger than 35-ft would be unable to make righthand turns and park in the first bus bays of each of the first two rows. A secondary access would be from the west from McMillan Avenue; however, this access point has a gate to access the bus bays to restrict non-transit vehicle access (green arrow in Figure 21).

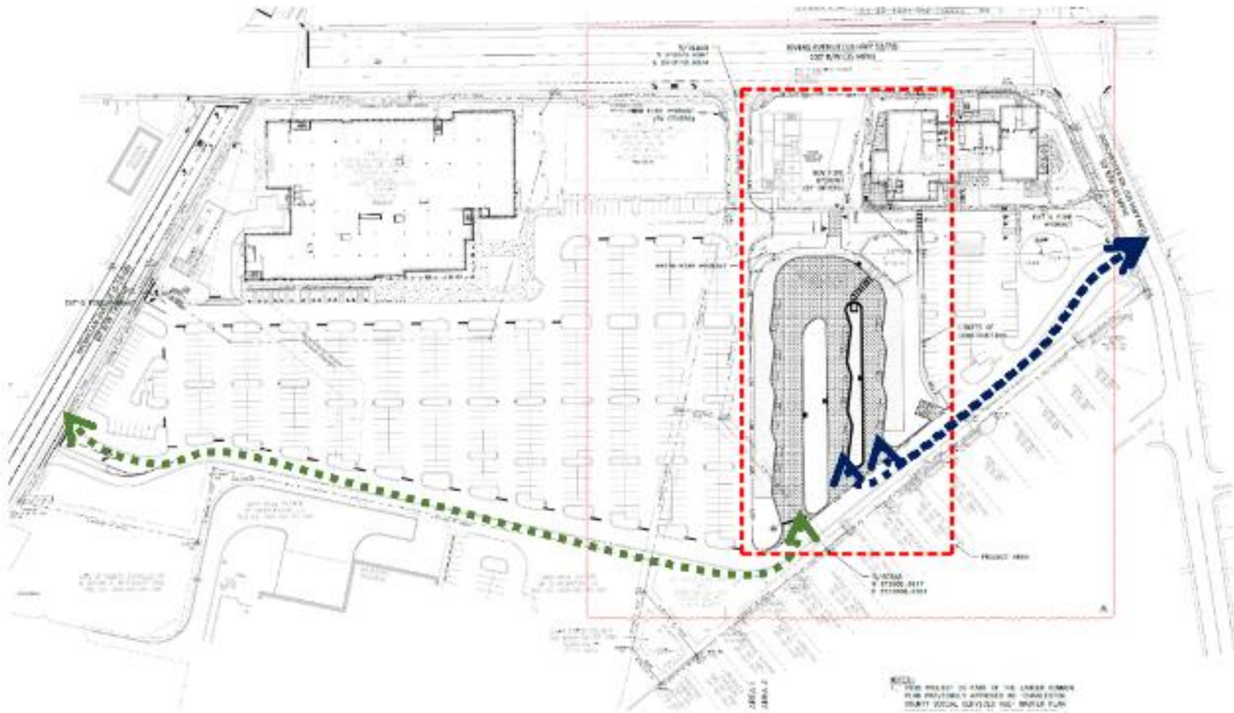


Figure 21: Bus ingress and egress at Shipwatch Square

The following sections outline the on-route charging considerations for CARTA operations at Shipwatch Square, the route optimization analysis wherein routing, operating, and scheduling changes to routes are analyzed; a summary of stakeholder and public outreach and engagement events and findings, and a Title VI analysis is provided in Appendix A.

6.2 ROUTE OPTIMIZATION

Based on stakeholder feedback and public comments, Stantec developed draft service changes for the CARTA routes that currently terminate at the Charleston SuperStop (Rivers Avenue / Cosgrove Avenue) or pass near it—routes 10, 11, 12, 13, 32, 102, 103, and 104. The draft routing changes were aimed at minimizing left turns (although many intersections around Shipwatch Square are intended to have transit signal priorities), minimize deviations needed to enter the Shipwatch Square bus bay area, minimize changes to routing to minimize disruptions to customers, while ensuring that all routes enter the terminal to facilitate passenger transfers and bus pulsing.

The routing proposals were workshopped with CARTA staff to refine the alignments. The proposed route alignments are described below by route.

6.2.1 Route 10

Route 10 is CARTA's most frequent and most patronized route, as well as a route that experiences heavy transfer activity at the SuperStop. As such, Route 10 is re-routed via Dorchester Road to enter Shipwatch Square to facilitate passenger transfers. To avoid prolonging running times and disrupting passenger trips, Route 10 vehicles will not charge during their dwell time at Shipwatch Square as this stop is a pass-through and not a terminal stop for the route.

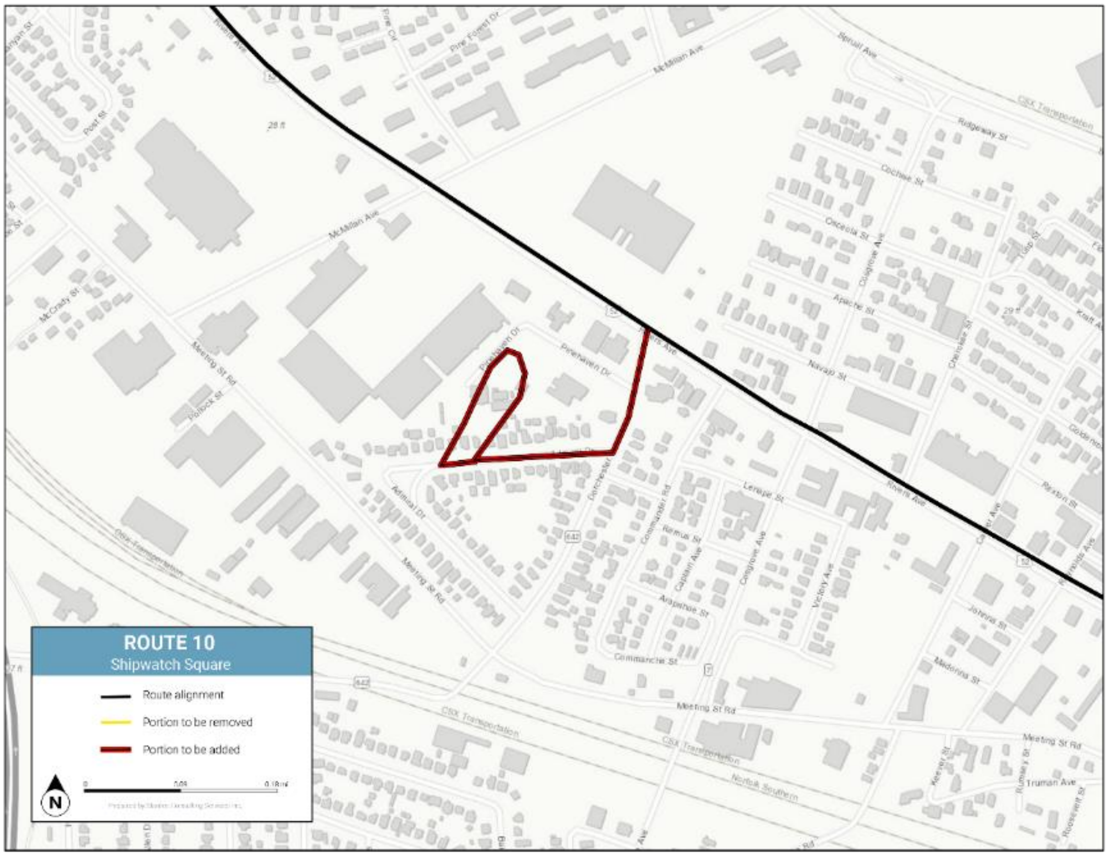


Figure 22: Proposed Route 10 Shipwatch Square routing changes

6.2.2 Route 11

Similar to Route 10, Route 11 does not terminate at the SuperStop, so the Shipwatch Square stop for Route 11 vehicles would be treated as a pass-through stop to facilitate transfers and boarding and alighting activity, but without a prolonged dwell time that would facilitate bus charging.

As Route 11 already travels along Dorchester Road, this route change needed is minor to route vehicles into Shipwatch Square via Dorchester Road.

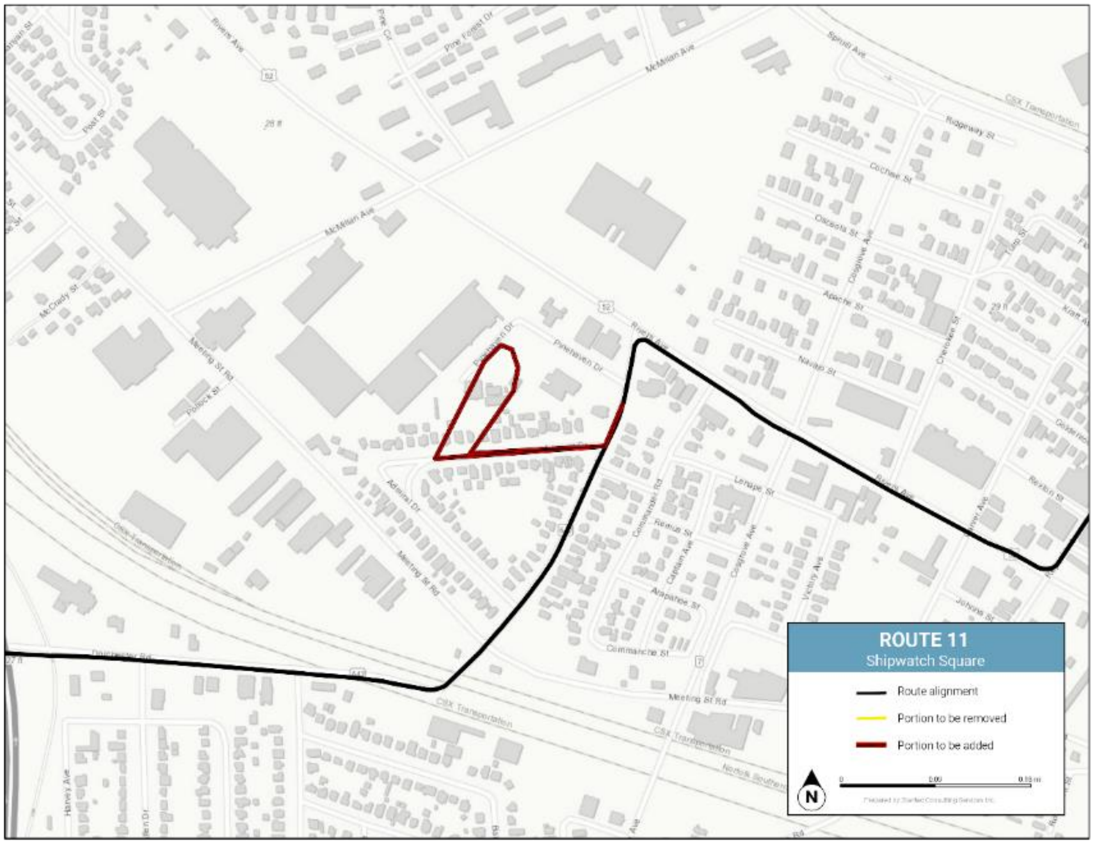


Figure 23: Proposed Route 11 Shipwatch Square routing changes

6.2.3 Route 12

Route 12 currently terminates at the SuperStop on River Avenue and Cosgrove Avenue. As such, to terminate at Shipwatch Square, Route 12 vehicles would use the Dorchester Road. entrance to access Shipwatch Square. As a result, Route 12 would no longer operate on Rivers Avenue and the stop at the current SuperStop would be removed. Nonetheless, Routes 10 and 11 will still provide service on Rivers Avenue.

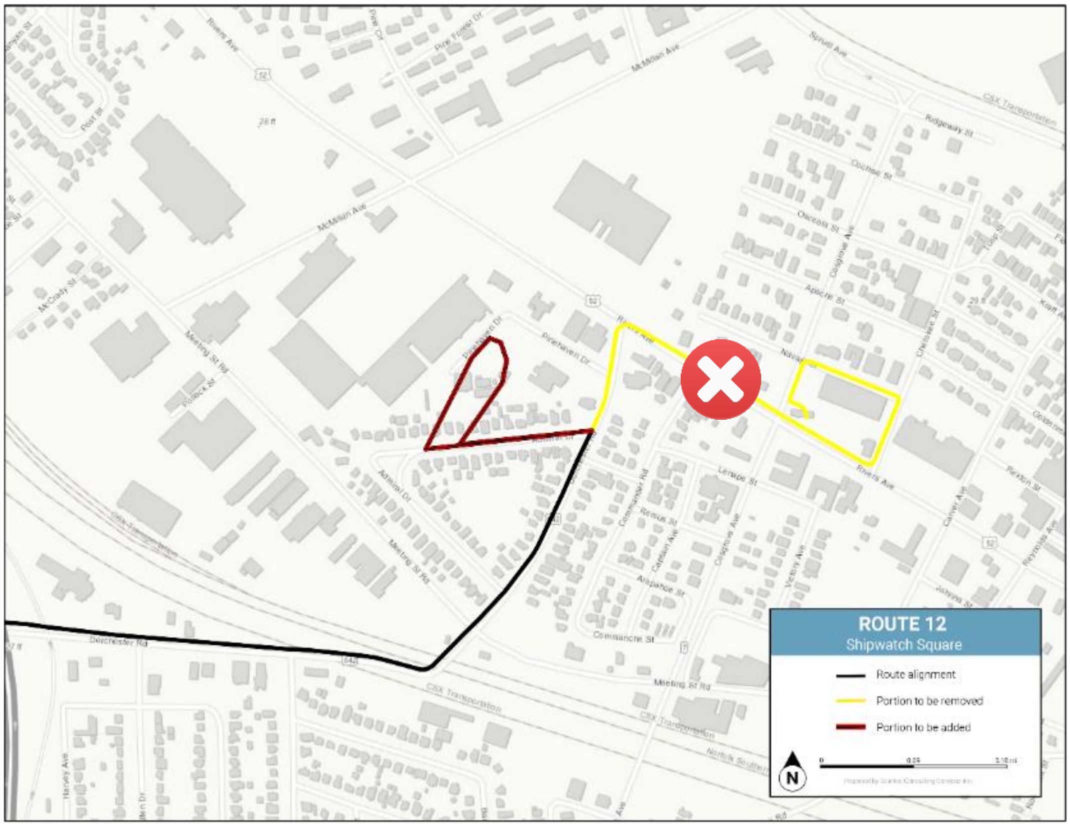


Figure 24: Proposed Route 12 Shipwatch Square routing changes

6.2.4 Route 13

Route 13 currently terminates/begins at the SuperStop via a large one-way loop—eastbound along Spruill Avenue, southbound along Reynolds Avenue, westbound along Rivers Avenue, the SuperStop, and then back in service north bound along Cosgrove Avenue.

To minimize out-of-direction travel for Route 13 riders, the proposed routing would use Cosgrove Avenue and Rivers Avenue to access the Dorchester Road approach for Shipwatch Square; the reverse routing would be used to leave Shipwatch Square for outbound trips.

As a result of this routing and others, the only portion of roadway that will lose service is Spruill Avenue between Cosgrove and Reynolds avenues. Customers along this section of Spruill Avenue will still have access to both Routes 11 and 13 less than 1,000 feet in either direction, and Route 10 on Rivers Avenue is 1,500 feet away. Reynolds Avenue still sees service via Route 11.

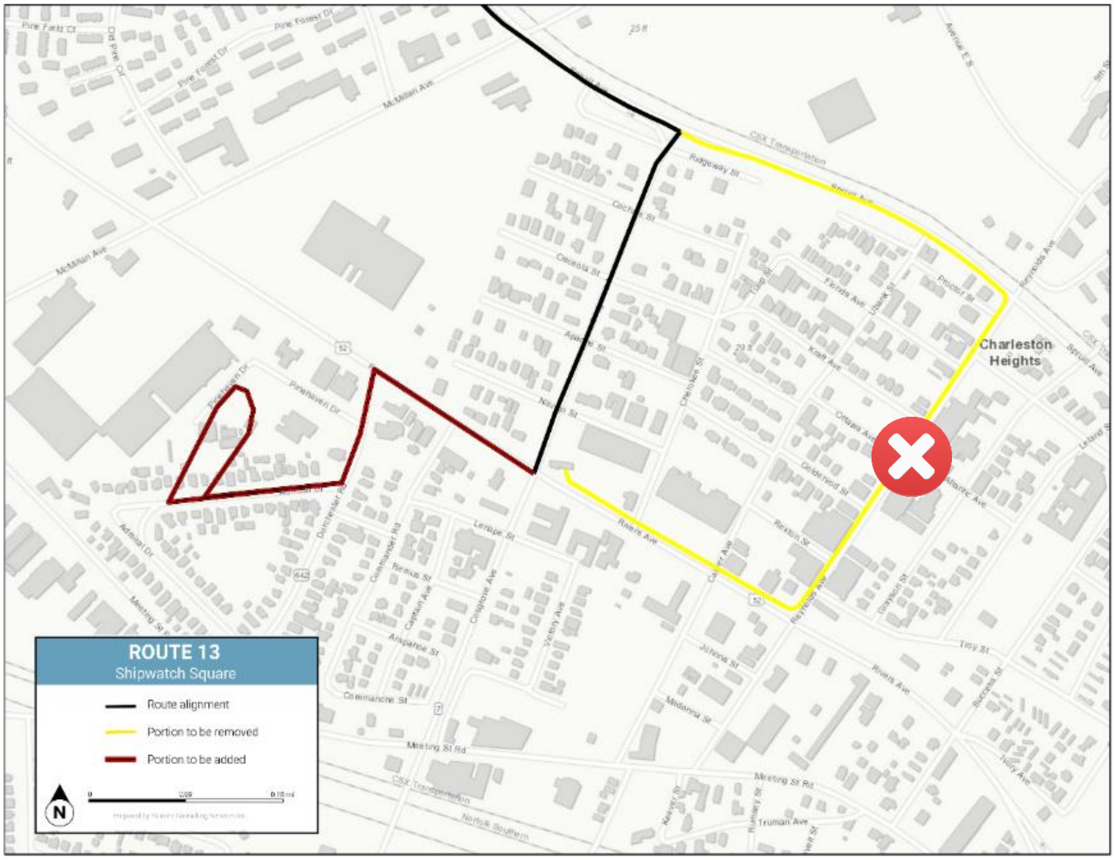


Figure 25: Proposed Route 13 Shipwatch Square routing changes

6.2.5 Routes 32 and 102

Both Routes 32 and 102 have similar approaches to the SuperStop along Dorchester Road and Rivers Avenue. Routes 32 and 102 are proposed to maintain a similar routing along Dorchester Road. to access Shipwatch Square. Note that Routes 102 and 103 are currently interlined on most trips, while Routes 13 and 104 are currently interlined as well.

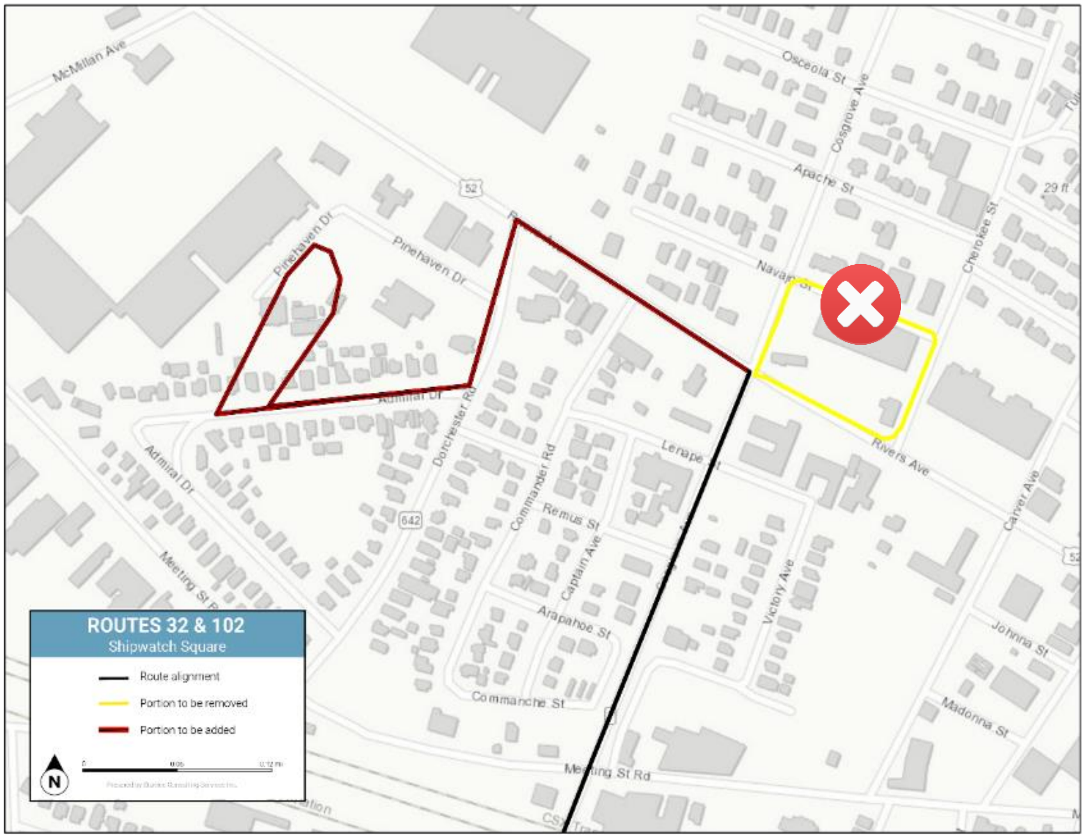


Figure 26: Proposed Routes 32 and 102 Shipwatch Square routing changes

6.2.6 Route 103

Route 103 currently accesses the SuperStop along Dorchester Road and Rivers Avenue. Therefore, Shipwatch Square access for Route 103 would be via the Dorchester Road entrance.

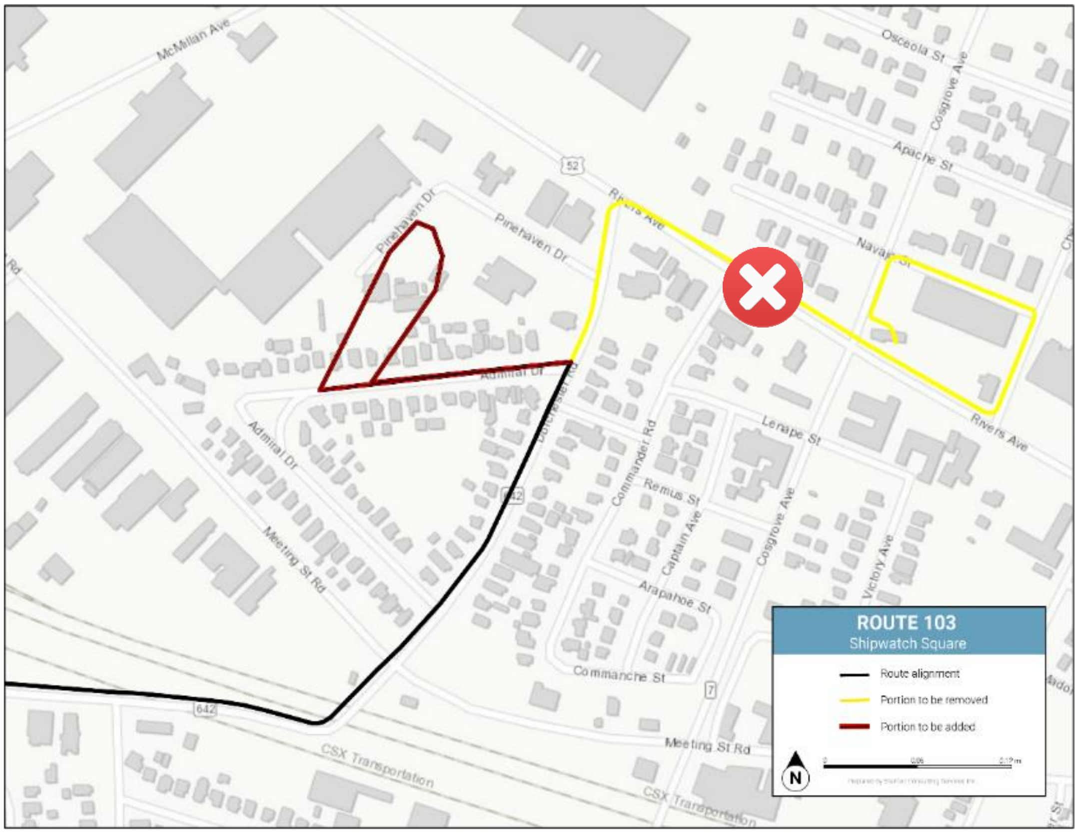


Figure 27: Proposed Route 103 Shipwatch Square routing changes

6.2.7 Route 104

Route 104 has a northerly approach to the SuperStop via McMillan Avenue and Rivers Avenue. To maintain a similar routing, the proposed Route 104 will continue on McMillan Ave south of Rivers Avenue to access Shipwatch Square via the McMillan entrance. As such, Route 104 service is removed from Rivers Avenue, but Routes 10 and 11 still provide service along Rivers Avenue between McMillan and Cosgrove Avenues.

Figure 28: Route 104 Shipwatch Square routing changes

6.2.8 All Routes

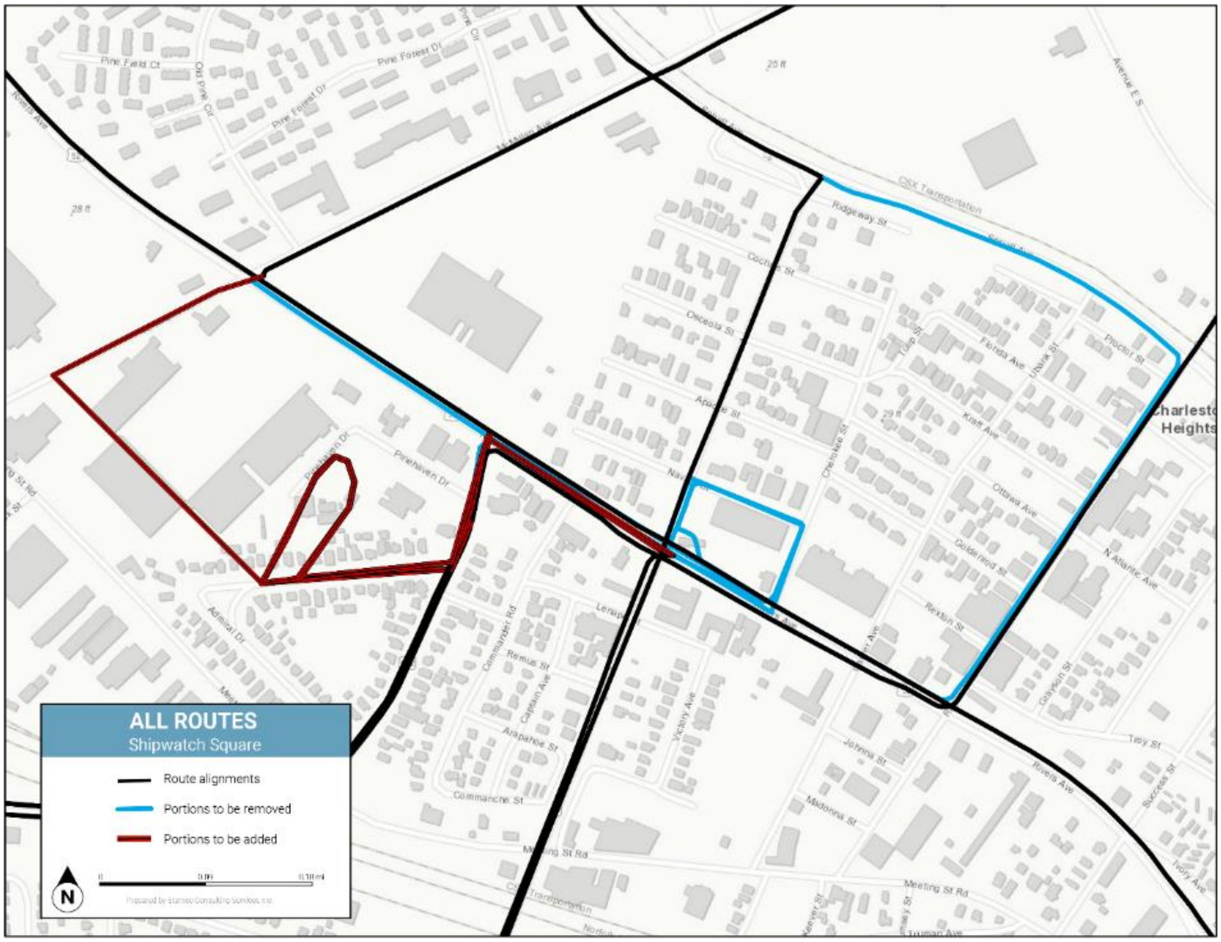


Figure 29: All Shipwatch Square routing changes

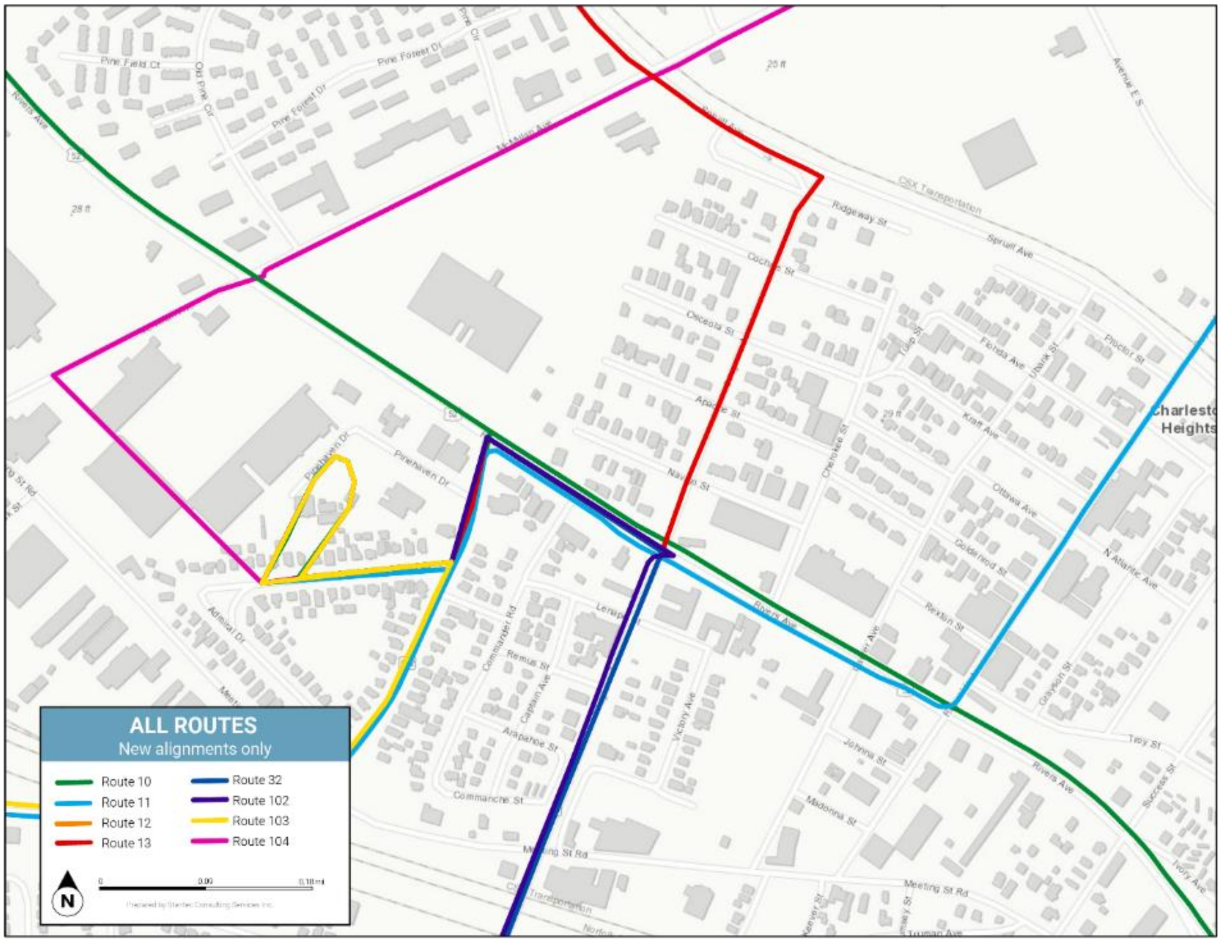


Figure 30: All proposed route alignments providing service to Shipwatch Square

6.3 SHIPWATCH SQUARE CHARGING CONSIDERATIONS

Based on discussions with CARTA regarding the desire to transition certain vehicle types and routes to fully battery-electric vehicles, Stantec determined the potential needs of charging "on-route'. On-route charging means either charging while in service operating with passengers, or during layovers.

First, Routes 10 and 11 were not considered for on-route charging because they do not lay over at Shipwatch Square; rather, this is a stop along their trip. In addition, given that top-up recharging would require anywhere between 5-10 minutes, to minimize passenger dissatisfaction with waiting onboard a bus while it charges, it was decided that Routes 10 and 11 would not charge at Shipwatch Square. These routes will enter that facility to facilitate passenger transfers, but additional time will not be allotted for vehicle charging.

Avoiding on-route charging means that for Routes 10 and 11, CARTA's scheduling department will need to adjust the vehicle blocking for these routes and potentially add more total vehicles to the route to provide similar levels of service as today.

Otherwise, the remainder of the routes that may need charging will recharge during layover time, between trips (either the same route in different direction), or when they are changing route through interlining.

The Stantec Project Team (Project Team) examined each trip for each vehicle block of each route passing through the SuperStop that would be relocated to Shipwatch Square and then assessed the necessary charging time that would be needed during each layover for each cycle (a cycle consists of an inbound trip, inbound layover, an outbound trip, and an outbound layover). Furthermore, we assumed that vehicles would not charge at the other terminal of their route, i.e., all layover charging would occur at Shipwatch Square.

Our analysis determined that only minimal adjustments to current layover scheduling of certain trips are needed to accommodate layover charging. Table 8 below summarizes the total recharging time required for each vehicle block, as well as additional layover time required if the charging time exceeds the currently scheduled layover time. How and when that recharging time is introduced into each layover will be decided by CARTA while keeping in mind that only one fast charger will be available in Phase I. Therefore, only one vehicle can charge at a time even if multiple vehicles have the same layover at Shipwatch Square.

Table 8: Shipwatch Square Fast Charging and Layover Implications

Block	Electrification Phase	Service Day	Total required charging time at Shipwatch Square (min)	No. of charging events (5 min events) per day	No. of charging events (10 min events) per day	Total added layover per day (min)
1302W	Phase I	Weekday	45	9	5	8
1301W	Phase I	Weekday	45	9	5	10
1202W	Phase I	Weekday	20	4	2	n/a
1203W	Phase I	Weekday	15	3	2	n/a
1303W	Phase I	Weekday	42	9	4	3
1201W	Phase I	Weekday	20	4	2	n/a
10201W	Phase II	Weekday	35	7	4	n/a
10301W	Phase II	Weekday	28	6	3	n/a
1201S	Phase I	Saturday	18	4	2	n/a
1202S	Phase I	Saturday	18	4	2	n/a
1203S	Phase I	Saturday	10	2	1	n/a
1204S	Phase I	Saturday	18	4	2	n/a
3201S	Phase I	Saturday	6	1	1	n/a
1201U	Phase I	Sunday	12	2	1	n/a

The total charging time that is needed at Shipwatch Square can be divided into charging events of different lengths (e.g., 5, 7, or 10 minutes) to help align charging time with layover time. Table 8 provides an example of how many charging events would be needed in a day depending on the length of each event (for example, five or ten minutes). Lastly, Table 8 only shows the vehicle blocks that would require layover charging (excluding routes 10 and 11 as previously discussed) to complete service due to range limitations. Based on the modeling, all other routes/blocks routed to Shipwatch Square, can rely on overnight depot charging.

In summary, all of the blocks charging at Shipwatch Square can be complete charging within the currently scheduled layover time except for Route 13. For Route 13, all cycles will require at least five minutes of fast charge every time the vehicle is at Shipwatch Square—currently, eleven (11) out of twenty-seven (27) layovers are under five minutes. As such, CARTA schedulers will need to build at least five minutes into these trips either by adjusting running times, adjusting headways, or by adding an additional vehicle to maintain a comparable headway as the current schedule.

While the exact length and timing of the charging events will be established by CARTA, some proposals are provided below for the weekday blocks that need layover charging (Table 9). Table 9 summarizes the current layover times[6] and the suggested start-and-end times for the fast charging. By following the suggested start and end times of the charging events, only one fast charging pantograph (450 kW) would be required for the blocks in Phase I, and a second pantograph would be required for electrification of Phase II blocks.

Table 9: Fast Charging Concepts for Shipwatch Square

Block	Electrification Phase	Vehicle ID	Shipwatch In	Layover (min)	Shipwatch Out	Fast Charge Starts	Charging Time (min)	Fast Charge Ends
1301W	Phase I	3406	7:15 AM	5	7:20 AM	7:15 AM	5	7:20 AM
1301W	Phase I	3406	8:58 AM	2	9:00 AM	8:58 AM	5	9:03 AM
1301W	Phase I	3406	10:15 AM	5	10:20 AM	10:15 AM	5	10:20 AM
1301W	Phase I	3406	11:55 AM	5	12:00 PM	11:55 AM	5	12:00 PM
1301W	Phase I	3406	1:15 PM	5	1:20 PM	1:15 PM	5	1:20 PM
1301W	Phase I	3406	2:57 PM	**3**	3:00 PM	2:57 PM	**5**	3:02 PM
1301W	Phase I	3406	4:15 PM	5	4:20 PM	4:15 PM	5	4:20 PM
1301W	Phase I	3406	6:00 PM	**0**	6:05 PM	6:00 PM	**5**	6:05 PM
1301W	Phase I	3406	7:15 PM	5	7:20 PM	7:15 PM	5	7:20 PM
1302W	Phase I	3405	7:58 AM	**2**	8:00 AM	7:58 AM	**5**	8:03 AM
1302W	Phase I	3406	9:15 AM	5	9:20 AM	9:15 AM	5	9:20 AM
1302W	Phase I	3407	10:55 AM	5	11:00 AM	10:55 AM	5	11:00 AM
1302W	Phase I	3408	12:15 PM	5	12:20 PM	12:15 PM	5	12:20 PM

[6] Provided in CARTA's blocking and schedule data.

Block	Electrification Phase	Vehicle ID	Shipwatch In	Layover (min)	Shipwatch Out	Fast Charge Starts	Charging Time (min)	Fast Charge Ends
1302W	Phase I	3409	1:55 PM	5	2:00 PM	1:55 PM	5	2:00 PM
1302W	Phase I	3410	3:15 PM	5	3:20 PM	3:15 PM	5	3:20 PM
1302W	Phase I	3411	5:00 PM	0	5:00 PM	5:00 PM	5	5:05 PM
1302W	Phase I	3412	6:15 PM	5	6:20 PM	6:15 PM	5	6:20 PM
1302W	Phase I	3413	7:54 PM	6	8:00 PM	7:55 PM	5	8:00 PM
1303W	Phase I	3505	6:55 AM	5	7:00 AM	6:55 AM	5	7:00 AM
1303W	Phase I	3506	8:15 AM	5	8:20 AM	8:15 AM	5	8:20 AM
1303W	Phase I	3507	9:55 AM	5	10:00 AM	9:55 AM	5	10:00 AM
1303W	Phase I	3508	11:15 AM	5	11:20 AM	11:15 AM	5	11:20 AM
1303W	Phase I	3509	12:55 PM	5	1:00 PM	12:55 PM	5	1:00 PM
1303W	Phase I	3510	2:15 PM	5	2:20 PM	2:15 PM	5	2:20 PM
1303W	Phase I	3511	3:58 PM	2	4:00 PM	3:58 PM	5	4:03 PM
1303W	Phase I	3512	5:15 PM	5	5:20 PM	5:15 PM	5	5:20 PM
1303W	Phase I	3513	6:58 PM	2	7:00 PM	6:58 PM	2	7:00 PM
1201W	Phase II	4503	12:12 PM	18	12:30 PM	12:20 PM	10	12:30 PM
1201W	Phase II	4503	3:02 PM	18	3:20 PM	3:05 PM	10	3:15 PM
1202W	Phase II	3431	1:52 PM	18	2:10 PM	2:02 PM	10	2:10 PM
1202W	Phase II	3431	4:46 PM	14	5:00 PM	4:50 PM	10	5:00 PM
1203W	Phase II	3501	10:19 AM	11	10:30 AM	10:20 AM	10	10:30 AM
1203W	Phase II	3501	3:46 PM	14	4:00 PM	3:50 PM	5	3:55 PM
10201W	Phase II	5023	9:13 AM	7	9:20 AM	9:13 AM	7	9:20 AM
10201W	Phase II	5023	11:13 AM	7	11:20 AM	11:13 AM	7	11:20 AM
10201W	Phase II	5023	1:13 PM	7	1:20 PM	1:13 PM	7	1:20 PM
10201W	Phase II	5023	5:13 PM	7	5:20 PM	5:13 PM	7	5:20 PM
10201W	Phase II	5023	7:13 PM	7	7:20 PM	7:13 PM	7	7:20 PM
10301W	Phase II	5024	8:13 AM	7	8:20 AM	8:13 AM	7	8:20 AM
10301W	Phase II	5024	10:13 AM	7	10:20 AM	10:13 AM	7	10:20 AM
10301W	Phase II	5024	2:13 PM	7	2:20 PM	2:13 PM	7	2:20 PM
10301W	Phase II	5024	4:13 PM	7	4:20 PM	4:13 PM	7	4:20 PM

6.4 POTENTIAL SERVICE AND OPERATIONAL CHANGES

By accounting for routing changes and layover charging requirements, Stantec has developed the following service plan and options for CARTA for the eight bus routes that will interface at Shipwatch

Square. Note that this is a planning-level service plan, meaning that the various route attributes (alignment length, running time, speed, layover time, headway) were generalized to the longest pattern and predominant headway. Specifics regarding short trips, different patterns, minor changes in headway and running time are not captured in the discussion below—CARTA's planning and operations team will need to finalize details based on street tests and scheduling to real-world conditions when Shipwatch Square becomes operational.

For most routes, serving Shipwatch Square will add 0.30 miles to 1.32 miles to each round trip (a cycle). For Routes 12, 103, and 104, serving Shipwatch Square will shorten the round-trip length; for these routes, since running time will be shorter, CARTA can operate these routes as today and in effect, these routes could see increases in layover time or donate that time to interlined routes, if possible.

For the routes with increased running time—Routes 10, 11, 13, 32 and 102—most of the estimated increases in round-trip running time range from about one minute to slightly over five minutes. As such, generally, CARTA will need to determine the optimal choice(s) for the trade-offs that come with increased cycle times due to layover recharging and re-routing:

- Trying to reduce the running time portion of cycle time through measures like bus stop dieting, transit signal priority, straightening routes, and so on to essentially speed up average moving speed. However, this will likely be a greater challenge since these routes operate in mixed traffic.
- Adjusting layover time. CARTA could reduce or increase layover time for certain routes, as long as sufficient time is protected to accommodate re-charging and recovery. As well, CARTA may also donate or transfer excess layover time from one interlined route to another interlined route to make-up the time needed for charging.
- Adding vehicles to a route. CARTA has chosen not to re-charge Route 10 and 11 vehicles on-route, so CARTA may need to increase equipment allocation to these routes. For the layover charging routes, the additional cycle time may require additional vehicles in order to maintain the specified or desired route headways. This is a costly option as more vehicles and operators will be required.
- Adjusting headways. As a more financially viable alternative to adding more vehicles to a route, CARTA could adjust headways by specifying headway(s) as a function of cycle time and assigned vehicles.

Table 10 provides a summary of running time changes and potential options for CARTA to pursue when it modifies its schedules and adjusts the vehicle blocking to accommodate layover charging and Shipwatch Square opening.

Table 10: Service impacts – Shipwatch Square

Route	Current round-trip route length (mi)	Est. New round-trip route length (mi)	Current Running time (two-way) (min)	New Running time (two-way) (min)	Current Layover time (two-way) (min)	Current peak headway (min)	Current off-peak headway (min)	Required charging time at Shipwatch Sq. (min)	Potential impact	Mitigation options
10	44.36	45.68	145.1	150.3	30	20	30	None	• Longer running times	• Adjust layover times • Maintain same fleet size, but increase headways by about 1 minute • Add an additional peak and off-peak bus to maintain headways as scheduled • On-route charging at a different location • Adjust blocking
11	33.40	34.32	103.0	106.3	17	40	45	None	• Longer running times	• Adjust layover times • Maintain same fleet size, but increase peak headways by about 1 minute • Add an additional peak bus to maintain headways as scheduled • On-route charging at a different location • Adjust blocking
12	39.76	39.35	152.8	151.0	27	45	60	10	• Shorter running times	• Adjust layover times

Route	Current round-trip route length (mi)	Est. New round-trip route length (mi)	Current Running time (two-way) (min)	New Running time (two-way) (min)	Current Layover time (two-way) (min)	Current peak headway (min)	Current off-peak headway (min)	Required charging time at Shipwatch Sq. (min)	Potential impact	Mitigation options
13	26.12	26.42	94.9	96.1	5	60		5	No impact—charging time is equal to layover time	
32	14.04	14.60	54.7	57.1	5	30		5	No impact—charging time is equal to layover time	
102	18.42	18.98	71.8	74.2	8	60		7	• Longer running times	• Adjust layover times • Adjust interlining with route 103
103	11.81	11.40	35.9	34.5	4	60		7	• Shorter running times	• Adjust layover times • Adjust interlining with route 102
104	21.33	21.06	70.0	69.0	10	60		5	• Shorter running times	• Adjust layover times • Adjust interlining with route 13

7.0 FLEET REPLACEMENT PLAN

The culmination of the BEB modeling and phasing program of the two-phase implementation is the fleet forecast and replacement schedule presented in the charts below. This plan first assumes that CARTA's fleet will grow by 20% to accommodate service improvements and expansion, and second, that buses will be replaced in a one-to-one manner from fossil fuel buses to BEBs. Overall, we anticipate that CARTA's fleet will be 100% zero-emissions by 2040, with all new purchases past 2030 being BEBs (Table 11).

Table 11: Fleet replacement schedule by year and by vehicle type.

FLEET FORECAST		2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Gasoline 22-ft	New					10	1													
	Retire					(10)	(1)						(10)	(1)	-	-	-	-	-	
Total 22-ft Diesel		11	11	11	11	11	11	11	11	11	11	11	1	-	-	-	-	-	-	-
BEB 22-ft	New												11	2	-	-	-	-	-	11
	Retire												-	-	-	-	-	-	-	(11)
Total 22-ft BEB		-	-	-	-	-	-	-	-	-	-	-	11	13	13	13	13	13	13	13
Diesel 30 & 35-ft	New	7				6	3	9												
	Retire	(34)				(6)	(3)	(9)						(7)	-	-	-	(6)	(3)	(9)
Total 30&35-ft Diesel		25	25	25	25	25	25	25	25	25	25	25	25	18	18	18	18	12	9	-
BEBs 30 & 35-ft	New	20												28	-	-	-	9	6	12
	Retire													(20)	-	-	-	-	-	-
Total 30&35-ft BEBs		20	20	20	20	20	20	20	20	20	20	20	20	28	28	28	28	37	43	55
Diesel 40-ft	New																			
	Retire			(2)				(3)		(1)	(15)	(3)								
Total 40-ft Diesel		24	24	22	22	22	22	19	19	18	3	-	-	-	-	-	-	-	-	-
BEB 40-ft	New	7		2	-	-	-	3	-	1	15	9	-	7	-	4	-	-	-	6
	Retire											(6)		(7)	-	(2)	-	-	-	(3)
Total 40-ft BEB		13	13	15	15	15	15	18	18	19	34	37	37	37	37	39	39	39	39	42
Total BEB vehicles	Total	33	33	35	35	35	35	38	38	39	54	57	68	78	78	80	80	89	95	110
Total BEB Percentage	%ZEB	35%	35%	38%	38%	38%	38%	41%	41%	42%	58%	61%	72%	81%	81%	82%	82%	88%	91%	100%
BEB purchase percentage		79%	0%	100%	0%	0%	0%	25%	0%	100%	100%	100%	100%	100%	0%	100%	0%	100%	100%	100%

Table 12 summarizes the quantity of BEBs by vehicle type in the fleet by year. The fleet is forecasted to grow from 93 total buses in 2022 to 110 total buses in 2040.

Table 12: Quantity of BEBs in the fleet by year.

	Bus Fleet																			
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
BEB 22-ft	0	0	0	0	0	0	0	0	0	0	0	0	11	13	13	13	13	13	13	13
BEB 30 & 35-ft	0	20	20	20	20	20	20	20	20	20	20	20	20	28	28	28	28	37	43	55
BEB 40-ft	6	13	13	15	15	15	15	18	18	19	34	37	37	37	37	39	39	39	39	42
Total BEBs	**6**	**33**	**33**	**35**	**35**	**35**	**35**	**38**	**38**	**39**	**54**	**57**	**68**	**78**	**78**	**80**	**80**	**89**	**95**	**110**
Non-BEBs	87	60	60	58	58	58	58	55	55	54	39	36	26	18	18	18	18	12	9	0
Total Fleet	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**93**	**94**	**96**	**96**	**98**	**98**	**101**	**104**	**110**

The graph in Figure 31 presents the transition plan to fully BEBs by 2040. Currently, CARTA's fleet is 35% BEB and this will steadily rise to 100% in 2040 through the replacement of diesel equivalents.

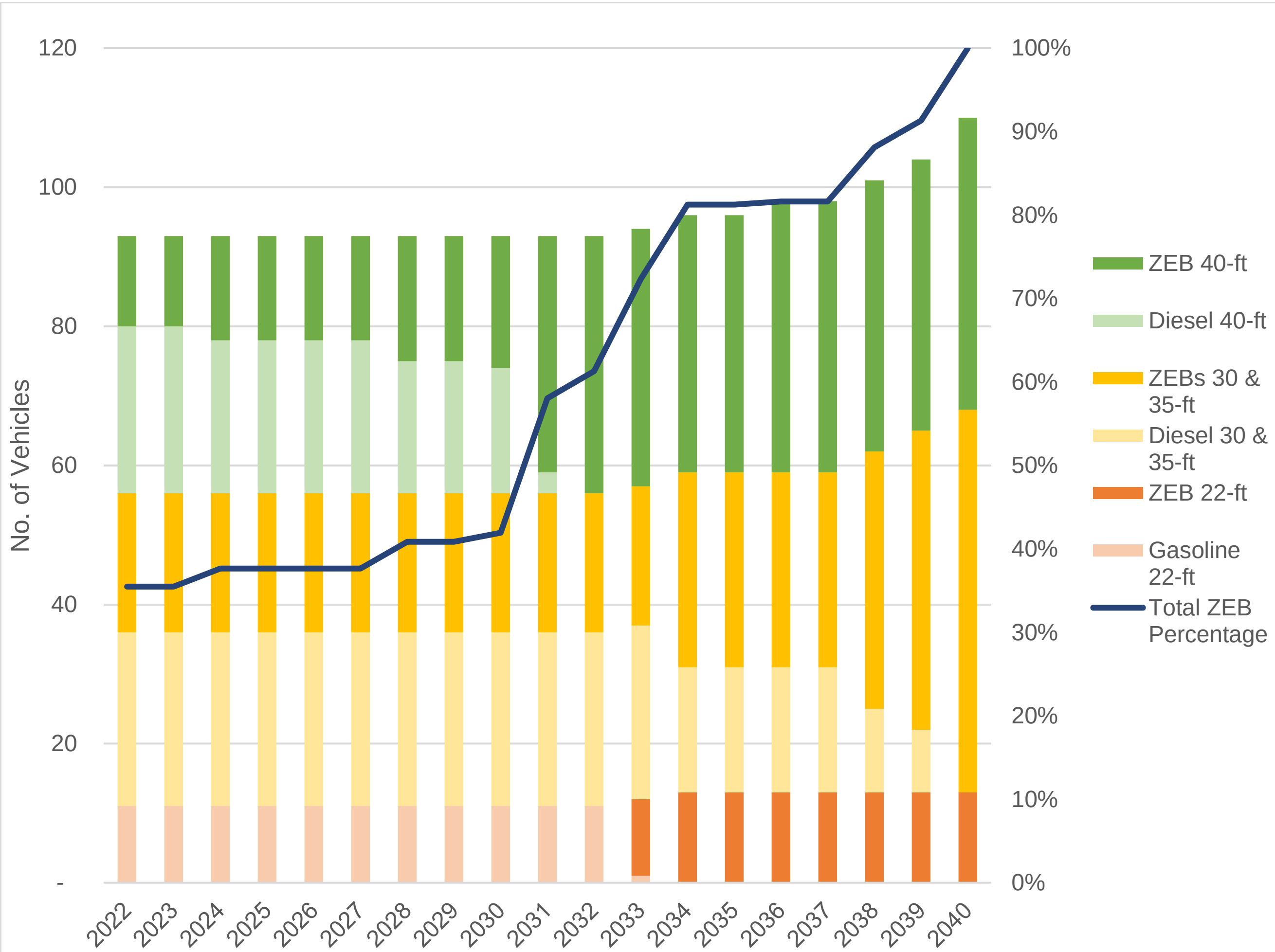


Figure 31: Proportion of the fleet as BEBs by year

While the analysis above is fleet-focused, Table 13 summarizes the phasing of the required charging infrastructure to support the rollout of BEBs. By the end of 2022, CARTA plans to have forty-six (46) total plug-in dispensers; by 2039, a total of thirteen (13) 120-kW charging units and four 1.2-MW centralized charging units will be installed to provide a total of 100 dispensers. The minimum power requirement in Table 13 reflects the results from the power modeling from Section 5.2, the "max power per installed equipment" shows how much power would be needed if all chargers were to be operated simultaneously, which will never be the case given that a charging management software will always regulate and optimized the charging strategy. Furthermore, the "Required/Recommended Installed Capacity" row reflects the optimal power requirement that needs to be installed at the facility in order the charge all vehicles according to an optimized charging profile and considers a safe contingency factor.

Table 13: Infrastructure phasing—chargers and dispensers.

	Infrastructure				
	2021	**2022**	**2030**	**2033**	**2039**
No. of Units (125 kW)	**6**		**7**		
Cumulative	6	6	13	13	13
Centralized Units (1.2 MW)		**2**		**1**	**1**
Cumulative		2	2	3	4
Cumulative Plug-in Dispensers	**6**	**46**	**60**	**80**	**100**
Min. Power Requirement (kW)	750	1,800		3,600	4,800
Max. Power per installed equipment (kW)	750	3,150	4,025	5,225	6,425
Required/Recommended Installed Capacity (kW)	**750**	**2750**	**5750**	**5750**	**5750**

8.0 CURRENT FACILITY PLANS

Beyond the existing fleet of six BEBs and supporting charging infrastructure (six dispensers each with 125 kW of power capacity), as part of Phase I, CARTA is currently acquiring twenty-seven (27) BEBs while also installing new charging infrastructure and expanding parking stall into a lease area adjacent to their property.

The current plans include:

- Six 125-kW chargers with a single-port dispenser
- Two centralized charging units (blue boxes in Figure 32), each with a 1.2-MW power capacity, capable of powering 20 single-port dispensers. This technology will provide power to 40 dispensers.
- A new 2,000 kVA utility transformer and trenching to connect to existing 750 kVA utility transformer
- Twenty (20) bus stalls for 40-ft buses at the leased property immediately south-west of the Leeds Avenue facility

Figure 32 highlights the layout of the under-construction improvements. The BEB Master Plan presented in Section 9 integrates these ongoing upgrades.

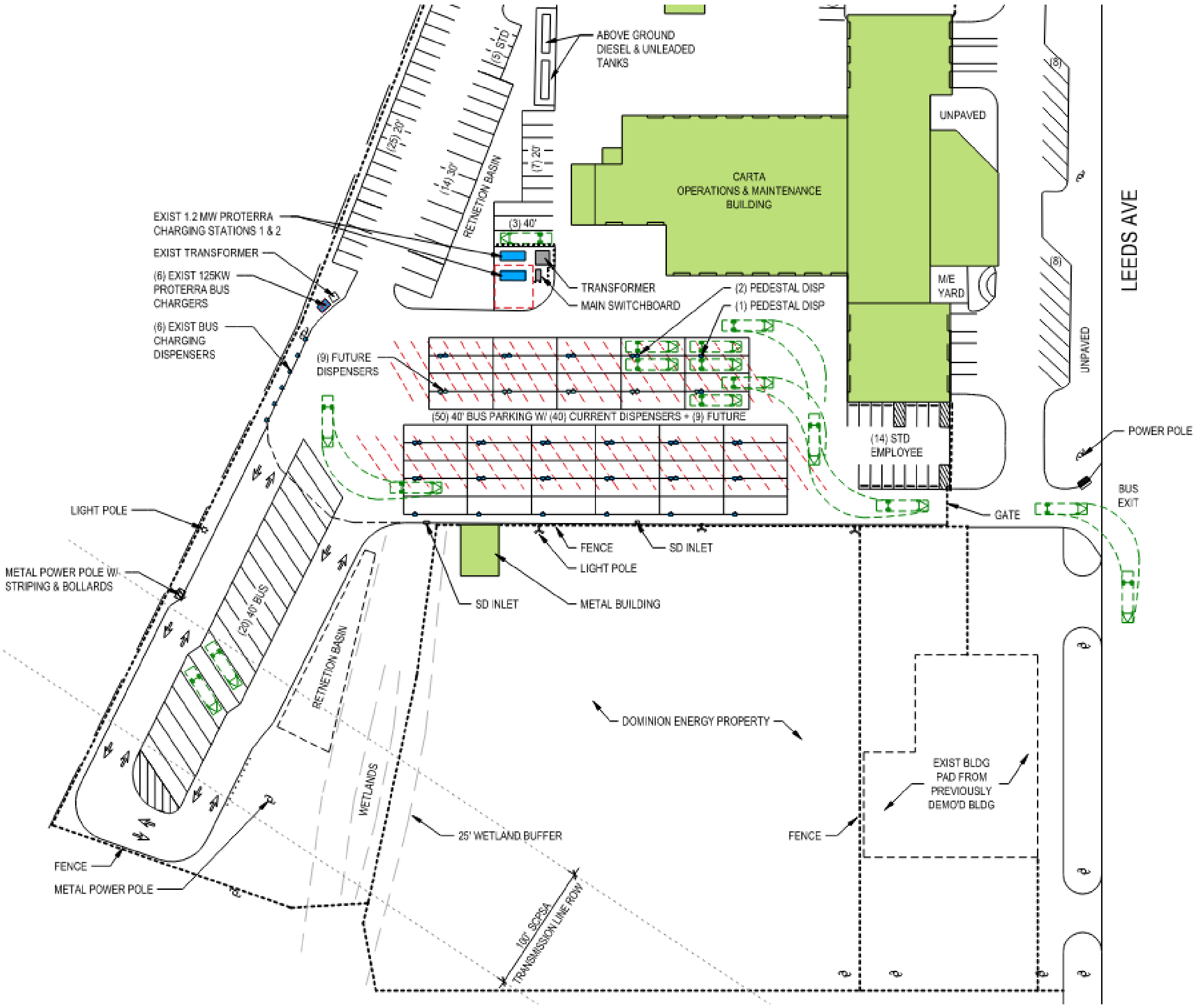


Figure 32: CARTA Phase I (A to C) Site Plan

9.0 MAINTENANCE FACILITY INFRASTRUCTURE MODIFICATIONS FOR BEB IMPLEMENTATION

This section outlines the proposed facility modifications for BEB implementation to CARTA's bus operations and maintenance facility. The BEB Master Plan has been developed proposing additional ground-mounted dispensers, to match the current charging infrastructure approach. With the potential future acquisition of the Dominion Energy property immediately south of the Leeds Avenue facility, there is sufficient space opportunity for additional bus stalls equipped with ground-mounted dispensers.

When the procurement of the forty (40) Proterra-supplied-and-installed charging dispensers was developed, an overhead canopy approach was considered. Although structural canopies can reduce required space for each bus stall and present an opportunity to implement photovoltaic (PV) systems to generate electricity, the additional costs of the canopy structure exceeded the project budget and was not the option selected by CARTA. A possible solar PV system limited to installation on the roof structure of the current O&M building is discussed in Section 2.

Since the facility will require new electrical service connections from Dominion Energy to serve the future phases of the fleet transition, the utility will likely require that a service study be performed to identify any transmission or distribution system upgrades that may be needed to support the additional power demands. The power supply upgrades needed to provide charging for the initial two 1.2 MW chargers and forty (40) dispensers has already been designed by CARTA and Dominion Energy. While the additional electric demand due to the Phase II BEB fleet deployment of an additional seventy-seven (77) buses is not large relative to what is often experienced at larger transit agencies, it will be up to Dominion Energy to determine if the local power distribution system has the capacity to serve CARTA's additional new charging loads as well as any other planned loads in the area. The recommendations below are focused on those infrastructure upgrades that are to be located on the agency's property and do not include any system upgrades that the service study may identify. The extent and timing of the system upgrades will determine the net cost to the agency.

9.1 PROPOSED MAINTENANCE FACILITY MODIFICATIONS

The following summarizes the proposed improvements for the proposed BEB Master Plan for Phase II (Figure 33):

- A new 3,000 kVA transformer and 4,000 A switchboard to provide adequate additional power to the facility, along with associated equipment pads and bollards. The new transformer will provide power to the Phase II chargers and will provide a means to partially charge the fleet in the event that there is a failure on one of the main power transformers. With the existing utility transformer of 750 kVA, in addition to the transformers to be installed in Phase I and Phase II, the total installed power capacity at the facility will be 5.75 kVA

- A new 5,000 kW generator with 2,200 gallons of onsite diesel fuel storage (or 5,500 gallons of Liquid petroleum gas) in order to support 100% bus service for one day[7]. The quantity of fuel maintained on site will depend on the anticipated utility outage duration and the availability of fuel deliveries. The current calculation assumes fuel needed for one day of outage. Alternatively, the generator could be fueled using pipeline natural gas if infrastructure is readily available near the facility.
- An expanded bus parking yard is required to accommodate the evolving fleet due to the addition space and movement constraints of BEB infrastructure and equipment. Per direction from CARTA, the Dominion Energy property to the south of the Leeds Avenue facility is a likely opportunity for the agency to expand operations. Within this adjacent property the following improvements and modifications are proposed:
    - Approximately 62,000 sq. ft. of site improvements for additional bus parking (about 56 buses) and charging equipment.
        - Electrical infrastructure (conduit, duct banks, and in-ground pull boxes) should be installed during site improvement work to minimize future trenching and re-work of the hardscape areas and to facilitate installation of future charging equipment as it required.
    - Two new 1.2 MW charging stations with about twenty (20) dispensers each. This will be an addition to the two 1.2 MW charging stations that are being installed by Proterra this year.
    - The six existing 125 kW chargers and their single-port dispensers along the west property edge will be removed and reinstalled to serve vehicles in this area.
    - Approximately 50,000 sq. ft. of site improvements for a new employee parking lot with about 105 parking spaces. The existing employee parking at the facility is already very constrained and not ideal with some employees parking within the bus yard and in the adjacent property.
    - New site lighting for the expanded parking areas, both bus and employee.
    - New perimeter security fencing will be required in this area as well.
- Seven new 125 kW, each with dual dispenser chargers – shown on the BEB Master Plan for the charging of the cutaway vehicle fleet.
- For all new charging equipment:
    - Equipment pads and associated bollard protection around chargers and dispensers
    - Power main feeder and sub feeders
    - Communication system panel/distribution cabinet and conduits to each charger
    - Underground service conduit connecting the power cabinets to the dispensers.
- Pavement replacement/repair for trenching associated with electrical distribution for dispensers and connections to new electrical service and switchboard.
- The removal and reinstallation of six dispensers from the Phase I implementation.

[7] Details on the generator size calculations are described in Section 10.1

- New pavement markings/striping as required for parking reconfigurations.
- No proposed modifications to the buildings other than potential bus charging within the maintenance bays as discussed in Section 9.5 below.
- Following complete transition to electric vehicles CARTA can remove all facilities and equipment associated with diesel/gasoline fueling and internal combustion engines.
  - The above-ground storage fuel tanks can be decommissioned and removed, providing additional space for parking or other uses. The fueling dispensers can also be removed from the service lanes freeing up space for other service needs.
  - Diesel tanks could be left onsite for fuel storage needed by the generators
  - The equipment and infrastructure throughout the facility for engine oil can be decommissioned and removed.

All the above-describe items are described in detail in Figure 33. Given that the charging equipment needs to be in place prior to the arrival of the buses as proposed in the Fleet Replacement Plan (Section 7.0), a specific phasing plan for infrastructure upgrades was developed. Table 14 shows what infrastructure needs to be in place at each year between now and 2040[8], assuming that all charging infrastructure for the first thirty-three (33) BEBs (Phase I) will be completed by the end of 2022. The infrastructure implementation plan for on-route charging equipment is not considered in the table below.

Table 14: Infrastructure Requirements per Year for Phase I and Phase II

	Equipment	2021	2022	2030	2033	2039	2040
Dispensers	Installation of single-port plug-in dispensers		40	14	20	20	
	Cumulative single-port plug-in dispensers	6	46	60	80	100	100
Individual Charging Units	Installation of individual units (125 kW each)	6		7			
	Cumulative single units	6	6	13	13	13	13
Centralized Charging Units	No. of centralized units (1.2 MW)		2		1	1	
	Cumulative centralized units (1.2 MW)		2	2	3	4	4
Transformer	Installed Power Capacity (MW)	0.75	2.0	3.0			
	Cumulative Power Capacity (MW)	0.75	2.75	5.75	5.75	5.75	5.75

[8] Installation of charging equipment should be planned 12 to 18 months in advance of the year that is describe in Table 14.

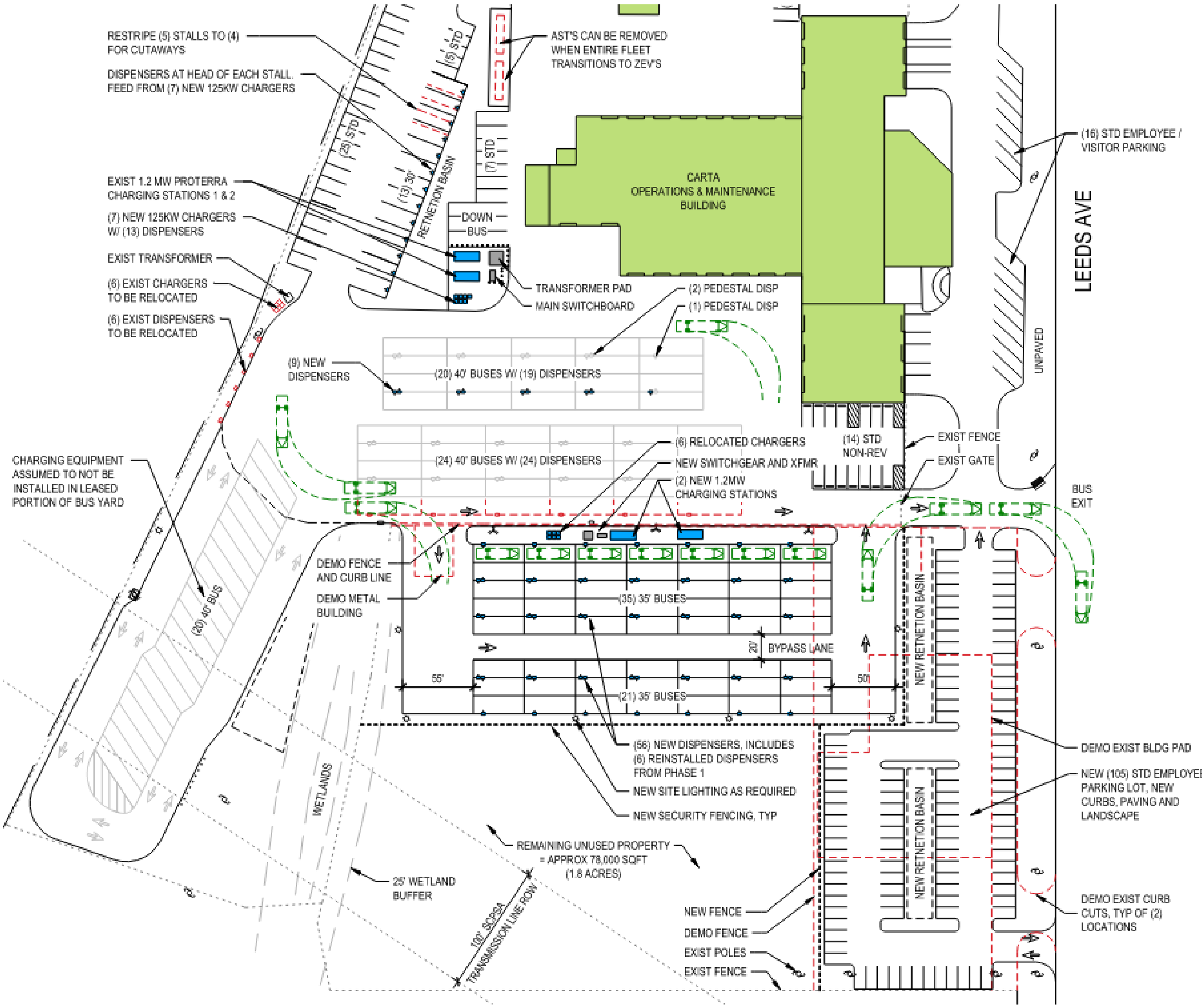


Figure 33: CARTA BEB Site Conceptual Master Plan for Phase II

9.2 GRID CONNECTION UPGRADES

The primary service conduit included in the BEB Master Plan options and estimate extends from the utility point of connection (meter) to the main distribution panel on the site. The extent of upgrades that will be necessary on Dominion Energy's side of the meter will need to be determined by the utility based on an analysis of the local power distribution system. Since the CARTA facility is in a commercial area, we anticipate that the utility system upgrades would not be significant. If upgrades to the Dominion system are necessary, the cost may be covered by the utility based on the additional electricity that they will be selling to CARTA for BEB charging. However, for the utility could expect CARTA to pay for the required utility upgrades either through a direct fee or through a monthly facility services charge.

Typically, CARTA will perform a service study 12-18 months prior to the new service start so they can include the most up to date information on anticipated new loads from all their customers in the area. The extent and timing of the system upgrades will determine the net cost to the agency.

9.3 COMMUNICATION INFRASTRUCTURE

Infrastructure for data communications within the charging system will include Industrial Protocol Ethernet wiring between each charger and its associated dispensers, as well as between each charger and a local data switch. The actual wiring will be conventional Cat 5E or Cat 6 Ethernet cable between devices. As the maximum length allowed for Ethernet is 100 meters or 328 ft., the dispensers cannot be too far from their respective charger. And though longer distances are possible with fiberoptic cable, the direct current (DC) power cables that need to run parallel with the Ethernet cables begin to have problems with voltage drop at this distance, so 328 ft. is a recommended limit.

Once the Ethernet lines from each charger are routed back to the facility's data switch, the data can be contained within CARTA's local network and managed directly by the agency. Alternately, the data can be routed to a cloud-based system – as needed to provide smart-charging and data aggregation—that is managed by a third party and/or is provided by the charger manufacturer. However, this would likely require coordination and approval of security and access, as it would necessitate outside entities operating within CARTA's local network, at least at some level.

9.4 FIRE PROTECTION CONSIDERATIONS

With the implementation of BEBs, fire protection and life-safety concerns can be significant. However, due to the relatively new advent of these associated technologies, building and fire protection codes have not specifically addressed most of these concerns. National Fire Protection Association (NFPA) 855 'Standard for the Installation of Stationary Energy Storage Systems' is a standard that can potentially be applied to BEB storage, but this particular standard is excessive relative to the capacity of the batteries onboard buses and considering all of CARTA's buses are stored outside. The need for enhanced fire protection systems has not been determined as a baseline requirement for BEB implementation and would be left up to the discretion of the local fire marshal and the local building officials. The need for additional fire lanes or fire 'breaks' within long continuous rows of bus parking may also need to be discussed with the local fire department.

If CARTA decides to install PV panels in the future above the buses' parking stalls, an NFPA 13 compliant automatic sprinkler system could be required because the canopy has a 'use' underneath it as defined by the California Fire Code. Again, this would be at the discretion of the local Authorities Having Jurisdiction's (AHJ's) interpretation of the code.

Furthermore, all modifications to the facility should be reviewed with the local AHJs, in particular the fire marshal. Fire truck access to the site and hydrant access will need to be reviewed and approved by the pertinent AHJs prior to implementation of any additional infrastructure for charging equipment or significant modifications to site circulation and fire track access. However, since the site is designed for bus movements, fire truck access is relatively straightforward and should be accommodated without significant changes to the facility.

9.5 MAINTENANCE BAY CHARGERS

The biggest impact to the actual maintenance building would be the installation of at least one charger within the maintenance bays upon further implementation of electric vehicles. For routine service, diagnostics, and to recharge a bus in the event the batteries are depleted during maintenance, a minimum 25-kW charger is recommended to be installed within the building. At full fleet conversion to BEB, a charging dispenser is recommended for at least every other repair bay. One high-capacity charger with multiple dispensers or individual relatively low wattage charging cabinets for each bay could be implemented depending on budget and phasing constraints. Alternatively, mobile charging equipment could also be implemented to use in the repair bays as the technology becomes more readily available. Like the charging equipment in the yard, the charging cabinets should be remotely located from the dispensers so as not to take away from the functional space in the repair bays. Remote dispensers could easily be located throughout the bays, mounted to columns or walls as needed to reach the appropriate charge ports on the various fleet of vehicles.

These chargers could likely be operated on the existing electrical service in the building due to the limited charging demand. However, to take advantage of lower electric vehicle electrical utility rates, the chargers could also be connected to the charging infrastructure serving the bus parking to ensure all vehicle charging is connected through one meter.

Figure 34: Charging cabinet and dispenser within maintenance bay

9.6 FALL PROTECTION AND SAFETY INFRASTRUCTURE CONSIDERATIONS

Fall protection systems are recommended for any vehicle maintenance and inspection shop. If considerable rooftop access is necessary in the future, CARTA should consider additional fall protection systems throughout the maintenance bays for safely accessing the rooftop of buses for the battery inspection and maintenance.

10.0 RESILIENCY

Planning for resiliency and redundancy is necessary not only to support operations during emergencies or other disruptions, but also to ensure that if the yard loses power, BEBs can still be operated. This is particularly important when considering a transition to electricity-powered buses and when considering potential power outages during severe weather events in the Southeast, like storms and hurricanes.

Several agencies have deployed solar PV assets to generate renewable energy to power functions like administration buildings. With the adoption of a BEB fleet, additional harvesting of solar PV energy, together with storage of this energy in stationary batteries, can be used to charge a portion of the fleet with energy that does not come 'from the grid'. As such, this strategy could be used to diminish some of the costs associated with charging, particularly during peak time-of-use periods, also known as 'peak shaving'.

Nevertheless, solar arrays and stationary batteries have limitations. The power generated with solar PV arrays will likely account for a small portion of the energy requirements of a BEB fleet, and in the case of stationary batteries, once they have been discharged to charge a BEB, they need to be recharged, which typically takes several hours. In the event of an emergency, relying solely on solar energy is impractical. Finally, the current costs of stationary batteries often make them economically impractical. As such, deploying complementary fossil fuel-powered generators is necessary to generate the power required to charge a BEB fleet.

The following sections:

- Describe the planning for emergencies (i.e., assuming that during an emergency, CARTA would operate 100% of its service for one day) and the required size of the backup diesel-fired generator.
- Describe the potential for solar energy generation based on solar canopy structures installed at the yard. Implicit in these assumptions is that stationary batteries would be deployed as well to capture the energy for later use.

10.1 BACKUP PLANNING

Transit agencies need to consider the portion of service (and thus of their BEB fleet) that will be deployed or operated during grid-outage conditions. This percentage will require backup power to charge for the anticipated emergency period. Some transit agencies consider the use of a battery electric storage system (BESS) to provide temporary relief; however, these additional assets require favorable energy policies to compensate such facilities for the additional services a BESS can provide.

Most agencies deploying BEBs in California, for example, have deployed generator systems using fossil fuels, mostly diesel-fired generators. Figure 35 shows an example of a mobile generator at Los Angeles Metro's Division 13 Bus Operations and Maintenance Facility. Additional facility space will need to be allocated for such a backup generator in addition to emergency fuel storage (if desired).

Figure 35: Backup mobile diesel generator at LA Metro Division 13, Los Angeles, CA.

Based on Stantec's estimates, Table 15 illustrates the size of the generator needed to maintain 100% of revenue service for one average weekday. The level of service that is desired, percentage of all normal runs, as an example, sets the requirement for the size of the generator required at the charging site.

Table 15: Estimated fuel consumption for back-up generation.

Generator Capacity (kW)	Charging Energy (kWh/day)	Fuel consumption (gal/day)	
		Diesel	LPG
5,000	30,000	2,200	5,500

Fuel consumption values are assuming operation on one fuel type only.

If CARTA wishes to operate for more days during an emergency, the size of generator will stay the same, but the required quantity of fuel will scale linearly. The total amount of fuel required to be stored onsite will depend on the anticipated duration of the utility electrical outage and the amount of time required to get a fuel delivery of diesel or liquid petroleum gas, as well as on environmental regulations and local policies.

For the purposes of the financial analysis, Stantec assumed the use of two 2,500 kW generators with storage capacity for 2,200 gallons of diesel in order to serve one revenue day at 100% service levels. Automatic transfer switches and generator controls would be used to start the generators automatically upon loss of utility power.

Adequate space is available on-site for new permanent backup generators near the planned location for the new chargers. The generators would occupy three parking spaces currently used for buses (Figure 36). A dedicated fuel tank could be added for stand-alone operation or a connection to the existing site diesel fuel storage system could be included to increase the available generator runtime.

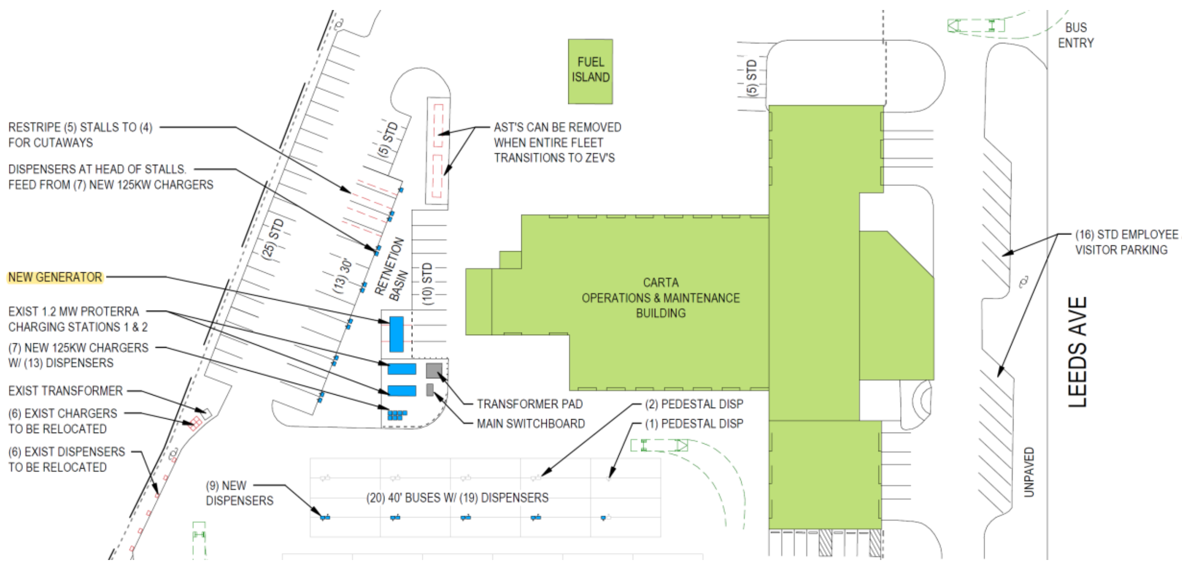


Figure 36: Proposed generator location in the site concept plan for the Leeds Ave facility

10.2 SOLAR PV

Apart from relying on the grid to charge the fleet during the day, another strategy CARTA can deploy to curb some of the costs associated with large electrical usage is to generate electricity via solar PV panels. Electricity generated in this manner is ‘free’ and ‘green’—it can be used to reduce the amount of electricity purchased from the grid.

A solar study was performed for CARTA's bus facility to understand the potential energy generation if solar PV panels were installed. The analyzed configuration of the solar PV panels assumed panels on the main building at the Leeds Avenue facility (Figure 37).

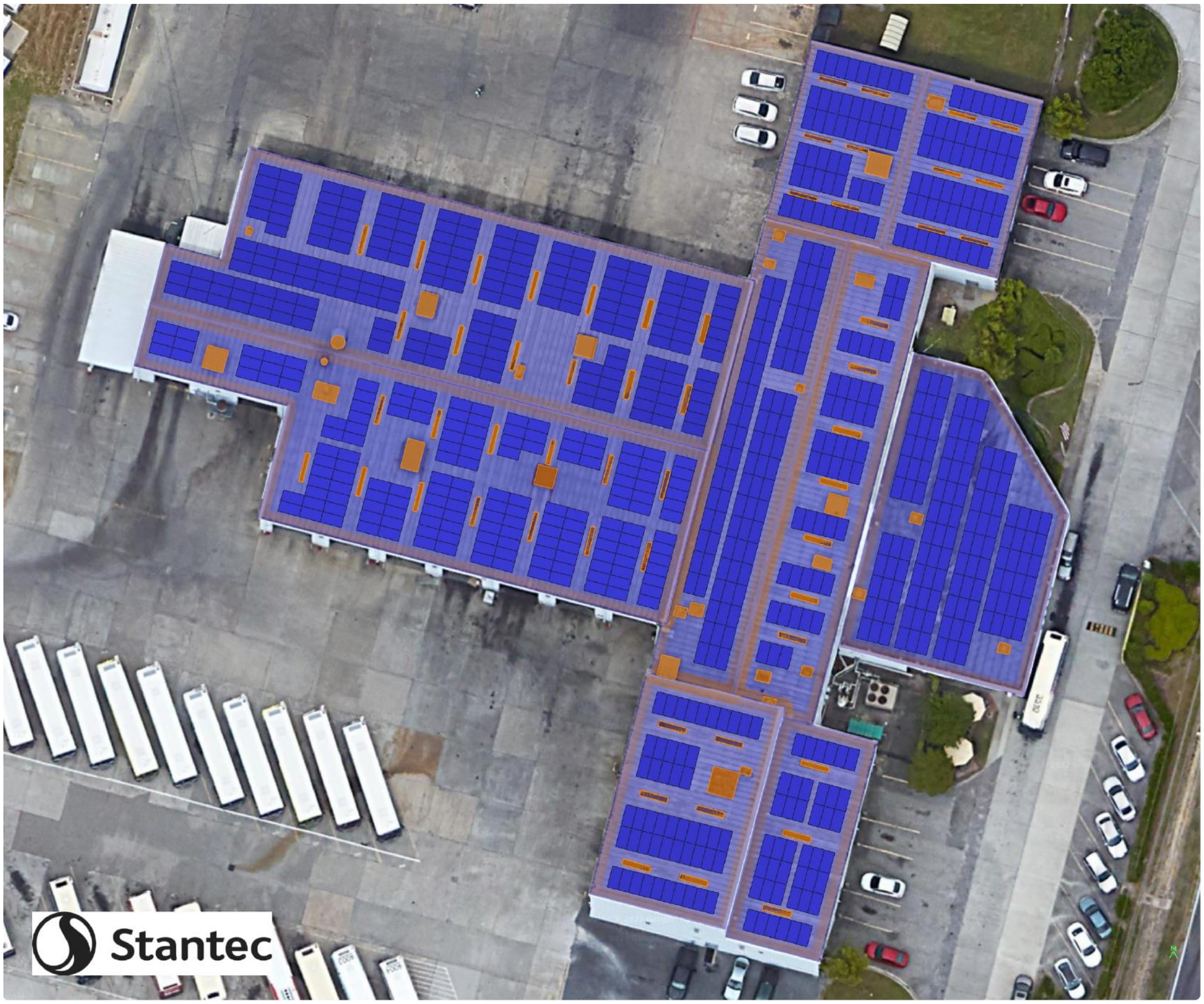


Figure 37: Solar panel configuration

Table 16 presents a summary of the sizes and performance specifications for the solar PV panels, as well as the estimated generation that can be harvested annually.

Table 16: Solar PV specifications and generation capacity

	Solar PV Size (kW DC)	Inverter Size (kW AC)	Average DC to AC Ratio	Estimated Generation - year 1 (MWh)	Performance Ratio
Solar PV System	440	395	1.12	590.8	77.8%

The projected annual production is estimated to be ~591 MWh using a DC module of 440 kW. The energy that can be harvested using PV panels was calculated for each month and is presented in Figure 38. Energy production peaks in the summer months with the prolonged duration of sunshine hours compared to winter months.

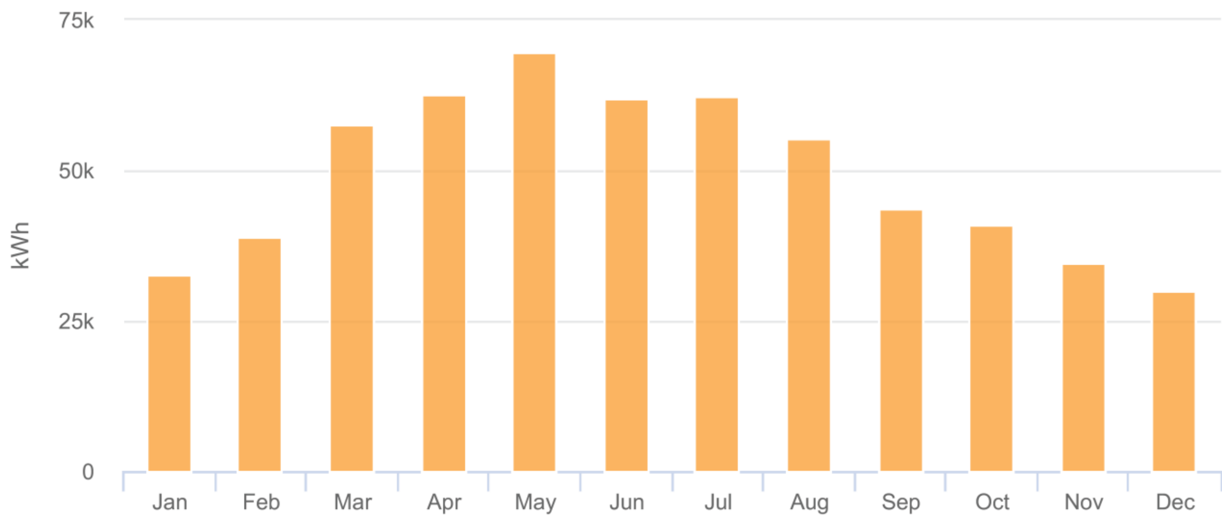


Figure 38: Monthly PV Energy Harvested with Solar Panels

The annual energy that can be harvested with PV panels accounts for ~8% of the total energy demand at the facility. However, because the hours of solar generation do not align with the hours of charging demand (i.e., solar PV generation is greatest during the day when the buses are in service), the solar energy cannot be utilized in its totality unless a battery storage system is in place. Nevertheless, the use of energy generated from solar panels can help charge vehicles during the day at times where energy from the grid is the most expensive (peak hours).

Using the hourly energy load needed to charge the vehicles and the projected hourly solar PV energy generation, a new adjusted energy load was modeled for the facility (to account for reduced grid-based power). Figure 39 shows the adjusted load when using solar PV, which reduces to overall energy needed from the grid. The dotted gray line notes the original load, and the orange bars note the new load the grid has to provide after accounting for the solar PV energy.

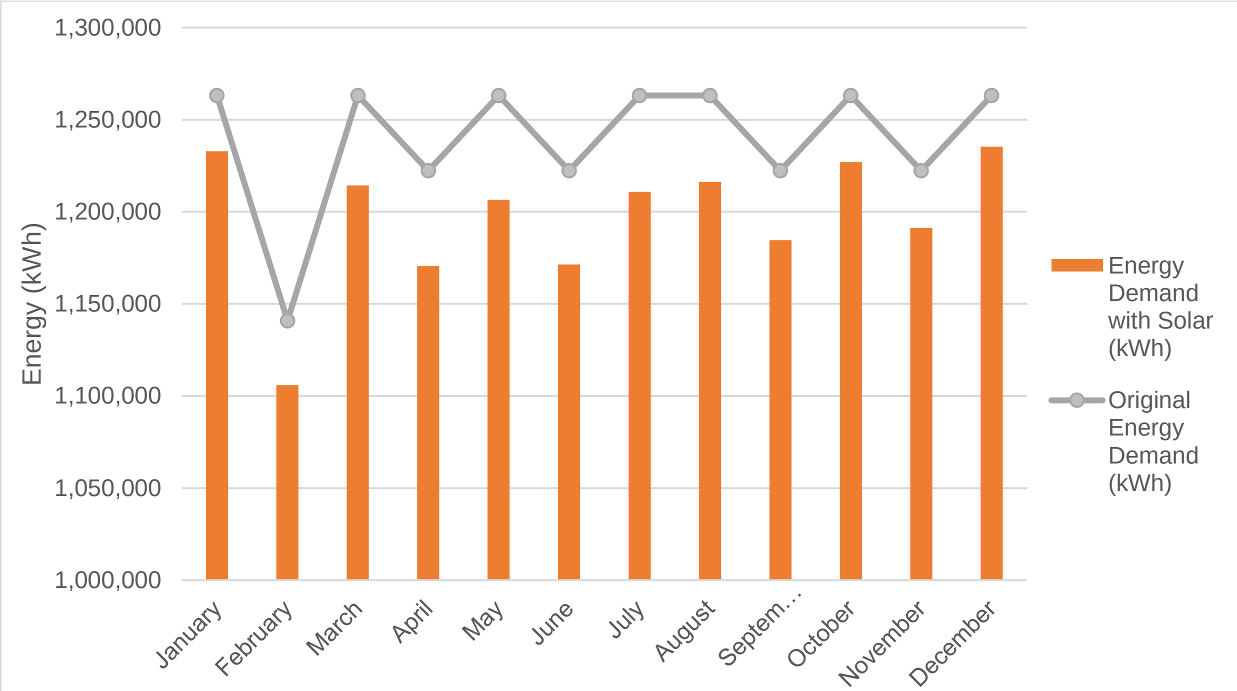


Figure 39: Daily Energy Profile with Solar PV.

Since electricity generation from solar PV occurs during the daytime, many BEBs will be unable to take advantage of this energy (since they are in service). As such, any excess energy generated would need to be curtailed (i.e., wasted) if the grid is not able to purchase it back. However, if CARTA implements midday BEB charging, then a large portion of solar PV electricity can be consumed.

If vehicles can charge according to the charging profile presented in Figure 18 (see Section 5.2), then the estimated annual savings from utilizing the solar-generated energy are $22,458. Table 17 presents the energy consumption and cost details with and without the electricity generated from solar PV.

Table 17: Annual Energy Cost with Electricity from the Grid with and without solar PV

	Solar PV Size (kWdc)	Estimated Generation - year 1 (MWh)	Electricity from Grid without Solar PV (MWh)	Electricity Cost without Solar PV	Electricity from Grid with Solar PV (MWh)	Electricity from Grid Cost with Solar PV	Estimated Annual Savings with Solar PV	Solar PV On-Site Utilization Rate
No Solar PV	-	-	14,872	$603,057	-	-	-	-
Solar PV on Roof	440	590,768	14,872	$603,057	14,366	$580,599	**$22,458**	86%

While there are savings associated with the use of solar, the cost of implementation needs to be considered as well. An informal cost assessment was conducted to determine the simple payback period of the capital cost investment in solar PV for the building rooftop when considering the annual energy savings and potential revenue from selling the excess generated energy back to the grid.

Table 18 shows the assumptions for the capital cost of the proposed solar PV system ($660,000), as well as the potential revenue if the net metering program[9] remains in place so that CARTA can sell the excess energy at an average price of ¢4 per kWh[10] ($3,443 revenue per year).

Table 18: Simple Payback Period for Solar PV Panels

Solar PV Size (kWdc)	Solar PV Capital Cost ($/kWdc)	Estimated Solar PV Capital Cost	Estimated Savings with Solar PV ($/year)	Exported Electricity (kWh/year)	Revenue from Exported Electricity ($/year)	Simple Payback Period
440	$1,500	$660,000	$22,458	84,899	$3,443	26 years

Considering the yearly savings from charging BEBs during the day directly with energy from the solar panels and the exported revenue, the simple payback period for the solar PV system is 26 years. This high-level assessment does not consider a discount rate, an escalation factor (i.e., increase in prices), or potential financial incentives (i.e., tax rebates). However, the assessment shows that a simple payback period of 26 years—which mirrors the expected lifetime of the equipment (25 to 30 years)—is only attractive with a net metering program in place and if CARTA can leverage incentives to reduce the upfront capital costs.

[9] Net Metering program from Dominion Energy considers a second meter that allows for the extra electricity to flow back to the grid and credit (or pay) the excess energy produced by the system.
[10] Assuming a credit for the net metering based on the average price cost for CARTA under the Dominion Time of Use (TOU) rate for Large General Services. A full year electricity cost assessment was conducted which averaged ¢4 per kWh.

11.0 OTHER BEB IMPLEMENTATION CONSIDERATIONS

11.1 ENVIRONMENTAL JUSTICE AND DISADVANTAGED COMMUNITIES

To advance environmental justice and equity goals, CARTA's BEB rollout can be prioritized in disadvantaged communities, or communities that suffer from poor environmental health and air quality when compared to the rest of the service area. To understand where these communities are located in CARTA's service area, we used data from the EPA's EnviroAtlas, an online mapping tool that features over 400 datasets to measure environmental heath across the United States at the census tract-level[11].

The maps in Figure 40 show the cumulative estimated cancer risk (left) and non-cancer respiratory risk (right) due to cumulative air toxics from the National Air Toxics Assessment, which combine air toxics including acetaldehyde, acrolein, arsenic, benzene, butadiene, chromium, diesel particulate matter, formaldehyde, lead, naphthalene, polycyclic aromatic hydrocarbons, and polycyclic organic matter

Cancer risk is defined as the probability of contracting cancer over the course of a lifetime, assuming continuous exposure. Respiratory risk is expressed as a hazard index, meaning that a rating of 1 or lower means air toxics are unlikely to cause adverse non-cancer health effects over a lifetime of exposure. The dark blue areas in the map on the right below show which parts of CARTA's service area have a respiratory hazard risk of 1 or higher, meaning that residents are at risk of non-cancer respiratory illness assuming continuous lifetime exposure.

[11] https://enviroatlas.epa.gov/enviroatlas/interactivemap/

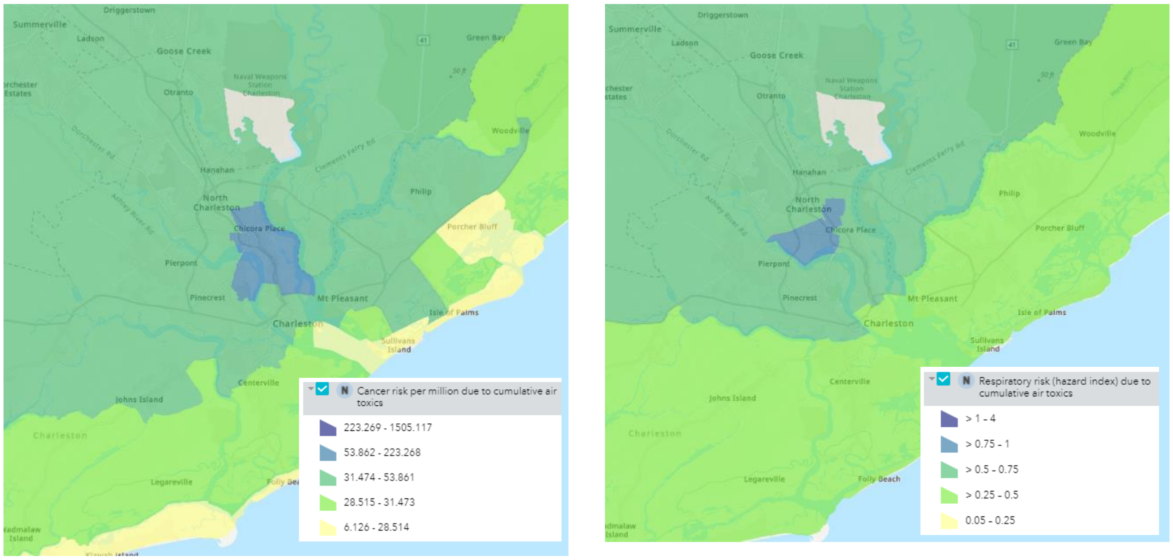


Figure 40: Cancer risk (left) and non-cancer respiratory risk (right) due to cumulative air toxics from the National Air Toxics Assessment in the CARTA service area

Figure 40 shows that risk for both cancer and non-cancer respiratory illness due to air toxics and poor air quality in CARTA's service area are concentrated in North Charleston and Chicora Place, very close to the area where the current Superstop is and where the new Shipwatch Square will be located. CARTA can further environmental justice goals and help to lessen the air pollution burden in these areas by prioritizing BEB rollout on the routes that currently serve the Superstop and will serve Shipwatch Square in the future.

11.2 MAINTENANCE CONSIDERATIONS

Early data suggests that BEBs may require less preventative maintenance than their diesel counterparts since they have fewer moving parts; however, not enough data currently exists to provide detailed insights into long-term maintenance practices for large-scale BEB deployment in North America. One early finding is that spare parts may not be readily available, so one maintenance consideration is to coordinate with original equipment manufacturers (OEMs) and component manufacturers to develop spare parts inventories and understand lead times for spare parts. It will also be important for CARTA to coordinate spare parts procurement needed for ongoing BEB maintenance sooner rather than later so maintenance can be completed without interruption.

In terms of preventative maintenance, BEB propulsion systems are more efficient than internal combustion engines and thus can result in less wear and tear. Without the diesel engine and exhaust, there are 30% fewer mechanical parts on a BEB. BEBs also do not require oil changes and the use of regenerative braking can help to extend the useful life of brake pads. Early studies from King County Metro show that the highest percentage of maintenance costs for BEBs came from the cab, body, and accessories system. It is recommended that CARTA require OEMs to provide a list of activities, time interval, skill needed, and required parts needed to complete each preventative maintenance task for BEBs.

Many current BEBs also contain on-board communication systems, which are helpful in providing detailed bus performance data and report error messages, which can assist maintenance personnel in quickly identifying and diagnosing maintenance issues.

11.3 WORKFORCE TRAINING

Ensuring CARTA's workforce is sufficiently prepared for the full transition to BEBs is of vital importance to make sure that service continues to operate smoothly and without interruption. Presented in this section are high-level training considerations, specifically for operations and maintenance staff/technicians. The recommendations are based on information provided by OEMs for BEBs and is meant to be a general guide to training requirements. While CARTA already has BEBs in operation and may have already developed their own workforce training program, this outline can be used to supplement agencywide training programs, as well as OEM-supplied training to prepare for a complete transition to BEBs.

With a focus on safety, it is highly recommended that all local fire and emergency response departments be given training as the layout, componentry, safety devices, and other features on the new technology. This should reoccur every few years. In the example workforce training schedule below, this training is provided every other year, but the specific frequency can be dependent on agency discretion. In addition, agencywide orientation to familiarize the agency with the new technology should also be conducted prior to the first BEB deployment.

Although not specifically training, dry runs on each route should be done with the ZEBs to validate range and identify opportunities for coasting and adjustment to the vehicle's acceleration profile. In turn, changes in timing points may be necessary or beneficial for all parties. This should be done with planning staff on board and schedules should be adjusted as appropriate. In tandem, based on having several vehicle types particularly during transition, dispatching training and instructions to staff on parking routines will be necessary.

In summary, the minimum required training recommendations are as follows for operators and maintenance technicians:

- BEB Operator training (total fifty-six (56) hours)
  - Operator drive training (four sessions, four hours each)
  - Operator vehicle/system orientation (twenty (20) sessions, two hours each)
- BEB Maintenance technician training (total 304 hours)
  - Preventative maintenance training (four sessions, eight hours each)

- Electrical/electronic training (six sessions, eight hours each)
- Multiplex training (four sessions, each session consisting of three eight-hour days)
- HVAC training (four sessions, four hours each)
- Brake training (four sessions, four hours each)
- Energy Storage System, lithium-ion battery and energy management hardware and software training (six sessions, eight hours each)
- Electric drive/transmission training (six sessions, eight hours each)

Further operator and maintenance/technician training will likely be needed to prior to the full deployment of BEBs at CARTA, in accordance with the phasing schedule. It is also recommended that CARTA conduct an agencywide orientation to the new technology (if not done so already) and host biennial introductory trainings with local fire and emergency response departments so that they are familiar with BEB technology and associated equipment in the event of an emergency.

11.4 ON-ROUTE CHARGING CONSIDERATIONS

Given the low successful electrification rate at the blocks and vehicle level, the use of on-route charging was added to the analysis to increase the driving range of the vehicles. On-route charging is usually provided by high-power rate chargers (>300 kW) that are able to charge buses passing through in as fast as five minutes, providing additional driving range.

The most common type of on-route charging is the overhead inverted pantograph where a charging head is lowered on to a set of DC charging rails on the top of the bus, this method reduces any additional weight and cost required to accommodate a charging mechanism that would come up from the bus. All of the BEB manufacturers have aligned with universal high-power opportunity chargers from companies such as Siemens (Figure 41) and ABB (Figure 42). Figure 43 shows an example of a power cabinet from Proterra that would need to be allocated in close proximity to the on-route charging pantograph.

Figure 41: Siemens 300 kW Overhead Charger

Figure 42: ABB 300 kW and 450 kW O/H Charger

Figure 43: Proterra 500 kW High-Power Charger

As previously discussed, these chargers have a higher cost and the need to install them along the route increases the complexities of installation. Therefore, on-route charging strategies focus on minimizing both the number of on-route chargers as well as the wait times for charging by the BEBs. Furthermore, it's important to consider the impact that overhead chargers may have on the built urban environment, right-of-way easements, and permitting constraints.

Given that CARTA will be utilizing overnight depot charging using plug-in dispensers, to the addition of on-route charging means that the procurement specifications should require that most vehicles have both overhead and plug-in charging capabilities. This could increase the cost of the vehicles at purchase, but the level of such increase will depend on and vary from manufacturer to manufacturer. Lastly, the assignment of vehicles to blocks that rely on the use of on-route charging will need to consider if such vehicles have the capabilities to use the pantographs used on-route.

Another critical consideration for the use of on-route charging is the coordination with the utilities. High power capacities will be required at each fast-charging location, whether it is one single charger or multiple in a location, the added peak power will likely require a new service and potentially upgrades to substations if the delivery capabilities are restricted, such as could be the case in a downtown location. Power requirements for the fast chargers at Shipwatch Square were described under Section 6. The power requirements and specifications of equipment for the Downtown location were out of the current scope and were not further investigated given that CARTA might decide to apply a different solution to accomplish a full fleet electrification, such as the use of buses with bigger batteries or reblocking of their system.

11.5 TECHNOLOGY TO SUPPORT BEBS

Technology for BEBs will help CARTA manage the fleet and its investment into zero-emission propulsion. First, for BEBs, charge management or smart charging technology is imperative to manage electrical demand including to curb potentially costly demand charges and to mitigate maximum power requirements of bus charging. Second, fleet tracking software (typically provided by an OEM) will help track useful analytics related to the fleet and operations to help CARTA make informed decisions.

11.5.1 Smart Charging

Smart charging refers to software, artificial intelligence, and switching processes that control when and how much charging occurs, based on factors such as time of day, number of connected BEBs, and SOC of each BEB. This requires chargers that are capable of being controlled as well as a software platform that can effectively aggregate and manage these chargers. A best practice is to select chargers where the manufacturers are participants in the Open Charge Point Protocol, a consortium of over 50 members focused on bringing standardization to the communications of chargers with their network platform.

A simple example of smart charging: if buses A, B and C return to the bus yard and all have an SOC of about 25% as well as 440 kWh battery packs, and are plugged in in the order they arrived (A, B, C, within a few minutes of each other). Without smart charging, they would typically get charged sequentially based on arrival time or based on SOC, with A getting charged first in about 2.2 hours, then

B would be charged after 4.4 hours, and C about 6.6 hours. However, if bus C is scheduled for dispatch after three hours, it would not be adequately charged.

But by implementing smart charging, the system would be provided the information that bus C is to be dispatched first and therefore would get the priority, thereby charging first in 2.2 hours, to be ready in time for its ‘hour three’ rollout.

Another implementation is to mitigate energy demand when possible. For example, if two buses are each connected to their own 150 kW charger, both need 300 kWh of energy and neither need to be dispatched for five hours, the system will only charge one bus at a time, thus generating a demand of only 150 kW; still fully charging both buses in four hours. However, if both buses need to be deployed in two hours, the system would charge both simultaneously as needed to make rollout.

Well-planned and coordinated smart charging can significantly reduce the electric utility demand by timing when and how much charging each bus receives. Estimations on the ideal number of chargers is critical to the successful implementation of smart charging strategies.

There are several offerings in the industry for smart charging, charger management, and fleet management from companies such as ViriCiti, I/O Systems, AMPLY Power, and Siemens. Additionally, the charger manufacturers all have their own native charge management software and platforms. These charger manufacturer platforms have management functionality and integration that often exceeds the abilities of the third-party platforms and can also similarly provide data and functionality; particularly in the yard when BEBs are connected to the chargers. However, the third-party platforms provide more robust data streams while the BEBs are on route, including real-time information on SOC and usage rates. These platforms can cost well over $100 per bus per month, depending on the number of buses, and type of package procured.

11.5.2 Fleet Tracking Software/BEB Reporting

Software like Fleetwatch provides agencies with the ability to track vehicle mileage, work orders, fleet maintenance, consumables, and other items. However, with more complex technologies like BEBs and hydrogen fuel cell-electric buses, it becomes crucial to monitor the status of batteries and fuel consumption of a bus in order to track its performance and understand how to improve fuel efficiency. Many OEMs offer fleet tracking software. While equipment providing automatic vehicle location and automatic passenger counting will continue to play important roles in operations planning, with BEBs tracking fuel consumption and fuel economy will start to form important key performance metrics for fleet management as well as help inform operations planning.

The screenshot below is an example of New Flyer’s tool (New Flyer Connect 360; Figure 44), but other OEMs also offer similar tools (like ViriCiti) all depending on an agency’s preference.

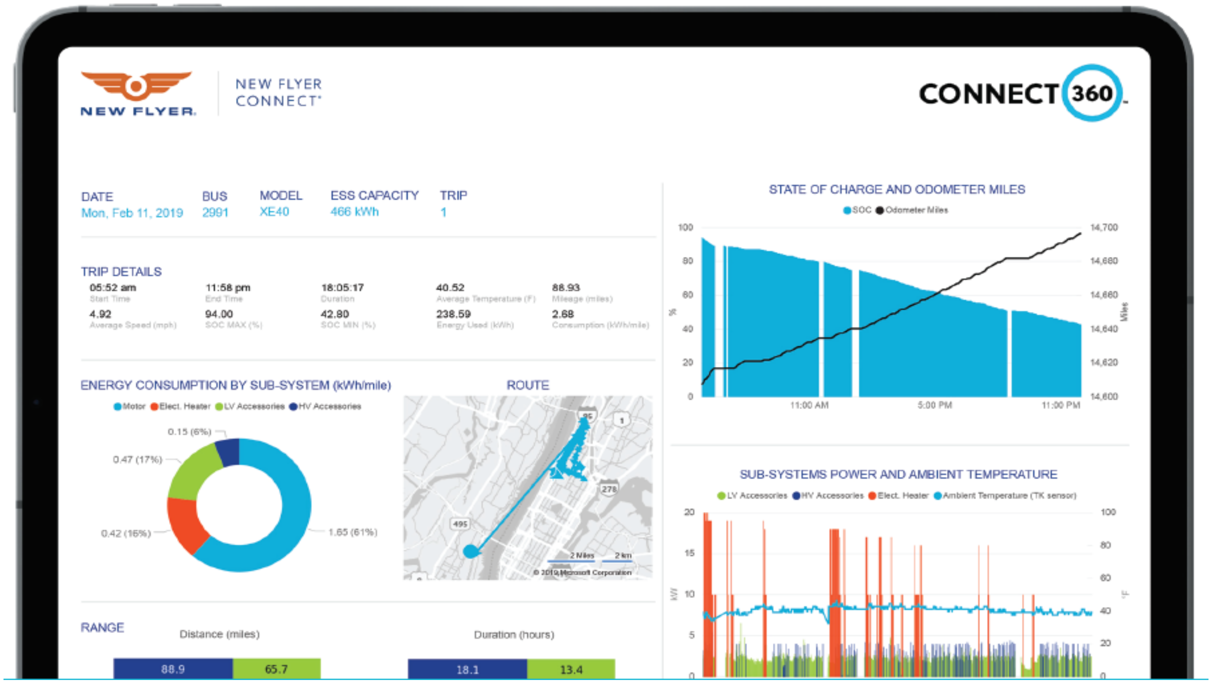


Figure 44: Example of New Flyer Connect 360.[12]

At a minimum, the fleet tracking software should track a vehicle's SOC, energy consumption, distance traveled, hours online, etc. Tracking these key performance indicators (KPIs) can help compare a vehicle's performance on different routes, under different ambient conditions, and even by different operators.

An example of other transit agencies using BEBs, the Antelope Valley Transit Authority operates a nearly 100% BEB fleet of over 50 vehicles, collecting and reporting the following information at its monthly board meetings:

- BEB vs. non-BEB miles traveled
- BEB vs. non-BEB maintenance cost per mile
- BEB vs. non-BEB fuel/energy costs by month ($ per kWh vs. $ per gallon)
- BEB vs. non-BEB fuel/energy cost per mile
- Average fuel consumption/fuel economy per month
- Total BEB vs. non-BEB fuel and maintenance costs per month
- Mean distance between failures

[12] https://www.newflyer.com/tools/new-flyer-connect/

- BEB vs. non-BEB fleet availability

The Toronto Transit Commission (TTC) is currently testing BEBs from three different OEMs and is tracking the following KPIs for its BEBs to compare with its internal combustion buses (Figure 45).

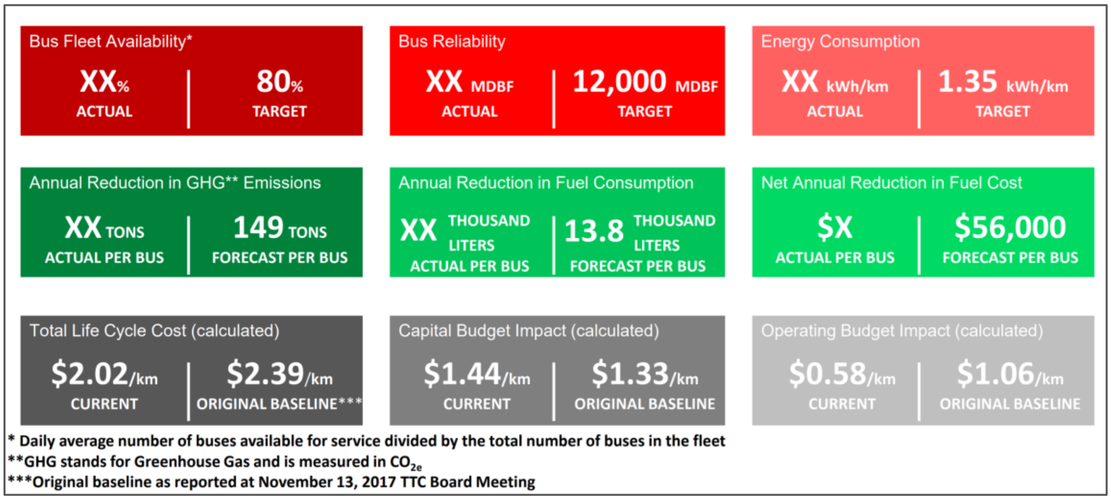


Figure 45: Example of TTC eBus KPIs.[13]

To obtain and track critical information, it is recommended that all BEB equipment be connected to CARTA's current data collection software, networks, and integrated with any existing data collection architecture. All data should be transmitted across secure virtual private network technology and be encrypted.

Beyond data from the BEB itself, charger data should be collected as well, such as the percentage of battery charge status and kWh rate of charge. Furthermore, it will be important for CARTA to track utility usage data from Dominion Energy to understand energy and power demand as well as costs.

[13] https://www.ttc.ca/About_the_TTC/Commission_reports_and_information/Commission_meetings/2018/June_12/Reports/27_Green_Bus_Technology_Plan_Update.pdf

12.0 FINANCIAL ANALYSIS

The financial analysis for CARTA's BEB rollout consisted of the modeling of a Base Case (assuming continued use of diesel and gasoline vehicles or 'business-as-usual' and the current complement of BEBs without increasing the proportion of the fleet that is BEB) and a BEB Case (assuming a transition to 100% BEB operations and the phasing out of diesel/gasoline vehicles), and a comparison between the two scenarios to quantify the financial impacts of the transition and of BEB operations. Jacobus & Yuang, Inc., Stantec's independent cost estimator, provided a detailed cost estimate of materials, soft costs, construction, and other line items for the BEB case.

The main assumptions for the cost modeling are:

- Financial modeling was completed in real 2022 dollars (2022$).
- A 3% discount rate was applied for all calculations.
- A projected fleet size growth of 20% (with a proportional growth of service levels from pre-pandemic services) to accommodate potential service improvements. Operational growth was considered in both the Base Case and the BEB Case over the twenty (20) years, increasing the fleet from ninety-two (92) vehicles to 110 while maintaining the same mileage per vehicle.
- Annual fleet vehicle mileage is 3,083,710 miles or 20,000 miles per 40-ft vehicle, 39,000 miles per 35-ft and 30-ft vehicles, and 26,000 miles per 22-ft cutaway[14].
- Modeling used a consistent format for both the Base Case and the BEB Case to facilitate clear comparison between the two. The modeling was developed on an annual basis from 2023 through to 2043.
- The BEB Case included the operation of diesel and gasoline vehicles (as well as BEB vehicles) during the transition period until fossil fuel vehicles are phased out in 2040 while considering operations during the transition from 2023 to 2043.
- For the Base Case, the current fleet of thirty-three (33) BEBs was assumed to continue in operation without adding more electric vehicles but replacing the existing ones when they reach their useful life (12-year life cycle for 40-ft buses). For the BEBs in both scenarios, a battery renewal was also factored in at the midlife of the vehicles.
- While Stantec's recommended strategy is to implement on-route charging to satisfy the operating needs of CARTA, the financial modeling assumes the purchase and implementation of all electric vehicles with a 1:1 replacement ratio. Capital cost for on-route charging equipment is outside the financial analysis scope.

[14] As a reference, CARTA reported ~3.1M vehicles miles in 2019 in NTD (fixed routes and demand response).

12.1 BASE CASE APPROACH

Stantec developed the forecast for the Base Case (business-as-usual) scenario, assuming that the existing fleet of diesel, gasoline, and electric vehicles is maintained and renewed through 2043. This model is inclusive of all scheduled fleet replacements and overhauls required during the time horizon. It should be noted that this Base Case assumes that the existing fleet of thirty-three (33) BEBs continue operations and are replaced at the end of their useful life, but no incremental electric vehicles are added in the Base Case.

Capital expenses modeled consist of fleet acquisition and vehicle overhaul costs starting 2023 through 2043. Vehicle overhauls were assumed to consist of a single transmission overhaul for the buses after seven years of service for 40-ft, 35-ft, and 30-ft vehicles. For the existing BEBs, a battery replacement at the midlife of the vehicle (six years) was considered for the same vehicle types.

Operations and maintenance costs were based on the historical data provided by CARTA and the fueling and mileage data reported to the National Transit Database (NTD). The following cost sub-categories were created:

- Fuel Cost: The cost per mile of the “2018/2019 NTD fueling and operational expenses” was used with an annual 2% increase ($0.38 per mile for demand response, $0.80 per mile for commuter coaches, and $0.30 per mile for local fixed routes).
- Bus Maintenance: The historical maintenance cost was extracted from CARTA’s annual budgets for vehicle maintenance provided to Stantec and was used in combination with the revenue mileage reported to the NTD for the corresponding fiscal years. In addition, a trend line was calculated from the historical data to predict the future maintenance price. The average maintenance cost is estimated at $0.68 per mile.

12.2 BEB CASE APPROACH

The BEB Case proposes a gradual transition to 100% BEB fixed-route revenue vehicles by 2040 and captures their operations from 2023 through 2043[15]. The transition follows the fleet replacement schedule presented previously in Table 11 (Section 7.0). The last purchase of diesel and gasoline vehicles is scheduled for 2028 reaching a full electrification by 2040. To minimize the financial burden, it is assumed that all vehicles will operate for their full useful design life as detailed below:

- 7 years for cutaways
- 12 years for low floor 35-ft buses
- 12 years for low floor 40-ft buses

[15] The forecast does not include the purchase and operations of demand response vehicles.

Capital expenses modeled consist of fleet acquisition, extended vehicle warranties, vehicle charging infrastructure, vehicle overhaul and battery replacement costs. Operational expenses consist of general maintenance and fuel/electricity.

Vehicle overhauls for BEBs were assumed to include two battery replacements for 40-ft, 35-ft, and 30-ft buses, in line with current operating practice of BEBs in other jurisdictions. While the first battery replacement would be covered by an extended warranty purchased with the vehicle during initial procurement, we included a subsequent out-of-warranty battery replacement to capture a more conservative approach and preempt battery degradation and range reduction. We assumed that the second (out of warranty) battery replacement would occur into the seventh year of the life span for 40-ft and 35-ft. buses (no battery replacements were assumed for cutaways).

Electricity/fuel costs were calculated based on the expected blended Dominion Energy rate, applied to CARTA's fleet and operational profiles.

The infrastructure costs consist of the conversion and modifications required for the CARTA facility. This includes outfitting the CARTA facility with the charging infrastructure required (see Section 9.1) to operate the BEBs. Any charging infrastructure or acquisition cost made before 2023 was excluded from this analysis.

12.3 ASSUMPTIONS AND INPUTS

Table 19 presents a brief description and the sources for the cost inputs of the Base Case and the BEB Case.

Table 19: Summary of cost inputs for CARTA Financial Analysis

Cost categories	Description	Inputs for Base Case	Inputs for ZEB Case
1. Fuel cost	Base Case: Fuel cost of diesel and/or gasoline per mile BEB Case: Electricity cost per kWh	\$0.65/mi for 40-ft buses, \$0.63/mi for 35/30-ft buses, and \$0.24/mi for cutaways calculated using inputs from the "2018/2019 NTD fueling and operational expenses"; 2% increase per year based on CARTA practices for budget projections and trendline applied to consider price increase of diesel and fuel	Initial value of \$0.04 per kWh with a price trend from the U.S. Energy Information Administration (EIA).[16]
2. Bus purchase price	Bus purchase price for every year between 2023 and 2043 including extended warranty cost	Purchase prices in 2019 extracted from CARTA Fleet Management Plan with a price trend based on market projections:	Purchase prices in 2022 with a price trend based on market projections: \$977,300 for 40-ft BEBs \$908,800 for 35ft/30ft BEBs

[16] Increased grid demand due to the broader adoption of EVs in the economy will require investment in the supporting electrical infrastructure that may cause an increase in the retail cost of charging power.

Cost categories	Description	Inputs for Base Case	Inputs for ZEB Case
		$520,500 for 40-ft $368,300 for 35-ft and 30-ft $118,200 for cutaways	$255,500 for E-cutaways Inclusive purchase of extended warranty. Sources include CalDGS and MBTA/CalAct[17].
3. Bus maintenance cost	Considers labor and parts for scheduled and unscheduled maintenance.	$0.70 per mile obtained from CARTA's budgets and revenue mileage reported to the NTD. A yearly increase of 3% was assumed	$0.27 per mile based on an average of observed maintenance costs from ZEB pilots, with a 3% increase annually
4. Battery replacement and/or diesel midlife overhaul	Base Case: Transmission overhaul BEB Case: Replacement of batteries after expiration of extended warranty coverage (past 500,000 miles)	$38,000 per overhaul for diesel buses[18]	Battery: $255 per kWh (applied to the battery size to be replaced) in 2032 and a price trend was applied based on market assessment
5. Infrastructure Modification Costs	Includes equipment, installation, testing, civil and electrical work, as well as contractor's fees and escalation factors. Includes transformers and control systems paid for by the transit agency	N/A	Cost estimation provided by Jacobus & Yuang, Inc.
6. Backup resiliency	Generator set and diesel fuel storage with piping	N/A	Cost estimation provided by Jacobus & Yuang, Inc.

12.4 COMPARISON AND OUTCOMES

The cost comparison between the Base Case and the BEB Case is presented in Table 20, incorporating both capital (orange) and operating (blue) expenses. The BEB Case has a total cumulative cost of $209,369,000 versus $179,897,000 for the Base Case, a difference of $29,472,000 or 16% increase over the Base Case. The financial assessment does not consider any potential rebates, grants, credits, or other alternative funding mechanisms that may be associated solely with ZE vehicles and associated infrastructure. Therefore, there may be several opportunities to offset the difference in the price between the two scenarios.

[17] California Association for Coordinated Transportation (CALACT) provides access to purchase a variety of transit vehicles from a purchasing cooperative at competitive and preapproved prices.
[18] Provided through an RFI to transit agencies in California.

Table 20: Cost Comparison 2023-2043

	Case (2023-2043)		
	Base	**BEB**	**Savings**
Fleet Acquisition	$106,530,000	$133,963,000	$(27,433,000)
Fleet Refurbishment/Battery Replacement	$7,565,000	$9,021,000	$(1,456,000)
Fleet Maintenance	$31,104,000	$28,443,000	$2,661,000
Fuel/Electricity	$34,698,000	$21,686,000	$13,012,000
Infrastructure	$-	$16,256,000	$(16,256,000)
Total	*$179,897,000*	*$209,369,000*	*$(29,472,000)*

Figure 46 shows the yearly cash flows of the two cases and includes the percentage of electrification for the entire fleet, reaching a 100% BEB fleet for the BEB Case in 2040. The spikes in costs for the BEB Case occur during the years that new modifications are made at the transit facility and/or when a procurement of BEBs is made (2031, 2033, 2034, 2039, and 2040). Figure 47 presents the cost categories for each case as a percentage of the total cost.

Figure 46: Annual Cash Flow for the Base and BEB Cases (bars) and BEB Fleet Composition (green line)

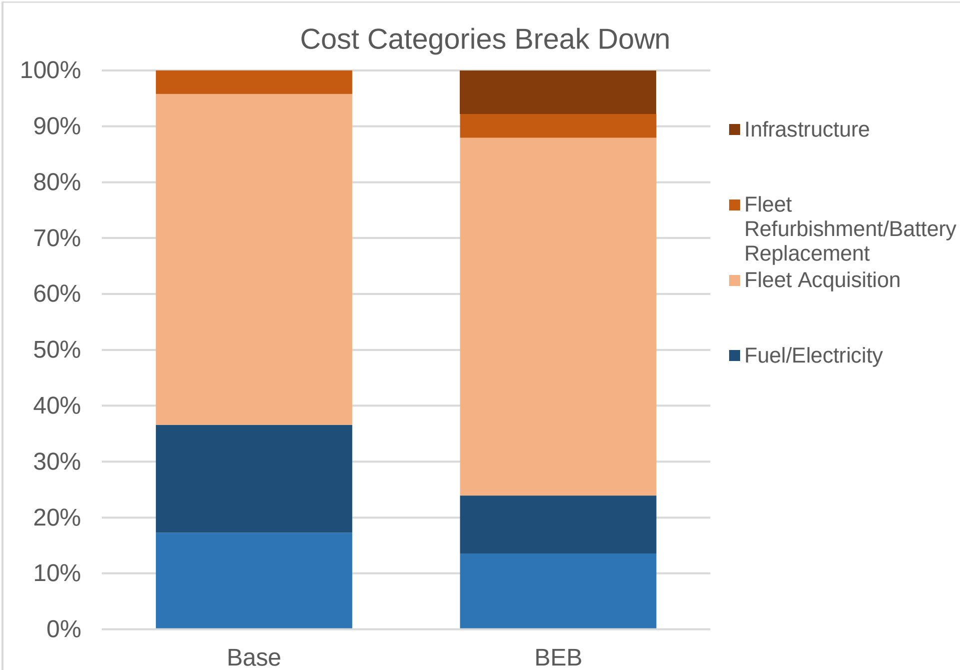


Figure 47: Breakdown of Cost Categories for the Base and BEB Cases

The procurement of BEBs represents $27.5 million more in expenses due to the purchase price difference between BEBs and fossil fuel vehicles. The conversion and upgrades to the facility to install charging infrastructure represents an additional cost of $16.3 million. Capital costs associated with vehicle overhauls and battery replacements are relatively minor in comparison to the acquisition, although the simplicity of BEB propulsion systems means that these maintenance costs are lower for this technology compared to the diesel and gasoline engine components in the Base Case.

The use of electricity as a 'fuel' represents an economic benefit of $13 million when compared to the existing diesel and gasoline refueling while the maintenance of BEBs also represents savings of $2.6 million. These savings are a direct reflection of the improved efficiency of BEBs over fossil fuel technologies, with the added benefit of eliminating emissions.

Lastly, Figure 48 shows the cumulative cost comparison between the Base Case and the BEB Case scenario.

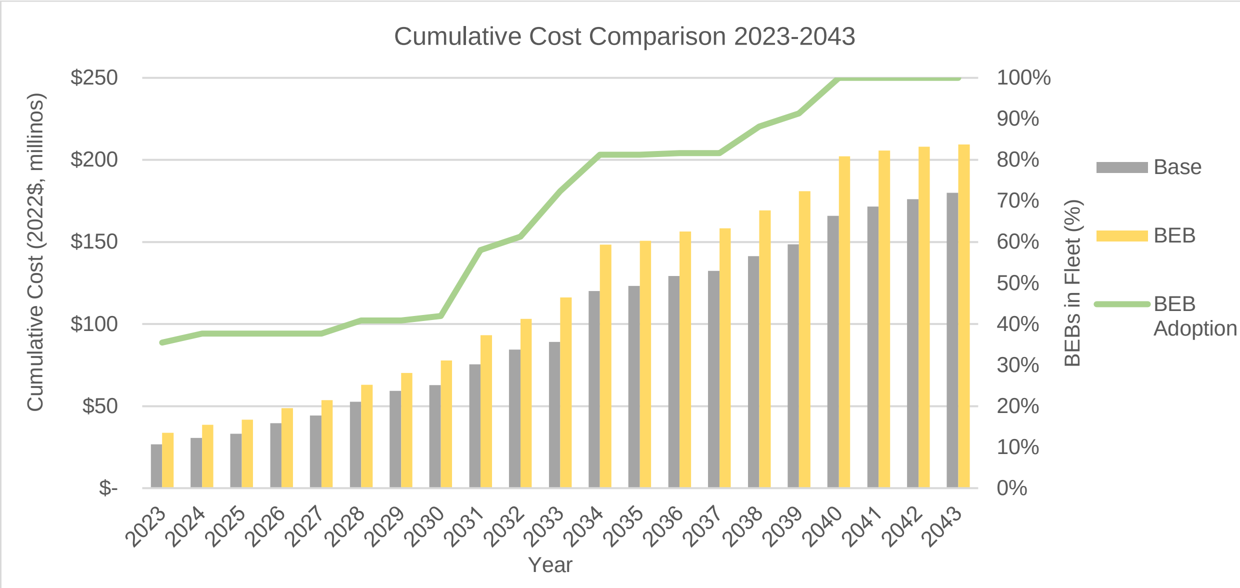


Figure 48: Annual Total Cost Comparison

13.0 POTENTIAL FUNDING SOURCES

Procurement of BEBs and related charging infrastructure can be through several Federal Transit Authority (FTA) funding sources:

5307 Urbanized Area Formula Funding: Annual funding, calculated for each agency or grantee by formula. These funds, for administrative, operating, and capital expenditures, can provide for the procurement of new buses, and as older diesel buses have reached the end of their useful life these can be replaced by BEBs.

5339 Bus and Bus Facilities Grants: This program has three components. The primary program apportions funds annual per formula much the same as the 5307 Program, with eligible uses for the purchase of new buses and the construction of bus-related facilities and infrastructure. This can include zero emissions bus and equipment procurement but is not limited to ZEB technologies. There are two competitive subprograms:

5339(b)– **Buses and Bus Facilities Competitive Discretionary Grants**. Eligible uses are the same as for the primary program, only that the funds are subject to a competitive application process. Applicants may be awarded all, some, or none of the amount requested, depending on the factors of strength of the application, number of competing applications within the state and nationwide, and the ability to scale the request for funds. For the 2022 Notice of Funding (NOFO) for 5339(b) funds, the total available pool is approximately $376 million

5339(c) Low or No Emission Vehicle Program (discretionary). This has been the main program funding the expansion of ZEBs in public transit. The 5339(c) competitive grant program will undergo a large expansion in available funds following the passage of the 2021 Infrastructure Investment and Jobs Act. As a comparison, the 2021 pool of funds was $182 million – to the 2022 NOFO increased to $1,122 million and will show slight increases through fiscal year 2026. For agencies seeking to transition to ZEB technology, replace diesel buses with zero emissions vehicles, and install ZEB fueling infrastructure, the Low or Now Emissions grant program has expanded significantly to accommodate the needs and demand for ZEBs.

Other programs, administered by state of South Carolina agencies, provide direct grant funding or loans for the adoption of ZEBs and/or the replacement of internal combustion engine buses.

Volkswagen Environmental Mitigation Trust (South Carolina): The goal of this program is to offset diesel fuel emissions by funding the adoption of vehicles using alternative fuel sources. BEBs are specifically eligible under this program in the state of South Carolina, which has a pool of $33.9 million available from the trust. BCDCOG has already been awarded $1.96 million from this trust for three of the Proterra BEBs delivered in 2021, and the associated charging equipment. As of January 2021, there was still $26 million remaining in South Carolina’s trust for future awards.

Diesel Emissions Reduction Act (DERA) Grants: This EPA competitive grant program is eligible to any regional, state, local, or tribal agency with jurisdiction over transportation or air quality, and awards funds for the replacement of diesel vehicles with clean energy technologies. The program is apportioned by state, and in South Carolina is administered by DHEC. Although South Carolina has not previously awarded DERA funds for transit buses, there is no provision against a transit agency applying for funds to replace diesel buses with ZEBs. The primary difference between procurement of a ZEB under the DERA program versus an FTA grant program is that the diesel vehicle(s) being replaced must be scrapped or rendered permanently disabled within 90 days of the procurement of the new clean energy vehicle. The South Carolina DERA funds available for the 2021 fiscal year applications was $294,000.

ConserFund Loans (South Carolina Energy Office): This loan program, currently offering a 1.5% interest rate, can be used for capital projects that promote energy efficiency. Fleet conversions are eligible projects if the project will result in overall energy savings. A ‘Technical Analysis’ prepared by a licensed professional must accompany the loan application and demonstrate the energy savings of the project. Borrowers are eligible to borrow between $25,000 and $500,000 per fiscal year, and government borrowers do not have to initiate repayment until one year after the completion of the project.

Locally generated funds- sales tax, partnerships, advertising sales, TIF, Capital Improvement District

State sources – fuel tax,

Transfer from FHWA allocation to MPO

CMAQ

14.0 PHASING AND IMPLEMENTATION PLAN

Table 21 provides an overview of the phasing plan for CARTA's BEB rollout strategy. Note that expenses are in the year of cost incurred, while the fleet quantity columns show when vehicles are delivered, which is offset from the purchase year. See Table 11 in section 7.0 for more details regarding the fleet replacement schedule.

Table 21: BEB implementation phasing plan, FY2022-2040

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2023		(20) 30 & 35-ft BEBs (13) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$0	$3,082,000	$3,082,000
FY2024	(2) 40-ft BEBs	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$1,801,000	$3,049,000	$4,850,000
FY2025		(20) 30 & 35-ft BEBs (15) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$0	$3,094,000	$3,094,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2026	(10) gasoline 22-ft cutaways (6) 30 & 35-ft diesel buses	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$3,818,000	$3,121,000	$6,939,000
FY2027	(1) gasoline 22-ft cutaway (3) 30 & 35-ft diesel buses	(20) 30 & 35-ft BEBs (15) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$1,890,000	$3,126,000	$5,016,000
FY2028	(9) 30 & 35-ft diesel buses (3) 40-ft BEBs	(20) 30 & 35-ft BEBs (18) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$6,392,000	$3,004,000	$9,396,000
FY2029		(20) 30 & 35-ft BEBs (18) 40-ft BEBs		(6) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (46) plug-in dispensers Recommended Installed Capacity of 2.75 MW	$4,073,000	$3,015,000	$7,088,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2030	(1) 40-ft BEB	(20) 30 & 35-ft BEBs (19) 40-ft BEBs	Installation of (14) single-port plug-in dispensers Installation of (7) individual charging units (125kW each) 3.0 MW installed transformer power capacity	(13) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (60) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$4,547,000	$3,102,000	$7,649,000
FY2031	(15) 40-ft BEBs	(20) 30 & 35-ft BEBs (34) 40-ft BEBs		(13) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (60) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$13,071,000	$2,341,000	$15,412,000
FY2032	(9) 40-ft BEBs	(20) 30 & 35-ft BEBs (37) 40-ft BEBs		(13) Proterra units (125 kW) (2) Proterra centralized units (1.2 MW) (60) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$7,822,000	$2,189,000	$10,011,000
FY2033	(11) 22-ft BE cutaways	(11) 22-ft BE cutaways (20) 30 & 35-ft BEBs (37) 40-ft BEBs	Installation of (1) Proterra centralized unit Installation of (20) single-port plug-in dispensers	(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$10,974,000	$2,064,000	$13,038,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2034	(2) 22-ft BE cutaways (28) 30 & 35-ft BEBs (7) 40-ft BEBs	(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (37) 40-ft BEBs		(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$30,392,000	$1,817,000	$32,209,000
FY2035		(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (37) 40-ft BEBs		(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$431,000	$1,818,000	$2,249,000
FY2036	4 40-ft BEBs	(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (39) 40-ft BEBs		(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$3,757,000	$1,857,000	$5,614,000
FY2037		(13) 22-ft BE cutaways (28) 30 & 35-ft BEBs (39) 40-ft BEBs		(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$83,000	$1,859,000	$1,942,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2038	(9) 30 & 35-ft BEBs	(13) 22-ft BE cutaways (37) 30 & 35-ft BEBs (39) 40-ft BEBs		(13) Proterra units (125 kW) (3) Proterra centralized units (1.2 MW) (80) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$9,227,000	$1,666,000	$10,893,000
FY2039	(6) 30 & 35-ft BEBs	(13) 22-ft BE cutaways (43) 30 & 35-ft BEBs (39) 40-ft BEBs	Installation of 1 Proterra centralized unit Installation of 20 single-port plug-in dispensers	(13) Proterra units (125 kW) (4) Proterra centralized units (1.2 MW) (100) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$10,283,000	$1,581,000	$11,864,000
FY2040	(11) 22-ft BE cutaways (12) 30 & 35-ft BEBs (6) 40-ft BEBs	(13) 22-ft BE cutaways (55) 30 & 35-ft BEBs (42) 40-ft BEBs		(13) Proterra units (125 kW) (4) Proterra centralized units (1.2 MW) (100) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$19,752,000	$1,330,000	$21,082,000

Year	Revenue fleet replacement schedule	Number of BEBs by year (cumulative)	Charging infrastructure and equipment changes	Charging infrastructure and equipment (cumulative)	Capital expenses (2022$)	O&M expenses (2022$)	Annual budget (2022$)
FY2041		(13) 22-ft BE cutaways (55) 30 & 35-ft BEBs (42) 40-ft BEBs		(13) Proterra units (125 kW) (4) Proterra centralized units (1.2 MW) (100) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$2,286,000	$1,328,000	$3,614,000
FY2042		(13) 22-ft BE cutaways (55) 30 & 35-ft BEBs (42) 40-ft BEBs		(13) Proterra units (125 kW) (4) Proterra centralized units (1.2 MW) (100) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$984,000	$1,327,000	$2,311,000
FY2043		(13) 22-ft BE cutaways (55) 30 & 35-ft BEBs (42) 40-ft BEBs		(13) Proterra units (125 kW) (4) Proterra centralized units (1.2 MW) (100) plug-in dispensers Recommended Installed Capacity of 5.75 MW	$0	$1,326,000	$1,326,000

APPENDIX A – ADDITIONAL SHIPWATCH SQUARE INFORMATION

OUTREACH AND ENGAGEMENT

Multiple outreach and engagement events were conducted to understand specific objectives related to moving the current SuperStop to Shipwatch Square. Specifically, these include:

- Understanding if the move will impact the ability of CARTA riders to access Shipwatch Square or their final destination;
- Understanding if the move will impact the ability of those visiting the social services centers to reach Shipwatch Square;
- Understanding if residents living locally will be able to access Shipwatch Square; and
- Raising public awareness regarding the new Shipwatch Square Transit Center.

To acquire this information, multiple outreach and engagement events took place. These include:

- Meetings with CARTA, Stantec, and representatives from the social services agencies who will be moving to Shipwatch Square;
- Creation of an online survey to collect data on how people are accessing the current SuperStop and if they will be impacted by the move to Shipwatch Square; and
- An in-person pop-up event at the current SuperStop. In person surveys were collected at this event which were then entered as responses for the online survey.

Social Services Engagement Meetings

CARTA and the Project Team met with two of the social services agencies who will be moving to Shipwatch Square. Table A-1 summarizes the major findings from these meetings[19].

[19] CARTA was not able to secure any discussion with local DHEC representatives.

Table A-1: Engagement summary

Agency	Major findings
Charleston County's Department of Alcohol and Other Drug Abuse Services (DAODAS)	• Current facility in downtown Charleston. • Scheduled to move to new location in 2022 or 2023. • The facility is open 24 hours, seven days a week the most activity occurs Monday-Friday during normal business hours. However, they take in patients at any time. • Most employees work typical Monday-Friday business hours, with fewer staff onsite during nights and weekends. • DAODAS estimates serving between 2,500-3,000 patients annually throughout the Tri-County area • Different services see influxes of patients at different times o 350 patients daily for opioid programs o Outpatient services are their most popular programs; there is a large influx in the mornings (9am-12pm) and evenings (5:30-8:30pm), Monday-Thursday • DOADAS works with agencies to get CARTA bus passes for their clients and believe many of their clients are CARTA riders. They believe that the central location will be much more convenient for patients to access compared to their current location. • DAODAS has about 90 employees. Most drive to work but some take the bus. They also believe it will be more convenient to reach Shipwatch Square than their current downtown location. • DAODAS also services people coming from rural areas, so TCL connections or the future BRT connection will help make this new location more accessible and easier to access. • DAODAS also works closely with One80 Place, a homelessness prevention organization. CARTA access between One80 Place and Shipwatch Square will be important to maintain. o One80 Place is currently served by Route 10 which will ensure connections between the two organizations is maintained. • DAODAS also noted that maintaining connections between local emergency rooms, hospitals, and medical facilities with Shipwatch Square will be important, as these are currently within walking distance of the current DAODAS facility, and many patients frequent both types of facilities.

Agency	Major findings
Charleston County Department of Social Services (DSS)	• Currently located adjacent to the Superstop. • Expected to move to the new location in October or November of 2022. • Only open Monday-Friday. • General employee shift times: 7:30am-6pm; 4pm-12am. • Customer service hours: 7:30am-5pm. • Highest customer activity period: 11am-3:30pm. • The DSS services clients across the entire county.. In addition, residents of Berkeley and Dorchester counties also frequent this office to file paperwork because it is more convenient for them to access (especially Berkeley County). • On average (pre-COVID-19), the DSS saw around 300 people every day to access the variety of different services offered (the most popular of which are food stamps and other economic support services). Typically, the first half of the month is busier than the latter half due to reauthorizing social services (such as SNAP). • As with the DAODAS, only a small minority of employees use CARTA to commute to and from work. More clients are using CARTA than employees. • DSS also sees a lot of clients using the Tele-Ride service, so considerations for a dedicated pick-up and drop-off point for Tele-Ride customers at Shipwatch will be important. • The DSS is expecting to see a large increase in the number of clients coming in next year, as annual reviews for programs that were put on pause during the COVID-19 pandemic will be resuming. The DSS expects to see more than the 300 people they see on an average day due to this. • Similar to the DAODAS, clients are coming from all over so maintaining the current transit connections at Shipwatch will be important for DSS clients. • The DSS is excited about the move, specifically due to new centralized social services, increased safety compared to the current SuperStop, and they believe that the perception of the DSS will improve based on the improved location. They also support enhanced pedestrian safety measures at Shipwatch as they believe the current SuperStop is very dangerous for pedestrians.

Overall, both agencies were excited and looking forward to the move, believing it will be an improvement based on their current locations. Both facilities stressed that they are major providers for the entire tri-county area, and the more centralized location will make it easier for their clients to access, especially clients coming from rural areas outside of Charleston and North Charleston. Relatedly, because clients are coming from all across the tri-county area, interviewees indicated that general robust transit access across the region should be provided to reach Shipwatch Square. They also felt that considerations for late-night and weekend service should be included for those accessing the services during these times. In addition, consideration for a dedicated Tel-A-Ride, CARTA's paratransit service program, pick-up and drop-off location could be important for many patients accessing the DSS.

Overall, the feedback from the information gathered was that the new Shipwatch Square location will be easier to access for a majority of social services patrons; however, CARTA should maintain communication with these social services providers to ensure their transportation needs continue to be met.

SuperStop Pop-Up Outreach Event

On Wednesday, October 6, 2021, the Project Team and representatives from CARTA held a "pop-up" community outreach event at the CARTA SuperStop. The pop-up was conducted from 3:00 pm to 6:30 pm in order to capitalize on the typical weekday afternoon ridership peak.

Prior to the pop-up, Liollio (a subcontractor leading outreach and facilities assessment) worked with Stantec to develop a standardized survey to gather relevant data for CARTA's use. The survey was designed to identify the user's frequency of ridership and gain an understanding of whether or not the pending change in location of the transit center would have an effect on riders' daily commute. Demographic data was requested from participants and collected when provided.

The Liollio team set up a table with flyers and provided printed boards on easels displaying the proposed location change for the SuperStop from its current location at Cosgrove Avenue and Rivers Avenue, to the Shipwatch Square development located along Dorchester Road (approximately 0.4 miles distance).

During the event, the Project Team distributed flyers to CARTA riders printed with a QR code that provided a link to the online survey. The Liollio team also conducted in-person interviews with riders waiting to for bus transfers, using the same format and questions as the online survey. Despite rainy weather on the day, Liollio team members recorded 58 in-person survey responses. After the event, the Liollio team scanned all in-person responses and entered the results into the Survey Monkey platform to aggregate all responses (in-person, and online) for analytical purposes.

Summary of in-person responses and feedback:

- The majority of respondents were transferring buses at the SuperStop;
- A minimal number of riders (3-4) were observed departing a bus and leaving the SuperStop on foot, suggesting that the current stop was the terminus of their trip;
- A minimal number of riders were observed starting their trip at the SuperStop;

- The majority of respondents were not aware of the proposed relocation of the bus transfer stop and expressed appreciation for the information;
- The majority of riders did not perceive the relocation of the bus transfer to Shipwatch Square as a negative impact to their daily commute;
- Negative feedback was received by a small group of survey respondents who walk to the SuperStop due to the increased distance and time of their walking commute;
- Preliminary renderings of the proposed bus transfer station were discussed with current riders. The majority of respondents felt that the enlarged waiting area in a conditioned space would improve their experience; and
- The Project Team also recorded suggestions expressed by riders concerning potential design and operational aspects of the new transit center (e.g., a recommendation to provide a security guard at the new waiting area). These comments were documented in the survey responses and can be viewed in Appendix A.

Title VI Analysis of Shipwatch Square Proposals

A Title VI service equity analysis was conducted to understand how proposed routing changes could impact Environmental Justice (EJ) communities' access to CARTA services. The goals of completing a Title VI Service Equity Analysis includes assessing the effects of the proposed service changes, assessing alternatives available for people affected by the change, determining if the proposals would have disproportionately high and adverse effects on minority and low-income riders, and describing the actions to minimize, mitigate, or offset any adverse effects.

CARTA defines a major service change inclusive of a number of different categories, including establishment of a new route, any schedule changes, emergency service changes of ninety days or less duration, demonstration service changes of 180 days or less duration, and major systemwide (full or partial) service changes, measured in miles or hours. The full table is shown in Figure A-1, and exemptions do exist for instances such as natural disaster, seasonal service and special events, temporary route detours (such as a result of road construction), and more.

Type of Service Change	Executive Director	CARTA Board No Public Hearing	CARTA Board With Public Hearing
Percent of revenue vehicle mile For a given route directly affected by change of service[1]	≤ 10%	> 10 % to < 25%	≥ 25%
Type of Service Change	Executive Director	CARTA Board No Public Hearing	CARTA Board With Public Hearing
Percent of ridership on a given route directly affected by change in service[2]	≤ 10%	> 10 % to < 25%	≥ 25%
New transit route establishment	--	--	Any
Schedule changes	Any	--	--
Emergency changes of 90 days or less duration	Any	--	--
Demonstration service changes of 180 days or less duration[3]	--	Any	--
Major system-wide (full or partial) service changes, measured in miles or hours	1% or less[3]	1 – 5%[3]	5% or more

Figure A-1: CARTA definition of major service change under Title VI

The proposed routing changes with the introduction of Shipwatch Square are not considered to constitute a major service change since the changes in revenue miles are minor, but an analysis was conducted to understand the impact that this move will have on minority and low-income populations.

CARTA and the FTA define low-income and minority populations as following:

- According to FTA Circular 4702.1 B, a minority person is defined as an individual identifying as American Indian and Alaska Native, Asian, Black or African American, Hispanic or Latino, and Native Hawaiian or other Pacific Islander. A disparate impact occurs if a proposed fare or major service change requires a minority population to bear adverse effects as a result of the change.
- According to FTA Circular 4702.1 B, low-income is defined as a person whose median household income is at or below the US Department of Health and Human Services poverty guidelines or within a locally developed income threshold that is at least as inclusive as these guidelines. For this Title VI analysis, the threshold of 125% of the US poverty level was used to define low-income populations to remain consistent with CARTA's previous Title VI service equity analyses. A disproportionate burden occurs if the proposed fare or major service change requires a low-income population to bear adverse effects as a result of the change.

The analysis was conducted at the block group-level using 2019 American Community Survey data[20].

Figure A-2 maps the proportion of non-White residents in each census block group across the service area, while also plotting the routes impacted by the Shipwatch Square project and the location of Shipwatch Square.

[20] Specific tables used for the minority analysis include B03002e1, B03002e2, B03002e3, B03002e4, B03002e5, B03002e6, B03002e7, B03002e8, B03002e9, and B03002e12. Tables used for low-income analysis include C17002e1, C17002e2, C17002e3, and C17002e4.

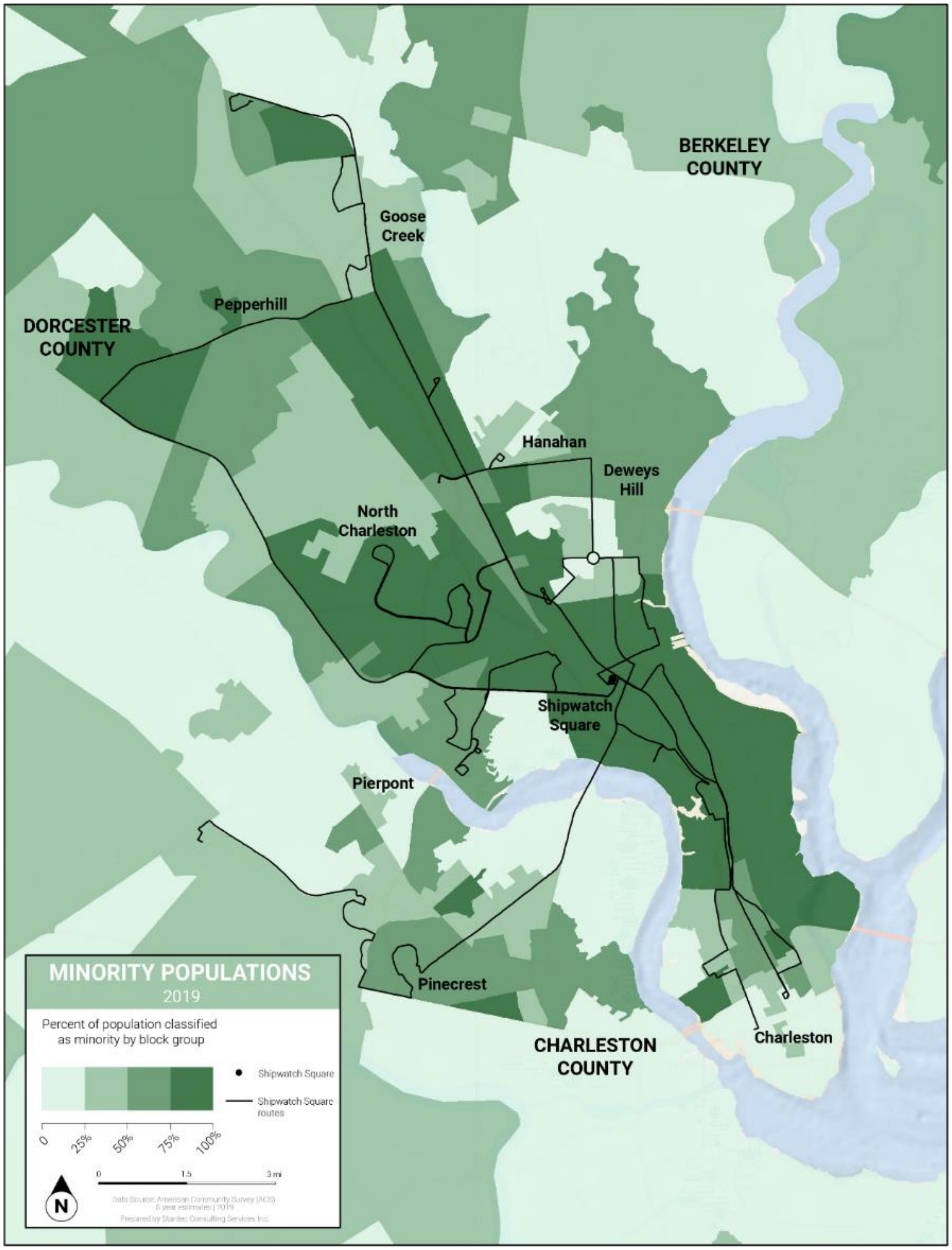


Figure A-2: Routes of interest for Shipwatch Square analysis and minority populations

Table A-2 summarizes the analysis of minority populations within 0.5-mile of the existing route alignments, the proposed route alignments, and the CARTA network as a while. Within 0.5-mile of all CARTA routes, about 44% of the service area population are non-White.

Table A-2: Minority population within 0.5-mile of routes and system

Route		Current route		Proposed route changes		Systemwide	
		Minority population	Total population	Minority population	Total population	Minority population	Total population
10	Number Percent	31,787 60%	52,720 100%	31,360 61%	51,356 100%	93,625 44%	214,106 100%
11	Number Percent	20,100 66%	30,684 100%	20,097 66%	30,646 100%	93,625 44%	214,106 100%
12	Number Percent	27,360 64%	42,640 100%	26,090 65%	40,311 100%	93,625 44%	214,106 100%
13	Number Percent	15,000 65%	23,004 100%	14,670 65%	22,542 100%	93,625 44%	214,106 100%
32	Number Percent	11,538 47%	24,706 100%	11,753 47%	24,802 100%	93,625 44%	214,106 100%
102	Number Percent	12,946 50%	25,917 100%	13,268 51%	26,231 100%	93,625 44%	214,106 100%
103	Number Percent	11,012 82%	13,470 100%	10,476 81%	12,895 100%	93,625 44%	214,106 100%
104	Number Percent	9,087 68%	13,440 100%	9,180 68%	13,498 100%	93,625 44%	214,106 100%

According to the analysis, no proposed route change alters the proportion of minority population within 0.5-mile of the routes of interest by more than 1%—as expected for such minor alignment changes. Nonetheless, all routes except routes 32 and 102 exceed the 10% threshold specified by CARTA for a potentially disparate impact on minority populations (for example, the system average of minorities is 44%, but route 10's coverage includes 60-61%). However, because the routing changes do not constitute a major service change and because the routing to Shipwatch Square will improve rider transfers and customer experience (better transfers, better waiting area, access to opportunities like Social Services within a short walking distance, etc.), the net findings are that no negative disparate impact due to the proposed changes.

Figure A-3 maps the proportion of low-income residents[21] in each census block group across the service area, while also plotting the routes impacted by the Shipwatch Square project and the location of Shipwatch Square.

[21] 125% of the US poverty level.

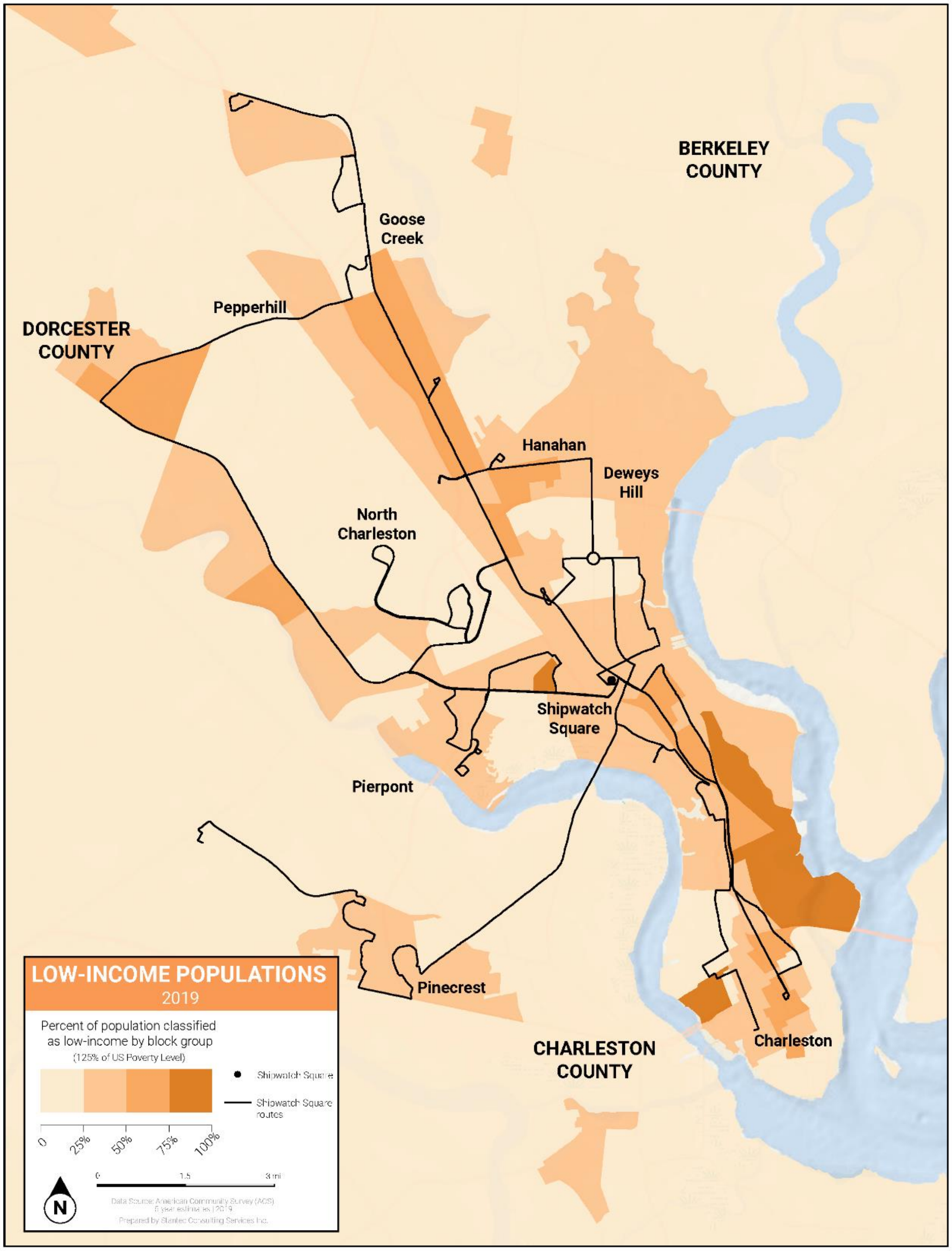


Figure A-3: Routes of interest for Shipwatch Square analysis and low-income populations

Table A-3 summarizes the analysis of low-income populations within 0.5-mile of the existing route alignments, the proposed route alignments, and the CARTA network as a while. Within 0.5-mile of all CARTA routes, about 23% of the service area population are low-income households.

Table A-3: Low-income population within 0.5-mile of routes and system[22]

Route		Current route		Proposed route changes		Systemwide	
		Low-income population	Total population	Low-income population	Total population	Low-income population	Total population
10	Number Percent	18,755 37%	50,205 100%	18,412 37%	49,153 100%	47,696 23%	205,598 100%
11	Number Percent	10,952 40%	27,584 100%	10,949 40%	27,546 100%	47,696 23%	205,598 100%
12	Number Percent	11,870 29%	41,179 100%	11,238 29%	38,868 100%	47,696 23%	205,598 100%
13	Number Percent	7,989 35%	22,797 100%	7,722 35%	22,345 100%	47,696 23%	205,598 100%
32	Number Percent	5,103 21%	24,529 100%	5,131 21%	24,625 100%	47,696 23%	205,598 100%
102	Number Percent	8,404 36%	23,346 100%	8,439 36%	23,659 100%	47,696 23%	205,598 100%
103	Number Percent	4,041 38%	10,678 100%	3,746 37%	10,107 100%	47,696 23%	205,598 100%
104	Number Percent	3,909 29%	13,255 100%	3,893 29%	13,328 100%	47,696 23%	205,598 100%

Similar to the impacts of route changes on non-White minorities, for low-income populations within 0.5-mile of the proposed routing changes, the changes amount to 1% or less depending on the route. Nonetheless, all routes except routes 12, 32 and 104 exceed the 10% threshold specified by CARTA for a potentially disproportionate burden on low-income populations (for example, the system average of low-income populations is 23%, but route 10's coverage includes 37%). However, because the routing changes do not constitute a major service change and because the routing to Shipwatch Square will improve rider transfers and customer experience, the net findings are that there is no negative disproportionate burden due of the proposed changes.

[22] Includes the population for whom poverty status is determined, which does not include institutionalized persons, persons in military group quarters and in college dormitories, and unrelated individuals under 15 years old.

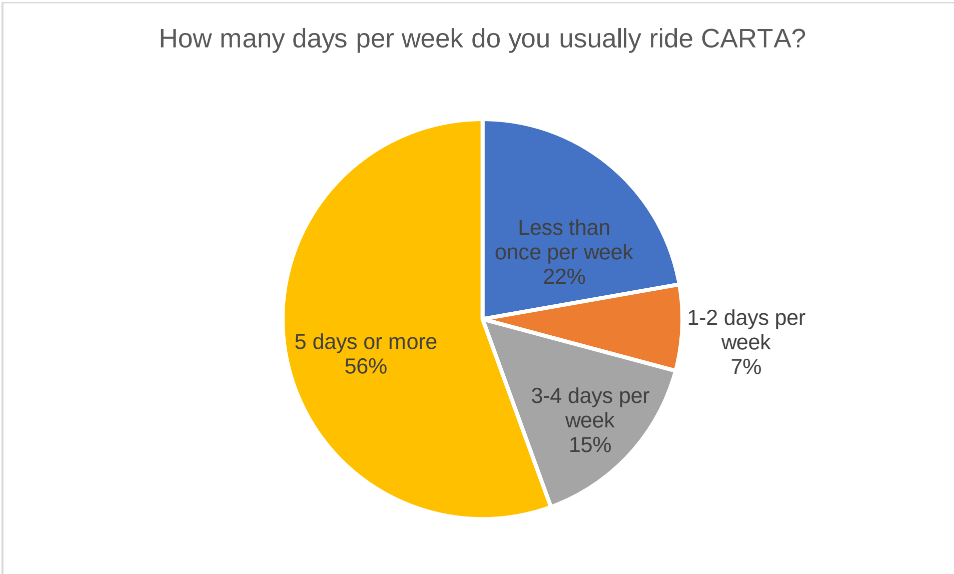
Survey Results

The question-by-question results from the survey can be found below. In total, the survey received 73 responses. Major themes and findings from the survey echo comments heard during the in-person pop-up event and are summarized below:

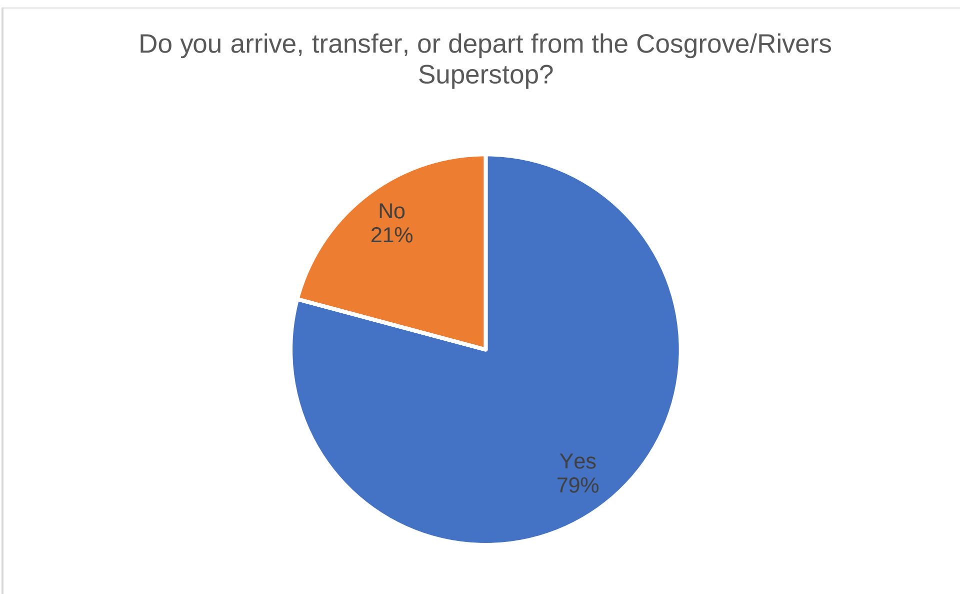
- 56% of survey respondents use CARTA five or more days per week (i.e., are very frequent riders).
- 79% of survey respondents arrive, transfer, or depart from the current SuperStop.
- The most common way survey respondents reached the SuperStop was by bus, with 64% of respondents reporting this is how they reached the SuperStop.
- Route 10 was the most common route used to reach the SuperStop, followed by routes 11, 12, and 13.
- 84% of respondents are using the SuperStop to transfer to another CARTA bus route.
- The majority (55%) of respondents said they do not use any of the social services that are planned to move to the County Services hub. However, for those that do use the services, the most popular response was the DSS, which 33% of respondents said they use.
- Of those who said that they would visit the County services to be located at Shipwatch Square, 41% reported that they would visit a few times per year, with 27% reporting once a year or less and 23% reporting about one time per month.
- The average survey respondent tended to identify as male, live alone, be 45 or older, have a driver's license, be black/African American, and report a 2020 total annual household income of $20,000-29,999.

Overall, it appears that the move to Shipwatch Square will not have a negative impact on how most riders currently using the SuperStop will travel. However, it is important to explore ways to make the pedestrian experience and pedestrian access to Shipwatch Square more robust so that it is not an obstacle for people living in the area who may now have a longer walk to Shipwatch Square.

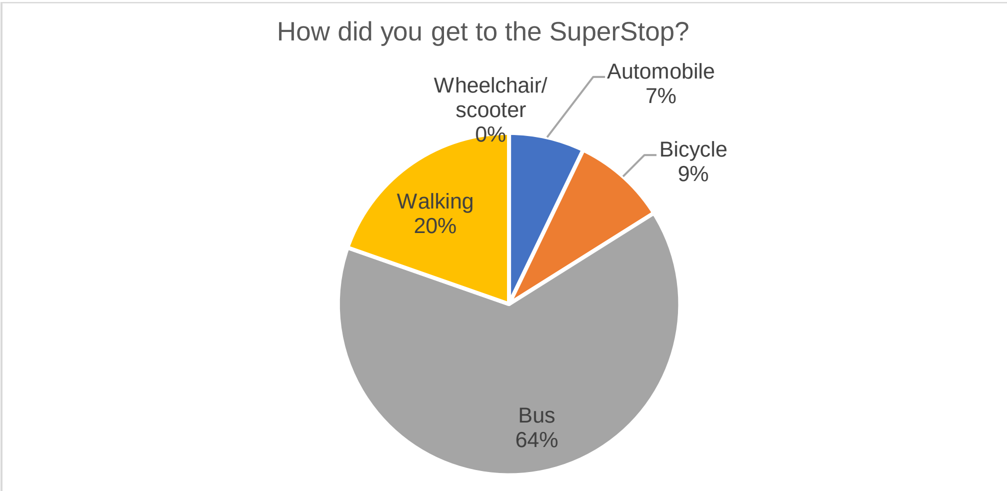
Question #1: How many days per week do you usually ride CARTA? (n: 72)



Question #2: Do you arrive, transfer, or depart from the SuperStop? (n: 72)



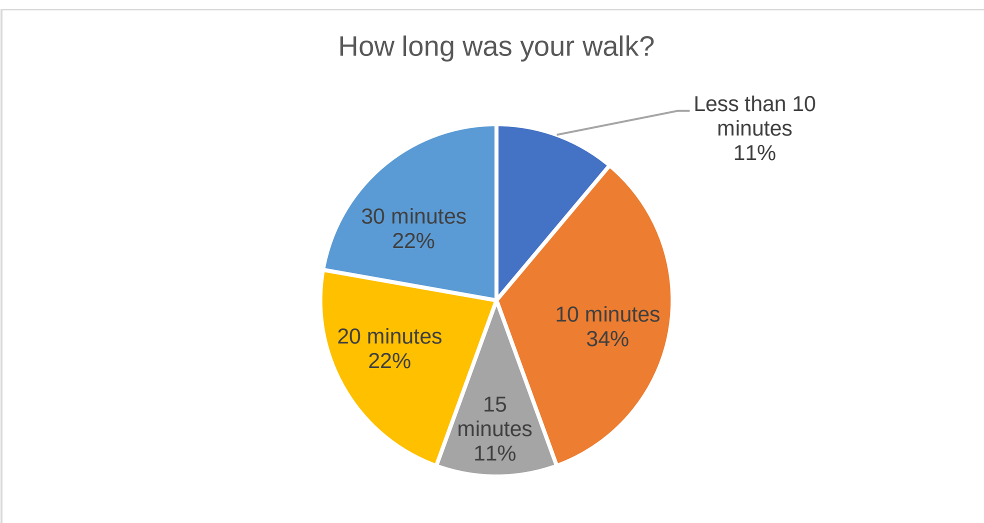
Question 2A: If yes, how do you get there? (n: 56)



Walking (n: 9)

- Where did you begin your trip?
    - Rivers & Meeting St Road
    - Murray Hill & Dorchester
    - Riverfront Park (2)
    - Tulip Street
    - Horizon Village
    - Sam Rittenberg Blvd by Church's Chicken
    - McMillan & Rivers

- How long was your walk?

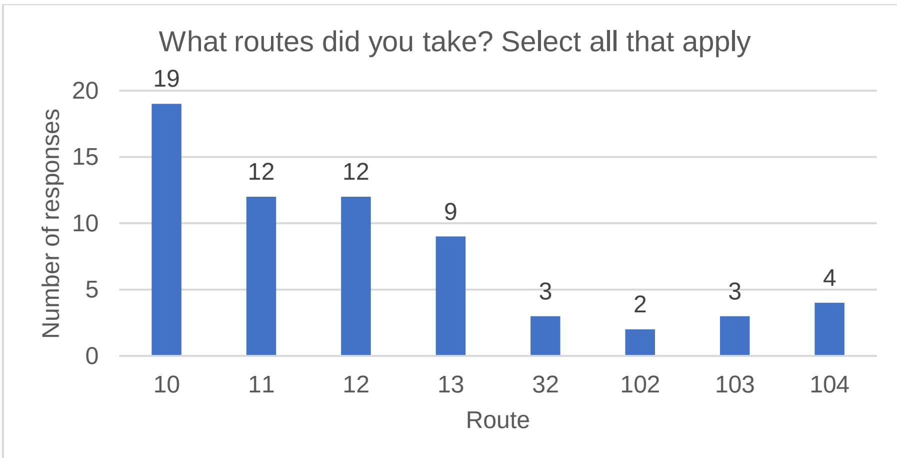


Wheelchair/scooter (n: 1)

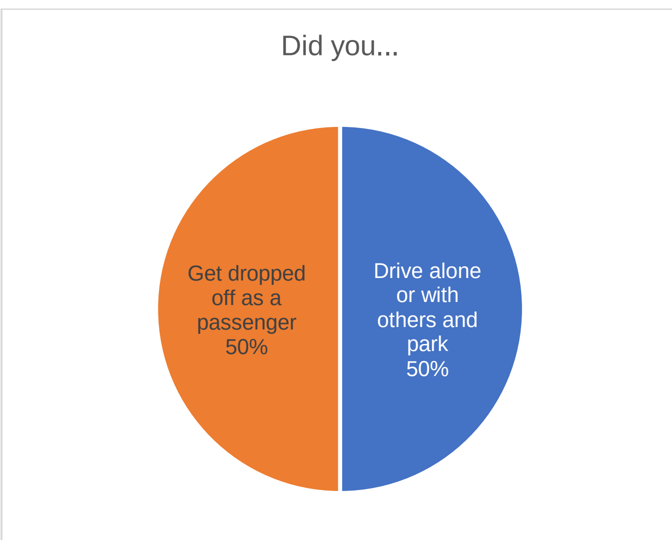
- Where did you begin your trip?
  - Cosgrove & Reynolds
- How long was your trip?
  - 10 minutes

Bus (n: 36)

- What route(s) did you take? Select all that apply (n: 64)



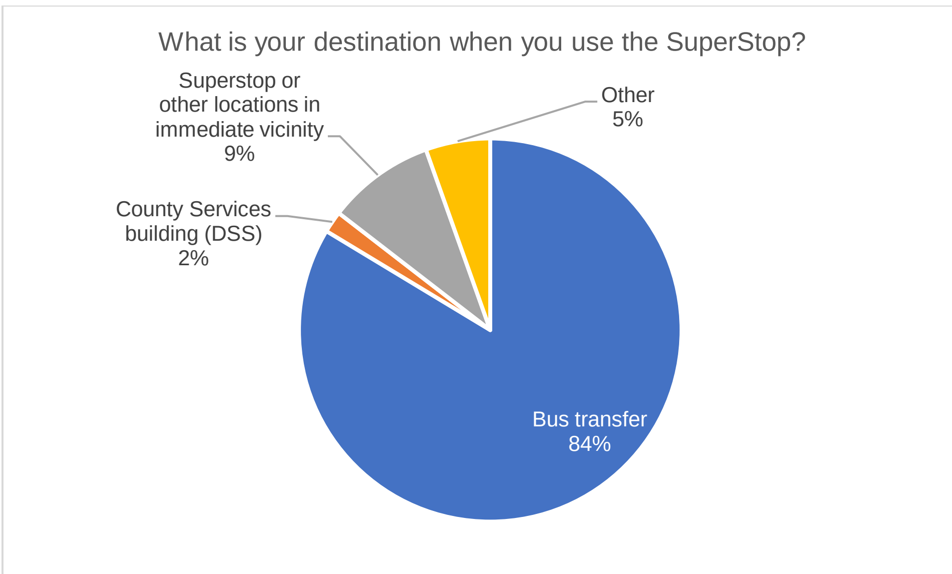
Automobile: did you… (n: 4)



Bicycle (n: 2)

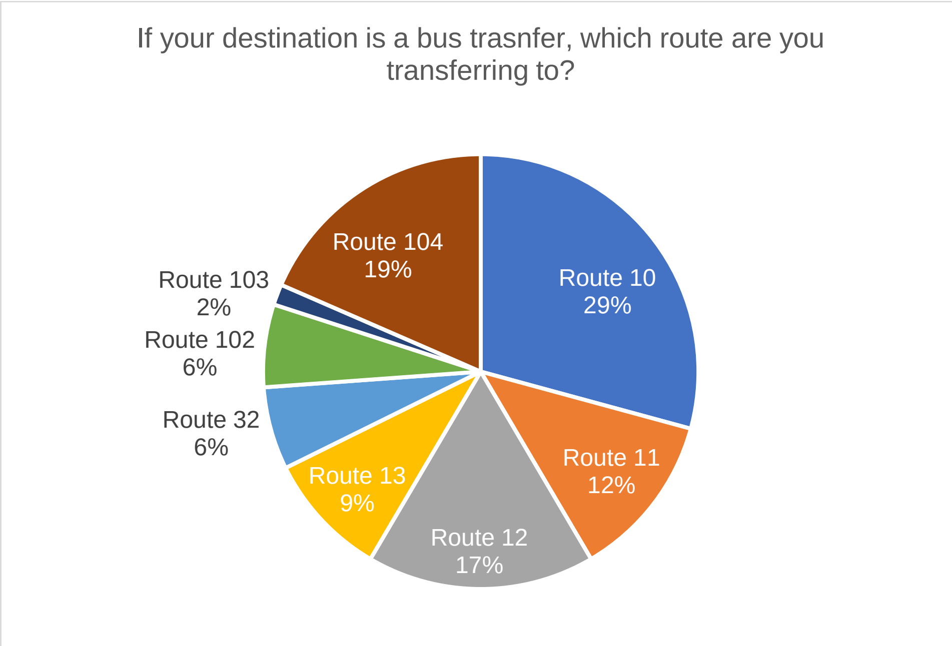
- Where did you begin your trip?
    - SuperStop
    - West Ashley
- How long was your trip?
    - 15 minutes
    - 30 minutes

Question #3: What is your destination when you use the SuperStop? (n: 55)

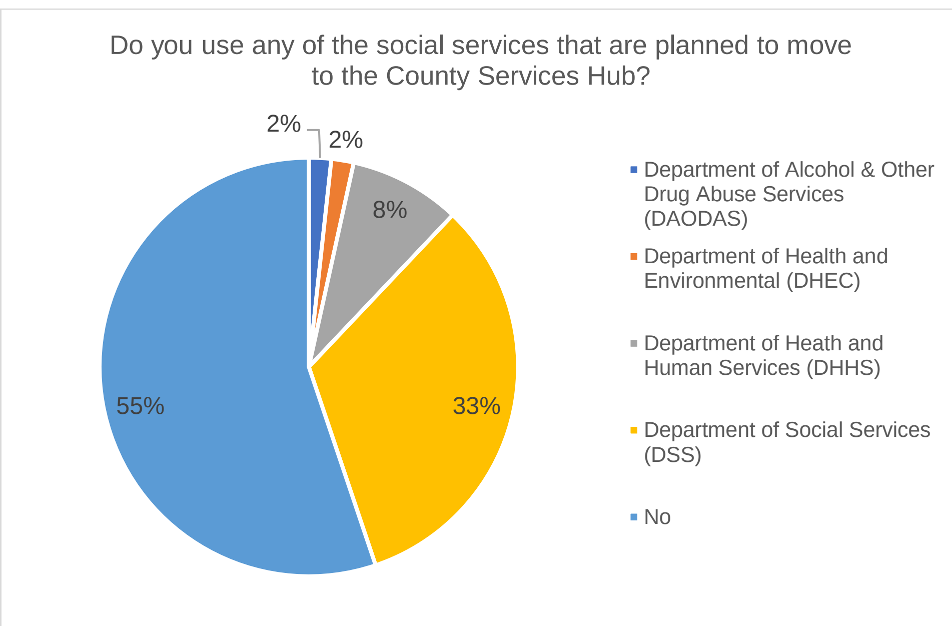


- Other responses:
    - Home, downtown, Mt Pleasant

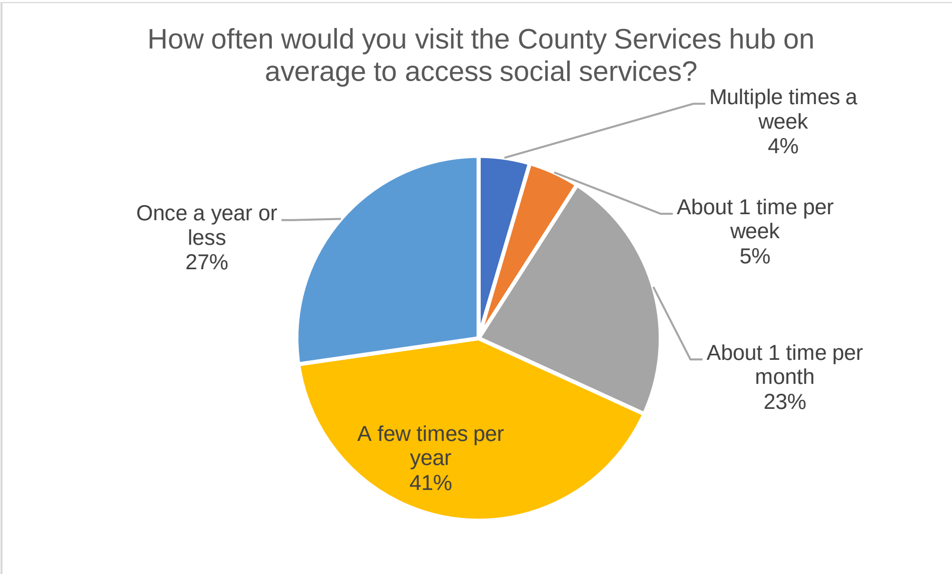
Question #4: If your destination is a bus transfer, which route are you transferring to? (n: 65)



Question #5: Do you use any of the following social services that are planned to move to the County Services hub? Select all that apply. (n: 58)

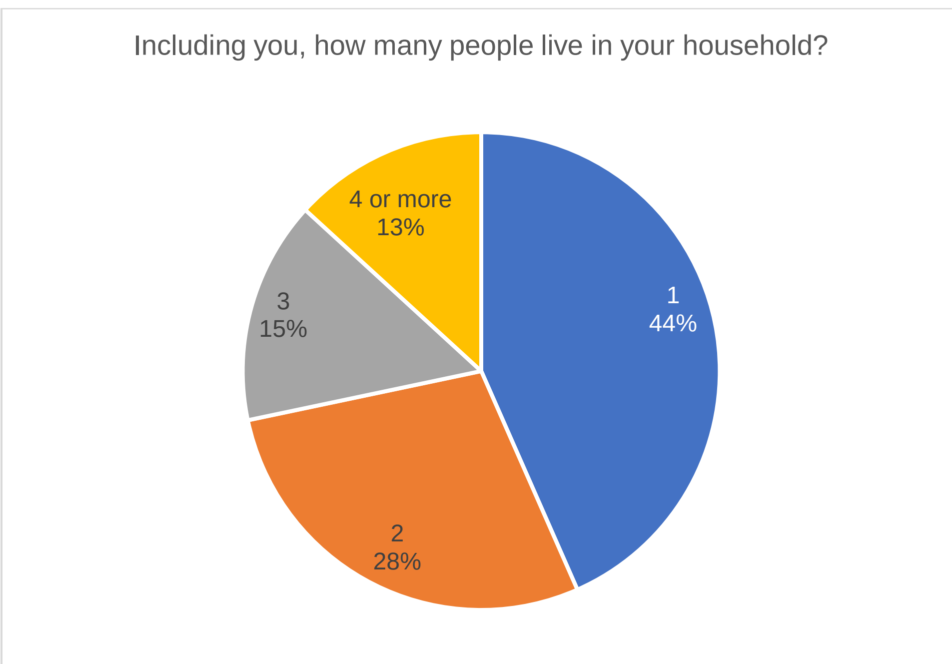


Question #6: How often would you visit the County Services hub on average to access social services? (n: 22)

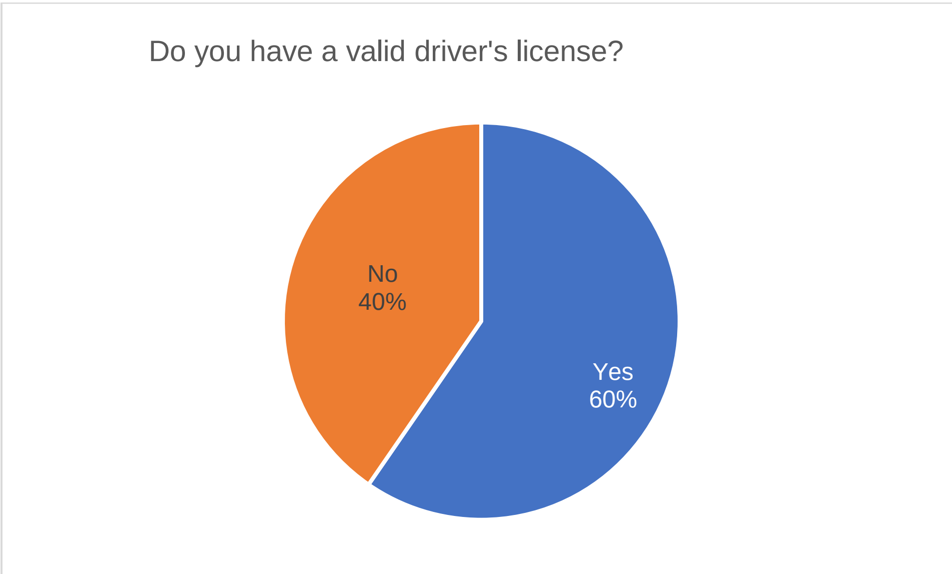


Demographic questions

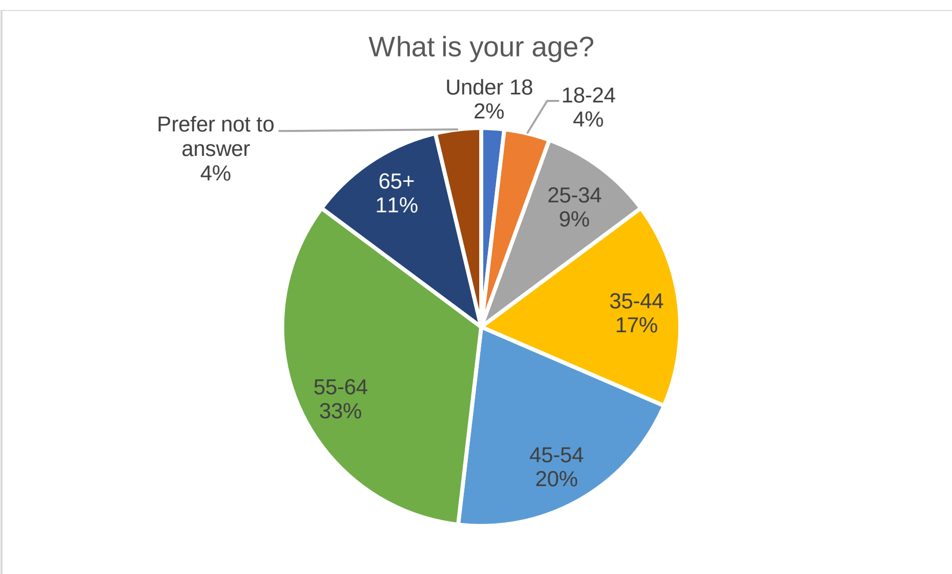
Question D1: Including you, how many people live in your household? (n: 53)



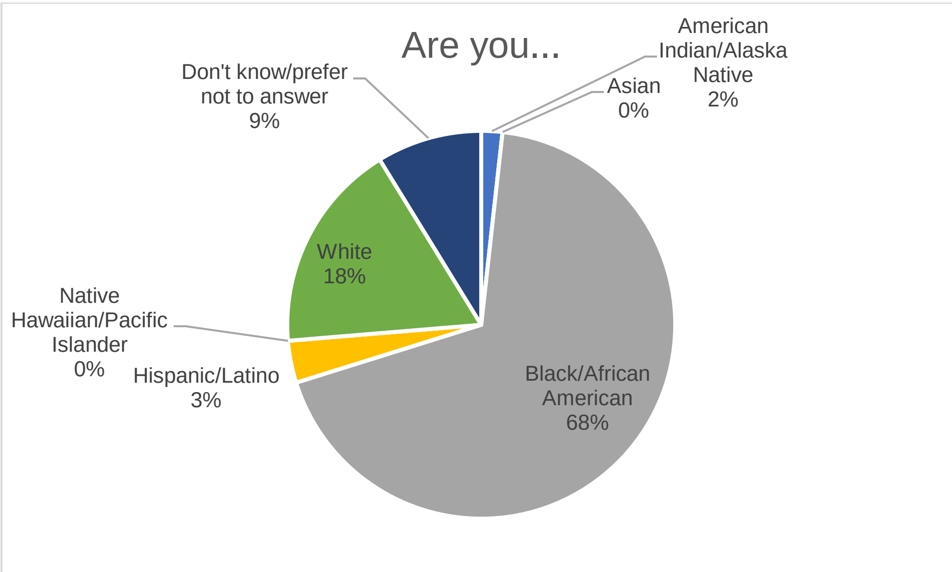
Question D2: Do you have a valid driver's license? (n: 52)



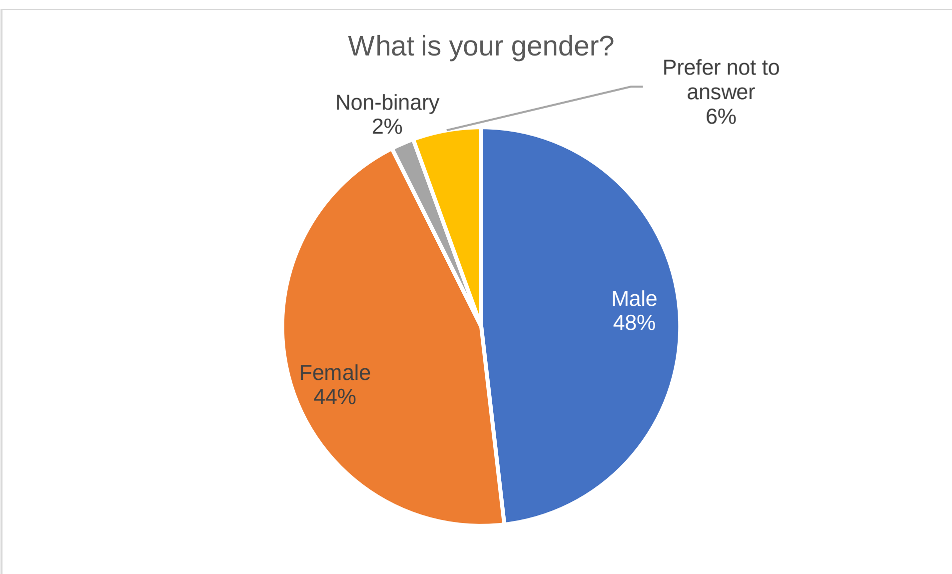
Question D3: What is your age? (n: 54)



Question D4: Are you… (n: 57)



Question D5: What is your gender? (n: 54)



Question D6: Which of the following best describes your total annual household income in 2020 before taxes? (n: 50)