Hampton Roads Transit

Zero-Emission Bus Transition Plan

Version: May 2022

Agency Contact Information

Transit Agency's Name:	Hampton Roads Transit
Mailing Address	3400 Victoria Boulevard Hampton, VA 23661
Transit Agency's Service Area	Norfolk, Portsmouth, Virginia Beach, Chesapeake, Hampton and Newport News
Total Number of Buses in Annual Maximum Service (2021)	281
Urbanized Area	Virginia Beach-Norfolk-Newport News
Population of Urbanized Area (2019)	1,799,674
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Acronyms

ATI	Advance Technical Institute
ATU 1177	Amalgamated Transit Union, Local 1177
BEB	Battery Electric Bus
CaaS	Charging as a Service
CIFIA	Carbon Dioxide Transportation Infrastructure and Innovation
CIP	Capital Improvement Plan
CNG	Compressed Natural Gas
DERA	Diesel Emissions Reduction Act
DFH	Diesel Fueled Heater
DRPT	Department of Rail and Public Transportation
EPA	Environmental Protection Agency
EV	Electric Vehicle
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
FY	Fiscal Year
HRRTF	Hampton Roads Regional Transit Fund
ICE	Internal Combustion Engine
IIJA	Infrastructure Investment and Jobs Act
HRT	Hampton Roads Transit
MAX	Metro Area Express
MERIT	Making Efficient and Responsible Investments in Transit
OEM	Original Equipment Manufacturer
PCS	Peninsula Commuter Service
PEER	Performance and Evaluation of Electric Bus Routes
QA/QC	Quality Assurance/Quality Control
RFP	Request for Proposal
SCIP	Smart Charging Infrastructure Pilot
SOC	State of Charge
SUV	Sport Utility Vehicle
TDCHR	Transportation District Commission of Hampton Roads
TSP	Transit Strategic Plan
VA DEQ	Virginia Department of Environmental Quality
VB Wave	Virginia Beach Wave
ZEB	Zero-Emission Bus
ZEV	Zero-Emission Vehicle

Executive Summary

Hampton Roads Transit (HRT) aims to provide the most optimal methods of transit service to residents of the Hampton Roads community. In doing so, HRT strives to offer transportation services and facilities that are safe, reliable, efficient, and sustainable. Consequently, HRT is transitioning its bus fleets to battery electric bus (BEB) fleets. This transition supports HRT's goals of prioritizing dependable transit services and environmental sustainability.

The number of transit agencies choosing to transition to zero-emission bus (ZEB) fleets has significantly grown in recent years. Additionally, recent legislation has identified ZEBs as being required to ensure a zero-emission future. ZEBs offer agencies an alternative to conventional diesel-fueled buses and provide a wide range of advantages including environmental and economic benefits. However, the upfront capital costs of transitioning and technological requirements of ZEBs call for thoughtful planning measures to ensure transit agencies are prepared for ZEB adoption.

As per the Bipartisan Infrastructure Law, the Federal Transit Administration (FTA) recently added a requirement for agencies applying for the Grants for Buses and Bus Facilities Competitive Program and the Low or No Emission Program to include a Zero-Emissions Transition Plan. This document outlines all components required in this plan including:

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

The long-term fleet management plan considers an analysis of HRT's current route system, current services offered, cost and ridership statistics, Performance and Evaluation of Electric Bus Routes (PEER) analysis modeling simulation results, current fleet size, technology and infrastructure requirements, maintenance needs, and start-up and scale-up challenges. These considerations aided in the development of the long-term fleet management transition plan that intends for HRT's fleets to be comprised of 100 percent BEBs by 2040.

In order to meet the costs of the transition and implementation to BEB fleets, a comprehensive research examination was conducted regarding current and future funding sources.

Legislation requiring transit agencies to transition to ZEB fleets is paramount to ensure transition plans are in compliance with applicable policies. An overview of policy and legislation impacting ZEB technology was conducted to ensure HRT's transition and implementation follow current regulations.

An integral component of developing a BEB fleet transition plan was an evaluation of current and future facility capabilities to ensure all technology requirements can be accomplished. Through this evaluation, several necessary modifications were identified.

HRT has a strong partnership with its utility provider, Dominion Energy. The productive relationship HRT has with Dominion Energy aides in the development of a charge management strategy and in their cooperation throughout the transition process.

Minimizing workforce displacement supports HRT's goals to provide reliable transit for the Hampton Roads community. HRT is committed to retaining and training all current staff members to familiarize them with BEB service, maintenance, and operations.

Key findings from the above analysis include:

- Converting HRT's fleet of approximately 281 buses to BEBs could eliminate more than 500,000 tons of CO_2 from the atmosphere
- HRT could achieve a 1:1 replacement of diesel buses to electric buses by 2040, assuming battery technology improves during that time
- To meet a 100 percent BEBs by 2040 goal, then at least 329 BEBs will need to be purchased at a pace of about 20 buses per year (from 2025 through 2040, plus an extra bus in one of those years)
- New Southside Facility will allow HRT to reach approx. 487,000 citizens (169 percent increase) and over 312,000 jobs (127 percent increase)
- The new Southside Facility, scheduled to be operational in 2026, would have electric chargers that can accommodate all buses in the facility (pending grant funds)
- Cost estimates for 329 BEB acquisitions, 66 replacement BEB procurements, and facility improvements for all 3 HRT facilities, is roughly $771,754,000

The process to transition to BEBs should and will be iterative to minimize risk, and to accommodate new developments in a rapidly evolving market. HRT will use the information outlined in this document to refine and determine the following:

- Address incomplete service blocks
- Refine infrastructure and other costs associated with the transition
- Explore collaboration opportunities
- Engage utilities

1 Transit Agency Overview

History

Hampton Roads Transit (HRT) serves a 432 square-mile area within the Hampton Roads region. HRT consists of six member cities: Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, and Virginia Beach, which have a combined population of about 1.79 million (2021). The service area is divided by the James River. The service area south of the river consists of Chesapeake, Norfolk, Portsmouth, and Virginia Beach, commonly referred to as the Southside. HRT's service area north of the James River includes the cities of Hampton and Newport News which, together with neighboring communities, are often referred to as the Peninsula or Northside (Figure 1-1).

Hampton Roads is home to numerous federal facilities and United States military installations, including Naval Station Norfolk, Joint Expeditionary Base Little Creek – Fort Story, Naval Air Station Oceana, and Joint Base Langley Eustis. These installations are a major generator of economic activity, with government spending accounting for 30 percent of gross domestic product in the Virginia Beach-Norfolk-Newport News Metropolitan Statistical Area in 2017 (Source: HRT TSP, March 2021).

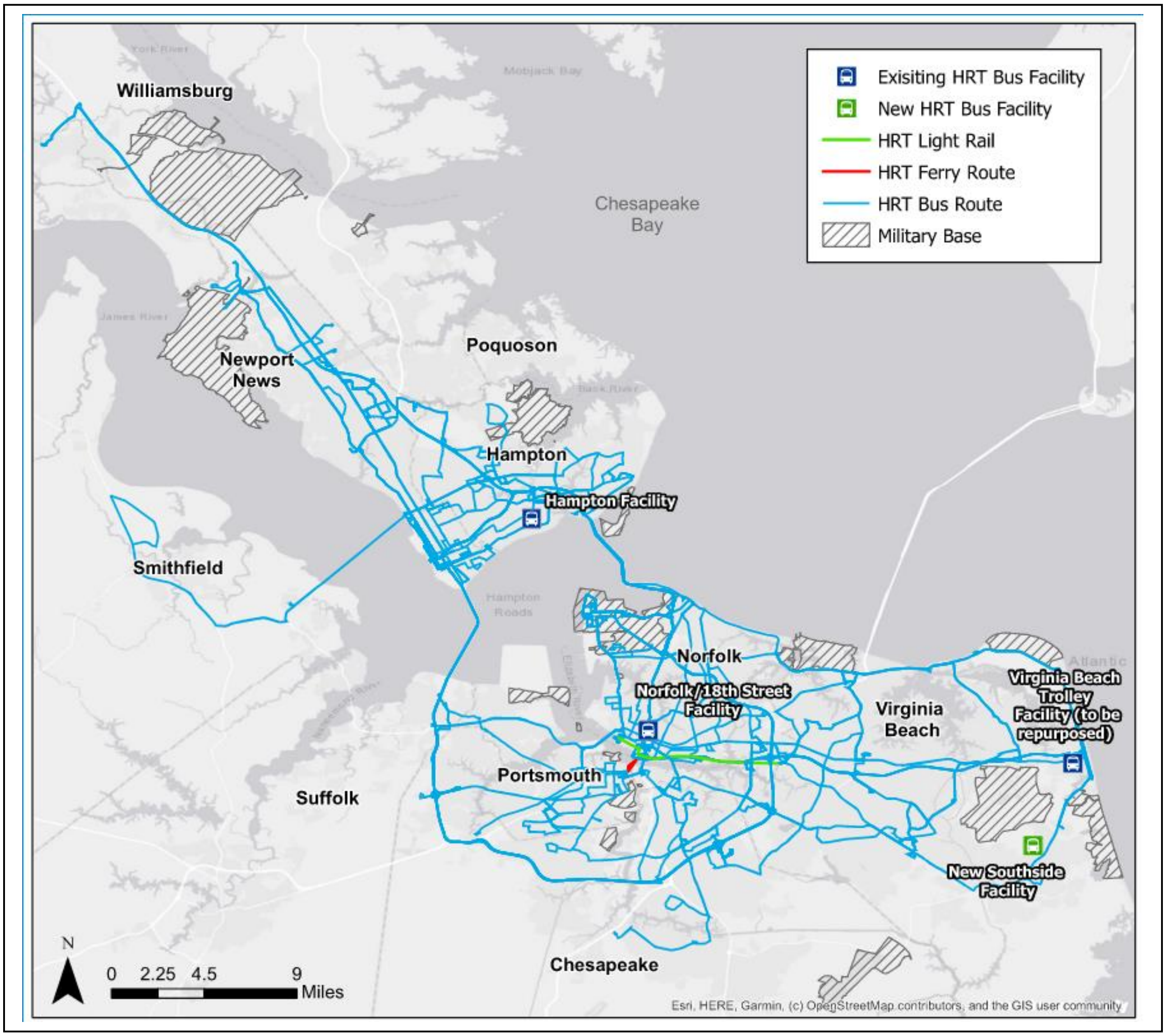
Originally, two transit systems developed separately on the Southside and Peninsula, Tidewater Regional Transit and Pentran, respectively. Electric trolleys operated in both areas before the turn of the 20th century and were gradually replaced by buses between the 1920s and 1940s. Paratransit service began in both regions between 1979 and 1980, and ferry service between Norfolk and Portsmouth – operated by Tidewater Regional Transit - was established in 1983. Late night bus service began on the Peninsula in 1991.

Tidewater Regional Transit and Pentran merged in 1999 to create the Transportation District Commission of Hampton Roads (TDCHR), which operates HRT. In 2008, HRT began an eight-route express bus service linking all six jurisdictions at the time; in 2011, HRT completed and opened Virginia's first light rail line, the Tide, which provides service through Downtown Norfolk to the border of Virginia Beach. HRT currently operates 69 fixed-bus routes, including three seasonal routes serving tourists in Virginia Beach.

The City of Suffolk, located on the Southside, was initially part of the TDCHR. HRT began service in the City of Suffolk in 2009. The City of Suffolk withdrew from the TDCHR in December 2011, and the change was effective in January 2012. The City of Suffolk now contracts with Virginia Regional Transit to operate Suffolk Transit.

Climate change, air quality and noise pollution considerations, and legislative guidelines have become more pressing. Meanwhile, available electric bus market products have become more diverse and cost-efficient. Therefore, HRT is prepared to take the next step in providing quality transit service to the Hampton Roads region by transitioning to a battery-electric bus (BEB) fleet.

Figure 1-1: Hampton Roads Transit Service Map



Source: Hampton Roads Transit, 2022, US Department of Transportation, 2022

Vision and Mission

HRT updated the agency's vision and mission statements as part of the *Transit Transformation Project* (completed December 2019) and internal strategic planning processes.

Vision: A progressive mobility agency that promotes prosperity across Hampton Roads through collaboration and teamwork.

Mission: To connect Hampton Roads with transportation solutions that are reliable, safe, efficient, and sustainable.

Core Values

HRT's core values influence the agency's desired culture and guide day-to-day business activities to achieve its vision and mission. The four core values are the guiding principles and behaviors that embody how HRT, and its workforce are expected to operate:

- Safety: We strive for safety excellence in all areas of our business
- Customer Service: We are committed to professional, courteous and dependable service
- Workforce Success: We are committed to effective hiring, training, and ongoing success of every team member
- Fiscal Responsibility: We are dedicated to diligent stewardship that is accountable, transparent, and delivers the most value for our customers and funding partners

Goals

HRT has identified four goals as part of the *Transit Transformation Project*:

1. Provide high-quality service that is easy to use and enhances people's lives.
2. Foster regional quality of life and economic vitality.
3. Ensure financial stewardship and cost-effective operations.
4. Build a culture for innovation and workforce success to ensure HRT remains relevant to the dynamic needs of the region.

The transition to BEBs supports HRT goals because BEBs offer safe, smooth, and quiet rides, improving the passenger experience. BEBs reduce noise pollution compared to diesel buses, improving quality of life for residents living along bus routes, even if they do not ride the bus. Crucially, BEBs do not emit greenhouse gases or particulate matter that their internal combustion engine (ICE) counterparts emit. While this improves the region's air quality for all, it can have outsize benefits for communities which primarily rely on transit, which are often disadvantaged neighborhoods facing environmental justice issues. For example, the improvement in air quality can lower rates asthma and other respiratory-related health conditions.

There are also economic benefits, as changes in bus technology provide manufacturing and training opportunities for vehicle manufacturers and bus operators. Maintenance costs for transit agencies are typically lower for BEBs than ICE buses, as there are fewer parts which require maintenance on BEBs. Operational costs will be lower for BEBs than ICE buses if an energy management system is in place.

Additionally, HRT's Board outlined six goals for the President and Chief Executive Officer's focus in Fiscal Year (FY) 2021 – FY 2022, three of which focus especially on implementing the Transit Strategic Plan (TSP) and Hampton Roads Regional Transit Program. The outlined six goals include:

- Initiate the first grouping of high-frequency routes on the Peninsula of the core regional backbone as approved in the Strategic Plan on June 25, 2020, by the TDCHR.
- Ensure the strategic integration of technology and enhanced customer amenities in the regional transit program implementation.
- Develop a comprehensive and integrated public communications plan including internal and external stakeholders to socialize and market the Strategic Plan and forthcoming transit investments to support the economic recovery of the Hampton Roads Region.

- Optimize resources to improve HRT's financial footing and fiscal sustainability to include proactive leveraging of available funds to deliver projects and services and reduce dependence on the line of credit.
- Develop and initiate strategies to improve transit ridership.
- Working with HRT's component city governments, draft a response plan for HRT's various modes of transportation to deal with flooding issues within HRT's footprint.

Interconnectedness of BEBs and HRT's goals:

- Use of BEBs and potential related infrastructure such as in-route charging could be useful at high-ridership locations.
- Qualified workforce recruitment would include BEB training.
- Implementation of BEBs offers new technology possibilities, as procurement of new vehicles allows HRT to update specification requirements, so vehicles are compatible with plans to enhance customer amenities such as mobile ticketing and real-time arrival information.
- The BEB pilot program and transition plan are opportunities to apply the communications plan with stakeholders as the plan develops into procurement, capital upgrades, and reports on operational improvements as a result of BEB implementation.
- Operations and maintenance costs of BEBs are lower than those of ICE buses, and electricity prices are generally less volatile than oil prices. As a result, fiscal sustainability of HRT operational costs can be lowered with BEBs.
- New vehicles and improved passenger experience on BEBs, which offer quieter and smoother rides than combustion engine buses, can improve ridership and attractiveness of service.

Service Provision Principles

HRT's vision, mission, and core values drive the agency's culture and purpose, which shape the service HRT provides to its customers. HRT also has goals and objectives to help guide the planning, provision, and sustainability of service. HRT's top priorities identified through public and stakeholder input are:

1. More reliable service (on-time arrivals and drop-offs)
2. Frequent service during rush hour (5:00am-9:00am and 3:00pm-7:00pm, Monday-Friday)
3. Real-time bus arrival information
4. Safety and security
5. Mobile ticketing and fare payment options
6. More sheltered stops in my city.

Regional Transit System

In 2020, the Virginia General Assembly passed legislation creating a Hampton Roads Regional Transit Program with dedicated regional transit funding for the first time. The explicit goal is to provide a modern, safe, and efficient core network of transit services across the Hampton Roads region. The estimated $31 million annually will fund enhanced service and purchase the rolling stock needed to provide what is now branded as the Regional Transit System (RTS).When fully implemented, RTS will result in nearly 200,000 additional revenue hours and over 2.4 million additional revenue miles of bus service annually. The much-improved services aim to achieve better reliability (a reliable network that supports regional connectivity, removing transportation barriers and improving access to jobs, retail, medical, recreation, education and workforce development opportunities); faster commutes (increased frequencies and spans of service); and new connections (expanded service to reach more people).

The centerpiece of the RTS is a new 13-route "regional backbone" bus service linking the six cities HRT serves with 15-minute frequency and enhanced customer amenities. Currently, many HRT routes operate on one-hour headways which limits the usefulness of transit in a metropolitan area with more than 1.7 million residents. With the resources provided through RTS and based on community input, HRT is establishing and following regional bus service standards; prioritizing high-frequency services; balancing resources between peak hour and all-day service; prioritizing connections across jurisdictions; providing sufficient coverage to ensure access to transit; and leveraging a data-driven approach and factoring of funding and operational constraints to prioritize and phase implementation.

The development of the new Southside Operating Division Facility will be instrumental in providing the expanded RTS service.

Zero-Emission Vehicle Technology Benefits

Transitioning to zero-emission technology embraces several benefits to the region as described in Table 1-1.

Table 1-1: Zero Emission Vehicle Benefits

Category	Benefit/s
Economic Competitiveness	• Reduce operational costs through savings from lower fuel and maintenance costs • Advance potential workforce development
Environmental	• Avoid tons of carbon emissions and pounds of nitrogen oxide emissions
Health	• Reduce noise levels • Decrease potential asthma and other air quality-related health issue exposure
Equity	• Offer equity integration strategies
Safety and Security	• Reduce dependency on fossil-based sources • Offer sustainable micro grid concept • Create more secure operations due to less outside energy dependency
Other	• Optimize energy consumption through regenerative breaking • Improve vehicle acceleration • Enhance customer experience

2 Clean Transit Regulations

FTA Mandate

Background

On December 1, 2021, the FTA announced the Zero-Emission Plan requirement as now part of the implementation of the Grants for Buses and Bus Facilities Competitive Program and the Low or No Emission Program. Under this mandate, any applications for projects related to zero-emission vehicles must include a Zero-Emission Transition Plan.

Zero-Emission Transition Plan Requirements

A Zero-Emission Transition Plan must, at a minimum:

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

State Legislation

Within Virginia

On March 19, 2021, Virginia Governor Ralph Northam signed Virginia House Bill 1965 into law. This law directs the State Air Pollution Control Board to implement a low-emissions and zero-emissions vehicle program for motor vehicles with a model year of 2025 and later. Regulations adopted by the Board to implement the program are exempt from the Administrative Process Act and shall not become effective prior to January 1, 2024.

On April 11, 2020, Governor Northam signed into law the Virginia Clean Economy Act. This mandate makes Virginia the ninth U.S. State to mandate a move to 100 percent clean electricity by 2050. Virginia is the first southern state to set such standards. The act is designed to spur clean job creation and reduce the State's carbon emissions.

As of December 2021, Governor Northam added Virginia to the 15-state joint memorandum of understanding to work together to advance the technology and market for electric medium- and heavy-duty vehicles, including large pickup trucks and vans, delivery trucks, box trucks, school and transit buses, and long-haul delivery trucks (big-rigs) (CALSTART 2021). The goal is to ensure that 100 percent of all new medium and heavy-duty vehicle sales be zero emission vehicles by 2050 with an interim target of 30 percent zero-emission vehicle sales by 2030.

Other States

Eight states have currently enacted legislation or funding requirements mandating the conversion of public transit fleets to Zero-Emission Buses (ZEB) 2040, as well as systemically banning the procurement of ICE vehicles as soon as 2023.

It has become important for transit agencies to understand battery electric bus (BEB) technology, its specifics, the way it will affect transit buses current operations, staff and key personal and solutions that could be implemented to keep the same efficiencies as using diesel buses. Advancements in bus propulsion technologies continue to provide transit providers with a diverse range of green technology options which can benefit them now and in the future.

Bipartisan Infrastructure Bill

President Biden's infrastructure bill features incentives as large as $12,500 for buying electric vehicles (EVs). The bill also features an Executive Order that sets a new target of zero-emission vehicles (ZEVs) representing half of all new vehicles sold by 2030. The Executive Order also introduces long-term fuel efficiency and emissions standards. The bill sets a schedule for these standards through at least model year 2030 for light-duty vehicles and for medium- and heavy-duty vehicles starting as early as model year 2027.

3 Bus Electrification Pilot Program

Overview

HRT began piloting BEBs in its fleet and started revenue service in May 2021. Six BEBs were initially deployed on Route 20, the busiest route in the Commonwealth of Virginia. Currently, HRT is testing BEB technology on other routes. The Pilot Bus Electrification Program was funded through a combination of federal and state grant sources, which combined for a total of $7.8 million for:

- Six, 40-foot all electric buses plus parts
- Seven charging stations
- Retrofit infrastructure of the 18th Street facility to accommodate operations and maintenance
- Workforce training to operate and maintain the new equipment

The goals of the pilot program are to:

- Evaluate battery performance in the HRT operating environment
- Analyze how best to deploy the buses in HRT revenue service
- Assess the need for in-route charging
- Evaluate the overall reliability and maintenance requirements of the buses
- Assess operations service blocks completion
- Outline a fleet replacement strategy
- Provide guidance on battery charging hardware infrastructure needs; facilities electrical utility power supply upgrades; existing bus garages modification to accommodate electrification and maintain operational service; and future-proofing new garage designs to facilitate long-term electrification adaptation/expansion.

Since the revenue service began, HRT operations continues to evaluate battery performance under multiple conditions including:

- Stopping and starting
- Air conditioning or heaters on
- Doors opening and closing
- Accelerating and stopping
- Carrying large amounts of passengers
- Multiple Routes

Recharging stations were installed at HRT's 18th Street maintenance shop at the Norfolk facility because it was the only facility easily capable of accommodating power needs of the buses.

Under the existing pilot program, HRT installed ViriCiti (now Chargepoint) software to track key indicators of BEB performance and to understand BEB operations while refining assumptions for future procurement and transition implementation.

Southside Bus Operating Division Facility

HRT is designing a new facility to support electrification efforts and to provide more efficient and frequent service. The new facility will be located at Corporate Landing Parkway in Virginia Beach. The new facility that is scheduled to be operational in 2026 will ultimately:

- Support zero-emissions goals of a 100% BEB fleet by 2040
- Accommodate expanded bus fleet in support of HRT's RTS Program
- Reduce energy consumption and harmful carbon emissions
- Reduce deadhead miles (62,000 per year)
- Allow HRT to serve approximately new 487,000 citizens (i.e., a 169 percent increase) and over 312,000 jobs (i.e., a 127 percent increase)
- Create 125 new jobs in Virginia Beach area

4 Route Analysis

Route Design and HRT Standards

Route Design

The alignment of each route is a key factor in its ability to successfully serve customers' mobility needs. "Route design" refers to route directness, connections to key origins and destinations, and how routes interface with other services that comprise the overall network. HRT key route design principles include:

- HRT routes should be designed to serve origins and destinations via direct pathways, minimizing out-of-direction movements. Direct pathways provide quicker trips than when compared to indirect routes. Faster commute times attract more customers, which increases fare revenue while minimizing costs associated with bus service.
- Bus routes should serve major mixed-use corridors throughout the service area, avoiding smaller neighborhood streets.
- High-frequency HRT routes should be designed to serve major corridors, offer more direct service, and provide transfer connections either on-street or at major transfer hubs in the urban core.

- Deviations off the basic alignment of a fixed route should be minimized whenever possible; however, under HRT's standards, routes may deviate off their primary alignment to serve major activity centers or provide coverage to areas with limited access. The time necessary for the deviation should not exceed five minutes, or ten percent of the one-way travel time of the existing route without deviation, and deviations must result in an increase in overall route productivity.

Schedule Standards

HRT's weekday service generally runs between 4:25 a.m. and 2:00 a.m. Each time period and route type have different service span standards. Weekend service generally runs between 6:00 a.m. and 12:00 a.m. Holiday service is updated on an annual basis. On holidays, routes will usually run weekend service schedules. These holidays include:

- New Year's Day
- Dr. Martin Luther King, Jr. Day
- George Washington Day
- Memorial Day
- Juneteenth
- Juneteenth (Observed)
- Independence Day
- Labor Day
- Columbus Day
- Veterans Day
- Thanksgiving Day
- Day after Thanksgiving
- Christmas Day
- Christmas Day (Observed)

HRT's Service

HRT's fixed-route bus service includes 53 local routes, eight Metro Area Express (MAX) regional express routes, five Peninsula Commuter Service (PCS) routes, and three seasonal routes in Virginia Beach (VB Wave and Bayfront Shuttle, which operate from May through September every year). HRT also operates a light rail, The Tide, in Norfolk and three ferries across the Elizabeth River to connect Downtown Portsmouth and Downtown Norfolk. HRT's demand response program is a shared ride paratransit service serving the cities of Chesapeake, Hampton, Newport News, Norfolk, Portsmouth, and Virginia Beach to and from locations within three-quarter miles of existing fixed-route bus, light rail, and ferry service during HRT's regular operating hours.

From March 31 to June 14, 2020, HRT implemented an Essential Service Plan which provided reduced levels of service because of the COVID-19 pandemic. Fares were free from March 31 to July 1, 2020. Regular levels of service were operated from June 14, 2020 through May 8, 2021. On May 9, 2021 HRT began the Service Reliability Plan because of reduced operator availability due to the COVID-19 pandemic. The Service Reliability Plan is designed to match the level of service to operator availability so reliable service can be delivered with fewer missed trips. The Essential Service Plan and Service Reliability Plan service data are not reflected in the service data in the TSP since they are temporary changes of service. However, Routes 919 and 922 are still currently suspended due to low ridership.

Local Bus Services

HRT operates fixed-route service seven days a week. Weekday service runs between 4:25 a.m. and 2:00 a.m. The time that service operates varies between the six member jurisdictions, as each city determines how early/late the service runs. Local routes operate on 15-minute to 60-minute headways during morning and afternoon peak periods. Southside routes include those that operate in Chesapeake, Norfolk, Portsmouth, and Virginia Beach; Peninsula routes operate in Hampton and Newport News.

Peninsula Commuter Service

HRT's Peninsula Commuter Service (PCS) is a five route, limited stop bus service that provides service to major employees on the Peninsula, which is comprised of the independent cities of Hampton, Newport News, Williamsburg, and Poquoson. PCS routes offer commuter service with only one or two trips per day, designed to coincide with shift change times of major employers.

Metro Area Express Service

HRT's Metro Area Express (MAX) service is an eight-route regional express bus service traveling between Hampton/Newport News and Norfolk/Virginia Beach, mostly along interstates. The routes are designed for commuters; MAX service is limited stop and operates on coach buses with free Wi-Fi. Some MAX routes operate throughout the day; others are designed for commuter service, only operating during peak periods.

Demand Response Paratransit

HRT contracts with First Transit and MV Transportation to provide Demand Response paratransit service for persons with disabilities. Paratransit service is offered within a three-quarters of a mile of any fixed-route bus service during HRT's hours of operation.

Other HRT Service

HRT also operates ferries, light rail, and trolleybus routes. While the light rail is already electric. electrification of the other services would be addressed under a future, separate transition plan.

Current Operating Statistics, Costs and Ridership

Fixed-Route Bus Services

Operating Statistics

HRT's fixed-route services operate out of three garages; the two year-round operating facilities are in Norfolk and Hampton, with another small seasonal (summer) facility in Virginia Beach. The agency has a 234 fixed-route peak vehicle need during the summer season and a 222 fixed-route peak vehicle need all other times. Annually, the HRT fixed-route services operate approximately nine million revenue miles and 750,000 revenue hours. Most of this service is operated in the Southside. Table 4-1 summarizes key operational statistics for HRT's fixed route buses.

Table 4-1: Operating Statistics by Service, October 2020

Service	Peak Vehicle Need (Summer Season)	Annual Revenue Miles	Annual Revenue Hours
Southside Service	147	5,567,443	474,738
Peninsula Service	44	2,624,613	215,764
VB Wave and Bayfront Shuttle Services (seasonal)	13	193,694	23,786
Peninsula Commuter Service (PCS)	2	49,939	2,558
Metro Area Express (MAX) Service	28	546,202	40,127
Total	**234**	**8,981,891**	**756,973**

Source: HRT TSP, December 2021

Operating Costs

In FY 2019 (pre-COVID-19 pandemic) fixed-route service operating expenses totaled over $68 million, with farebox revenue generating just over $12 million, covering approximately 18 percent of the operating costs.

Ridership

In FY 2019, HRT's Southside, Peninsula, PCS, MAX, and VB Wave routes served a combined total of over 11 million riders (Table 4-2).

Table 4-2: HRT Ridership, FY 2019

Routes	FY 2019 Ridership
Southside	7,100,293
Peninsula	3,224,922
PCS	85,054
MAX	389,558
VB Wave	277,070
Total	**11,076,897**

Source: HRT TSP, December 2021

Paratransit Service

Operating Statistics

HRT's paratransit service operates during the same hours and days as the regularly scheduled fixed-route service. HRT paratransit serves areas within three-quarters of a mile of any fixed route. HRT contracts out both the call center, which takes all the trip requests and creates the daily scheduling, and the daily operations. The service transports passengers using accessible lift vans and sedans that are a combination of owned and leased vehicles.

Paratransit services account for approximately 25 percent of the revenue hours and miles across all of HRT's modes. The table below details the peak vehicle need and revenue miles for HRT's paratransit services.

Table 4-3: Operating Statistics for Paratransit Services, FY 2019

Peak Vehicle Need	Revenue Miles	Total Hours
103	3,719,272	266,860

Source: HRT TSP, December 2021

Operating Costs

In FY 2019, demand response operating expenses totaled $13,281,517.

Ridership

In FY 2019, HRT carried 372,813 passengers on its paratransit service. Of the jurisdictions, Norfolk had the highest paratransit ridership, followed by Virginia Beach and Newport News. Annual ridership for paratransit service broken down by jurisdiction is shown below.

Table 4-4: Annual Demand Response Ridership, FY 2019

Jurisdiction	Ridership	System Rank
Chesapeake	32,109	5
Hampton	52,504	4
Newport News	66,479	3
Norfolk	107,711	1
Portsmouth	24,652	6
Virginia Beach	89,358	2
Total:	372,813	

Source: HRT TSP, December 2021

Ferry Service

Operating Statistics

Ferry services account for less than one percent of the revenue hours and miles across all of HRT's modes. The Elizabeth River Ferry has three stops—High Street, North Landing, and Waterside—that result in a route 1.5 miles long. Ferry service is also provided to the Harbor Park baseball stadium between April and September when the Norfolk Tides play home games. Table 4-5 shows key operational statistics for HRT's ferry services for FY 2019.

Table 4-5: Operating Statistics for Ferry Service, FY 2019

Peak Vehicle Need	Route Length (miles)	Revenue Miles	Total Hours
2	1.5	18,734	6,100

Source: HRT TSP, December 2021

Operating Costs

For FY 2020, total ferry budgeted expenses equaled $1,465,478.

Ridership

In FY 2019 ridership on the Elizabeth River Ferry totaled 301,321. On average, the ferry service carried approximately 730 passengers on weekdays, 1,330 on Saturdays, and 770 on Sundays.

Light Rail Service

Operating Statistics

Light rail services account for approximately three percent of the revenue hours and miles across all of HRT's modes. Table 4-6 details the peak vehicle needs, revenue hours, and miles for HRT's light rail services.

Table 4-6: Operating Statistics for Light Rail Service, FY 2019

Peak Vehicle Need	Route Length: Average One-Way Trip (miles)	Revenue Miles	Total Hours
6	7.4	385,467	29,797

Source: HRT TSP, December 2021

Operating Costs

For FY 2020, total light rail budgeted expenses equaled $10,624,388.

Ridership

Annual ridership on light rail totaled 1,397,192 trips in FY 2019.

5 Performance and Evaluation of Electric Bus Routes Analysis

Overview

As part of the long-term fleet management plan, a Performance and Evaluation of Electric Bus Routes (PEER) analysis and modeling simulation was conducted. The PEER simulation evaluated how BEBs would perform using HRT's existing block schedule and provides the agency with a tool to test various alternative operating scenarios. The PEER model determines the total energy demand of a 100 percent BEB fleet, individual block completion rates, and the power requirements needed at each of HRT's operating facilities. The model provides critical information needed for the agency's planning, staging, and phasing of a ZEB fleet. The full HRT PEER report analysis is in Appendix A.

Purpose

The purpose of the PEER analysis is to provide an evaluation of a BEB's expected performance on every trip on each of the transit system's routes to develop a real-world operating range that accounts for:

- Bus stop dwell time
- Ambient temperature
- Passenger counts
- Route grades and elevation
- Bus type and properties

Key Findings

The key finding from the PEER analysis are:

- Using an industry-typical 40-foot BEB with a current battery capacity of 518 kWh, 81 percent of the 335 currently operated weekday blocks can be completed before the battery capacity of the bus is depleted.
- After approximately six years of use (a seasoned battery), 69 percent of the blocks could be completed.

- Bus range with a new battery is modeled to between 102 and 203 miles
- Bus range after six years is modeled to be between 82 and 162 miles.
- Block energy consumption rates range from 1.93 kWh to 3.79 kWh per mile.
- Assuming an improvement in battery technology resulting in a 54 percent increase in battery capacity, 97 percent of the blocks can be completed with a new battery.
- After six years of using the same new and improved battery technology, 90 percent of the blocks can be completed.
- HRT could achieve a 1:1 replacement of diesel buses to electric buses, assuming the fleet replacement process takes several years, and battery technology improves during that time. Some of the blocks will need to be rearranged to maximize the capacity of the BEBs.

Block Analysis

The PEER analysis provides essential information to determine if blocks can be completed with facility-only charging, or if in-route charging is required. If in-route charging is deemed necessary, then proposed locations can be evaluated for satisfying block range needs and providing desired comfort levels in terms of block completion and remaining state of charge (SOC). Utilizing the results of the block analysis that determines the SOC remaining after each bus returns to the facility, a peak kWh charging demand can be determined for each half-hour period throughout the night.

Blocking is used in this analysis to optimize schedules by dividing parts of scheduled routes among vehicles and drivers to optimize the schedule. Blocks are defined as paths taken by a bus from when it leaves the facility to when it returns to the facility. During this period, the bus may assist in providing service on multiple routes. Routes are when bus service is operated along a prescribed route according to a fixed schedule.

Energy requirements are simulated for each route and are based upon:

- Temperature
- Route elevation profile
- Regional solar loading
- Passenger loading by route
- Bus type and properties
- Heating mechanism (diesel versus electric)

As of Fall 2019, HRT operated 335 blocks from two maintenance facilities—3400 Victoria Boulevard, Hampton and 509 East 18th Street, Norfolk. For the sake of this analysis, blocks dispatched from HRT's 3400 Victoria Boulevard facility are called Northside blocks and those dispatched from 509 E. 18th Street are called Southside blocks. Several blocks (generally MAX routes) are dispatched from one facility and return to another at the end of their assignments. These are called Northside/Southside blocks in this report.

Modeling Assumptions

To model the potential variety of operating conditions in HRT's service area, a variety of ambient temperatures and bus types were simulated in PEER. The temperature and bus types assumptions are shown below and described in detail in the following sections.

- Vehicle types modeled with both new and seasoned batteries

  - A typical 35-foot BEB (440 kWh capacity)
  - A typical 40-foot BEB (518 kWh capacity)
- Ambient Temperature Profiles
  - Summer Operations: 89° F
  - Winter operation with electric heat in use: 31° F
  - Winter operation with a Diesel Fueled Heater (DFH): 40° F

Completion Rates Using HRT's Existing Block Schedule

The following tables show the results of the PEER simulation system-wide using HRT's 2019 block schedule. Table 5-1 shows the number and percentage of HRT's existing block assignments that could be completed with BEBs with a new battery, under winter conditions, without DFH. Table 5-2 represents the completion rates of all blocks using seasoned batteries, under winter conditions, without DFH.

Table 5-1: Block Completion Summary – New Battery without DFH

Block Group		40-foot BEB		35-foot BEB	
	Number of Blocks	Blocks Completable	Completion Percentage	Blocks Completable	Completion Percentage
All Blocks/All Facilities	335	271	81%	252	75%
Northside/Southside	19	17	89%	17	89%
Northside	73	47	64%	43	59%
Southside	243	207	85%	192	79%

Table 5-2: Block Completion Summary - Seasoned Battery Without DFH

Block Group		40-foot BEB		35-foot BEB	
	Number of Blocks	Blocks Completable	Completion Percentage	Blocks Completable	Completion Percentage
All Blocks/All Facilities	335	232	69%	217	65%
Northside/Southside	19	16	84%	16	84%
Northside	73	39	53%	37	51%
Southside	243	177	73%	164	67%

Future Battery Technology

From the route and block analysis data generated from PEER, the energy required to complete each block was calculated. Using these results, the minimum theoretical battery capacity needed to achieve 100 percent completion on all blocks was calculated. The results are shown in Table 5-3 and Table 5-4.

Table 5-3: Battery Capacity Needed for 100 Percent Block Completion – With DFH

Bus Type	Modeled Battey Capacity (kWh)	Battery Capacity Needed for 100% Completion (kWh)	
		New Battery	Seasoned Battey
35-foot BEB	440	874	1,092
40-foot BEB	518	914	1,142

Table 5-4: Battery Capacity Needed for 100 Percent Block Completion – Without DFH

Bus Type	Modeled Battey Capacity (kWh)	Battery Capacity Needed for 100% Completion (kWh)	
		New Battery	Seasoned Battey
35-foot BEB	440	960	1,200
40-foot BEB	518	1,000	1,250

As shown in table 5-3, 100 percent of HRT's 2019 service blocks can be completed with battery capacity reaching 1,142 kWh even with a seasoned battery on a 40-foot bus. This number increases to 1,250 kWh when a DFH is not used. These capacities represent the amount of energy required for the most energy intensive block in the schedule. These capacities are achievable but may take considerable time before they become available for commercial purposes. Smaller capacities can be used to complete 100% of HRTs service, but longer, and more energy intensive blocks would need to be split into smaller ones what would be serviced by more vehicles.

The energy values for each block were also used to determine block completion based on a range of theoretical battery capacities. This analysis was done on all blocks, assuming winter conditions.

Energy Consumption

Table 5-5 and Table 5-6 show the minimum, average, and max energy consumption of each bus type on all blocks from all facilities when the buses are operated in winter.

Table 5-5: All Facility Energy Consumption at Winter, With DFH-Equipped BEBs

Block Group	Bus Type	Minimum Energy Consumption (kWh/mi)	Average Energy Consumption (kWh/mi)	Maximum Energy Consumption (kWh/mi)
Northside/ Southside	35-foot	1.88	2.26	2.36
	40-foot	2.00	2.38	2.48
Northside	35-foot	1.79	2.60	3.31
	40-foot	1.92	2.73	3.45
Southside	35-foot	2.01	2.76	3.65
	40-foot	2.13	2.89	3.79

Table 5-6: All Facility Energy Consumption at Winter, Without DFH-Equipped BEBs

Block Group	Bus Type	Minimum Energy Consumption (kWh/mi)	Average Energy Consumption (kWh/mi)	Maximum Energy Consumption (kWh/mi)
Northside/ Southside	35-foot	2.01	2.45	2.56
	40-foot	2.13	2.57	2.68
Northside	35-foot	1.90	2.83	3.67
	40-foot	2.04	2.96	3.80
Southside	35-foot	2.17	3.02	4.06
	40-foot	2.29	3.15	4.20

In general, the smaller the bus, the less energy it uses per mile. However, this can be misleading because it does not ensure that the smaller bus will go farther. Since the 35-foot bus has a significantly smaller battery, the 40-foot bus will usually have a longer range.

Total Energy Requirements

Table 5-7, Table 5-8, Table 5-9, and Table 5-10 show the total energy requirements to complete HRT's 2019 block schedule during winter, spring and summer. The "Block Energy from Facility" column represents the amount of energy required to charge the buses at the facility for every block. As noted in the previous sections, some blocks require more energy than today's batteries can store. The tables below describe the additional energy required daily from other non-maintenance facility locations (in-route chargers) to complete all of HRT's blocks. The energy needed from the in-route chargers is displayed in "Block Energy from Elsewhere" column. As battery technology improves, the amount of energy required by in-route chargers will decrease and eventually become zero. In that case, the energy required at the facility will increase by the amount found in the "Energy from Elsewhere" column. The actual energy required at the facility will depend on the number of electric buses acquired and the number of blocks they are completing daily.

Table 5-7: Energy Requirements for Each Facility for 40-foot Bus in Winter – Without DFH

Block Group	Block Energy from Facility [kWh]	Block Energy from Elsewhere [kWh]	Total Block Energy Required [kWh]	Number of Blocks	Blocks Completable	Completion Percentage
Northside/Southside	3,823	384	4,207	19	18	90%
Northside	20,900	4,101	25,001	73	47	64%
Southside	55,300	3,462	58,762	243	207	85%
All	80,022	7,947	87,969	335	271	81%

Table 5-8: Energy Requirements for Each Facility for 40-foot Bus in Winter – With DFH

Block Group	Block Energy from Facility [kWh]	Block Energy from Elsewhere [kWh]	Total Block Energy Required [kWh]	Number of Blocks	Blocks Completable	Completion Percentage
Northside/Southside	3,607	294	3,901	19	18	90%
Northside	20,047	2,877	22,924	73	48	67%
Southside	51,715	2,084	53,799	243	216	89%
All	75,369	5,256	80,625	335	282	84%

Table 5-9: Energy Requirements for Each Facility for 40-foot Bus in Spring

Block Group	Block Energy from Facility [kWh]	Block Energy from Elsewhere [kWh]	Total Block Energy Required [kWh]	Number of Blocks	Blocks Completable	Completion Percentage
Northside/Southside	3,069	152	3,221	19	18	95%
Northside	17,518	792	18,310	73	61	84%
Southside	42,403	367	42,770	243	237	98%
All	62,991	1,311	64,302	335	316	94%

Table 5-10: Energy Requirements for Each Facility for 40-foot Bus in Summer

Block Group	Block Energy from Facility [kWh]	Block Energy from Elsewhere [kWh]	Total Block Energy Required [kWh]	Number of Blocks	Blocks Completable	Completion Percentage
Northside/Southside	3,192	179	3,371	19	18	95%
Northside	18,106	1,137	19,243	73	58	79%
Southside	44,497	534	45,031	243	233	96%
All	65,795	1,850	67,645	335	309	92%

Model Recommendations

In summary the transition strategy recommendation is:

1. Sequence the procurement of BEBs over several years to match blocks that can be completed with current technology, in anticipation of future technology that will allow for most, if not all, blocks to be completed. This approach can also be used to reduce or even eliminate the need for in-route charging. Coordinating the Fleet Replacement Plan with charging infrastructure installation based on the PEER results will allow the agency to take advantage of the time required to install charging infrastructure prior to BEB deliveries. As the infrastructure and fleet installation/delivery continues, energy density increases will be experienced allowing additional blocks to be completable until 100 percent fleet electrification is achieved.
2. Combine separate blocks for buses that return to the facility with significant SOC remaining. Mid-day charging could also be done to combine even more blocks together. However, this may

increase operating costs due to higher “peak” or “demand” electricity costs during the mid-day hours.

3. Adjust or split longer blocks, particularly within the longer blocks deploying from Hampton, since many of the blocks from this facility are unable to be completed, even with a 54 percent increase in battery capacity from future battery technology.
4. Investigate the feasibility and planning for the addition of in-route chargers on selected routes included within longer blocks. Carefully analyze the range extension needed and the time periods available for in-route charging opportunities with consideration for available HRT property. For these longer blocks, complete another similar block analysis but with specific in-route charging locations taken into consideration.
5. Install a charge management system to optimize the facility charging requirements and minimize (or eliminate) peak power demand.

Other Considerations

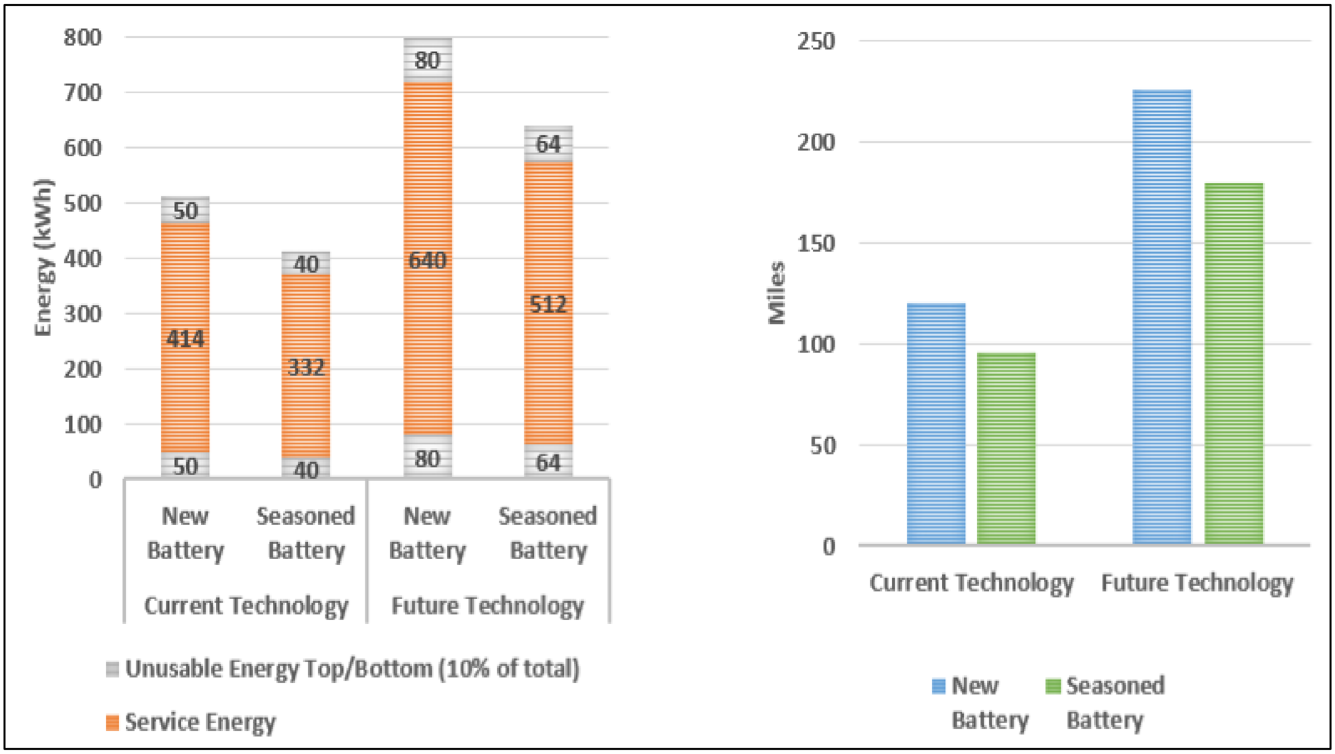
The PEER analysis simulation was conducted using 2019 General Transit Feed Specification (GTFS) data. Results from the PEER simulation may differ when analyzing more recent GTFS data.

6 Technology Portfolio

Batteries and BEB Manufacturers

The technology and market products available in the BEB industry are rapidly changing, as is battery efficiency. For the purposes of this transition plan and based on anticipated market products, HRT assumes the performance of new batteries with a battery capacity of 518 kWh and a service energy of 414 kWh will be utilized. The level of service energy is based upon maintaining a minimum SOC of 20 percent. Service energy for a seasoned battery is further reduced by 20 percent to 332 kWh, as shown in Figure 6-1. Estimated degradation of 20 percent is contingent upon the number of re-charging cycles and the level of battery discharge typically occurring.

Figure 6-1: Current and Future Battery Power



Notes: Future advancements in energy density will result in an annual ~5 percent increase. A seasoned battery faces a 20 percent performance reduction over 5 to 7 years. Average miles are an approximate number and is impacted by real world conditions including temperature, passenger load, route elevation, etc. Conventional diesel buses generally allow for 300-mile trips before needing to re-fill. Based on available BEB market products, BEBs are expected to travel for approximately 150 miles before requiring re-charging, depending on route conditions. Numbers in the Figure are approximations.

Bus manufacturers who may support HRT's transition plan include New Flyer, Proterra, and Gillig. BEB market products are currently expected to require approximately 20 months from order to delivery, though these durations would be affected by COVID-19 related supply chain impacts, and changes in nationwide BEB demand.

BEB Warranties

The cost of purchasing and maintaining BEBs will also be affected by the use of battery warranties. Factors such as the average SOC can affect the longevity of a battery's life. Therefore, the operations and standards used by transit agencies can affect battery life, and the life span of two batteries of the same type may not be the same, depending on how the buses are operated.

Batteries are one of the most expensive components of a BEB. A new battery, based on market products available today, can cost up to $200,000. A battery warranty from the BEB manufacturer can cost approximately $35,000 - $40,000 per year across a 12-year warranty, but batteries are likely to need replacement prior to the completion of a 12-year cycle. As a result, HRT will need to determine whether battery warranties are appropriate for its transition plan and revise its capital and operating costs accordingly.

Infrastructure Concerns

While the pilot program has already begun transitioning the fleet to BEBs, transitioning the entire fleet to BEBs will require careful planning. Specific infrastructure concerns related to BEB infrastructure when transitioning to a large-scale BEB fleet are described below.

BEB Infrastructure

BEB infrastructure will require significant power supply as well as space to accommodate charging equipment. A possible solution to space requirements is to redesign existing bus yards to hold additional required equipment.

Utility Provider

Dominion Energy is currently assisting HRT in providing energy requirements for the pilot program. Dominion Energy is also assisting with wind energy for the new Southside facility; there is a potential partnership to utilize Dominion offshore wind energy to partially power the facility and electric buses with wind energy for the new Southside facility. There is also a potential opportunity to negotiate fixed demand charges.

Dominion Energy's Smart Charging Infrastructure Pilot (SCIP) Program supports EV adoption in Virginia and will inform the design of managed charging programs and other EV customer offerings in the future. The SCIP Program provides rebates for qualifying EV charging stations, charging infrastructure and installation, commonly referred to as "make-ready," and network fees.

Dominion Energy has been cooperative with HRT throughout the electric bus pilot program and development of existing HRT facilities. HRT anticipates a productive partnership with Dominion Energy throughout the transition plan process.

7 Current Fleet and Future Acquisitions

Current Bus Fleet

The following sections summarize the revenue fleet by mode and the non-revenue fleet by type. The FY 2017 Capital Improvement Plan provides an in-depth fleet asset management plan, with a detailed schedule for replacement, expansion, overhaul and rebuild for each vehicle within the fleet.

Revenue Fleet

The HRT fixed-route bus fleet consisted of 281 vehicles, including 264 diesel buses, 11 hybrid buses, and 6 BEBs. Ninety percent of the fleet, or 253 total buses, were manufactured by Gillig. The HRT fleet also includes 10 Optima buses, 7 Nova buses, and 15 Hometown Trolley buses. Hometown Trolley buses are only operated on VB Wave routes, which operate during summer months. Aside from the trolley-style buses, the remainder of HRT's fleet is standard buses that range in length from 29-foot to 40-foot. HRT has no articulated buses or over-the-road coaches. In addition to the buses listed above, HRT has 3 ferries, 9 light rail transit vehicles, and 108 paratransit vehicles. Of its paratransit vehicles, HRT owns a total of 79 paratransit vans, including 76 cutaway vans and 3 vans, and leases an additional 29 sedans through MV Transportation. Regardless of ownership, all paratransit vehicles are operated by MV Transportation. HRT does not own the vehicles used in its vanpool program. Instead, vanpool drivers use a van leased from a third-party or one that they themselves own. Vanpool drivers are also responsible for vehicle maintenance.

HRT is in the process of purchasing new diesel and hybrid buses for service expansion. These new buses are each expected to have a 12-year useful life. The procurement schedule for these new non-BEB buses are as follows:

- 2022 – 24 new 40-foot diesel buses to serve Hampton
- 2023 – 12 new 40-foot diesel buses to serve Norfolk
- 2024 – 12 new 40-foot hybrid to serve Norfolk and Virginia Beach

As a result, by 2024, HRT will have 329 buses.

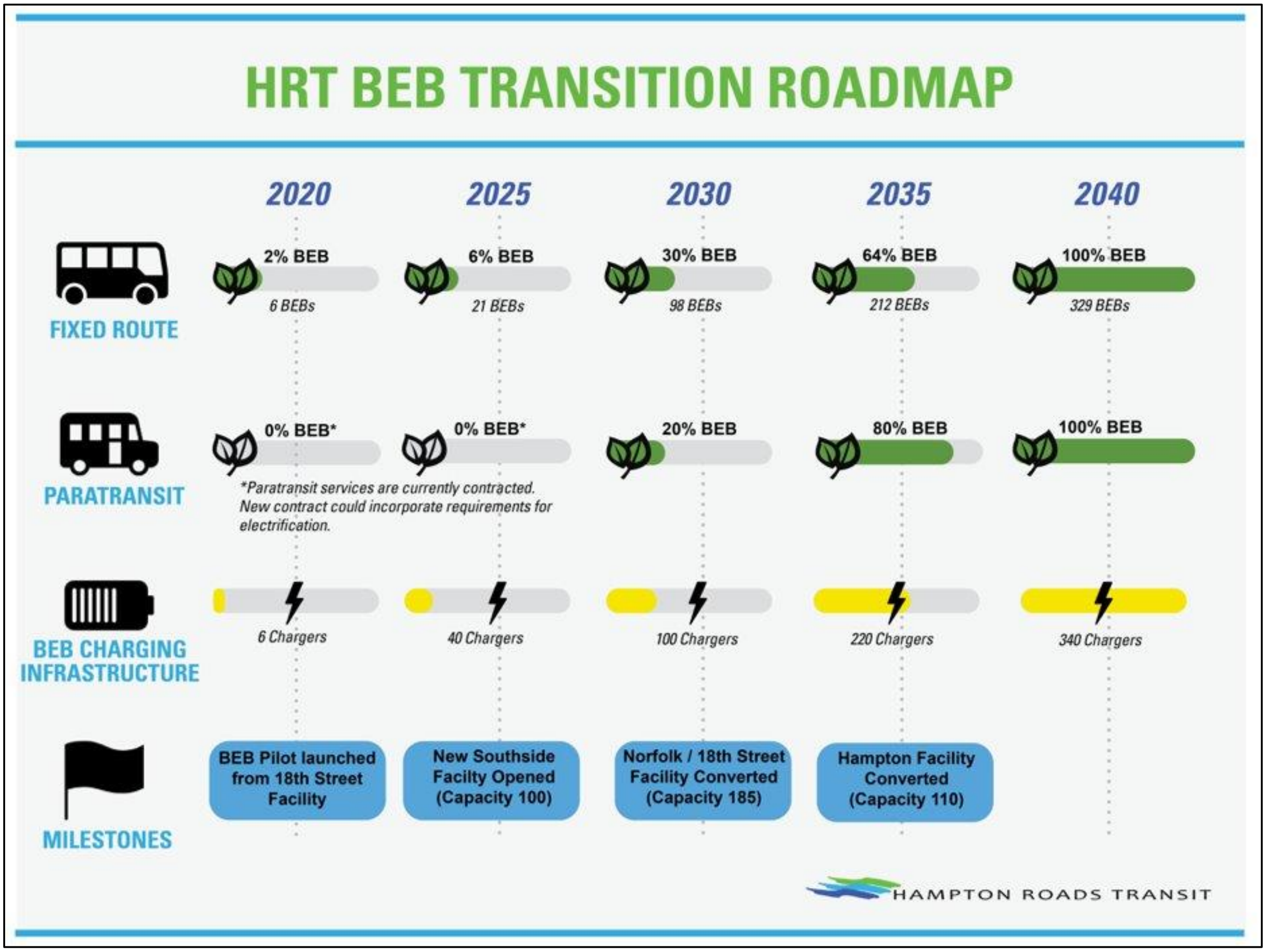
Non-Revenue Fleet

HRT's non-revenue fleet consists of sedans, vans, SUVs, pick-up trucks, special purpose vehicles, and non-revenue buses that are used as system support vehicles by HRT's administrative and maintenance staff. In total, there are 134 non-revenue vehicles employed by HRT for purposes that range from revenue vehicle maintenance to facility upkeep to sedans driven by upper management.

BEB Transition Roadmap

A comprehensive BEB transition roadmap is displayed in Figure 7-1. Under the current proposal, by 2030, 30 percent of the fixed route bus fleet will be BEBs, 64 percent by 2035, and 100 percent by 2040. In the paratransit fleet, 20 percent will be BEBs by 2030, 80 percent by 2035, and 100 percent by 2040. This roadmap is also predicated on the milestones listed on the bottom of the figure, including facility conversions and opening dates. These targets are predicated on the assumption that HRT receives necessary federal funding and grants.

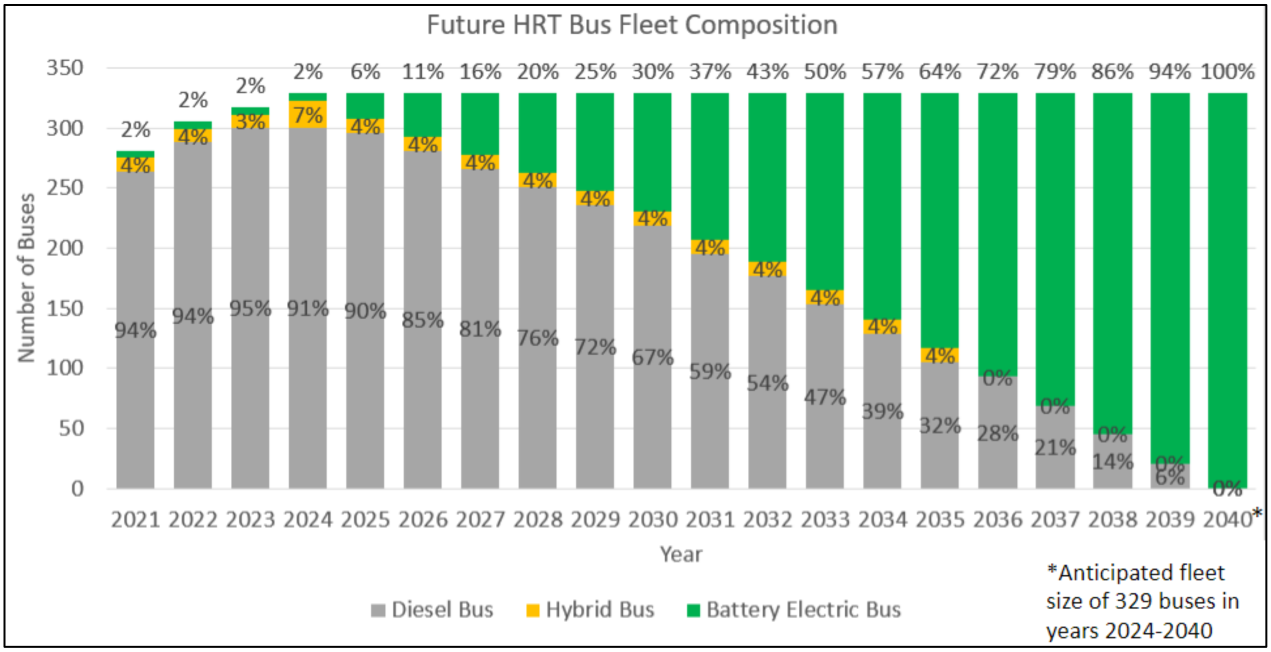
Figure 7-1: HRT BEB Transition Roadmap



Bus Replacement Schedule over 20-year Period

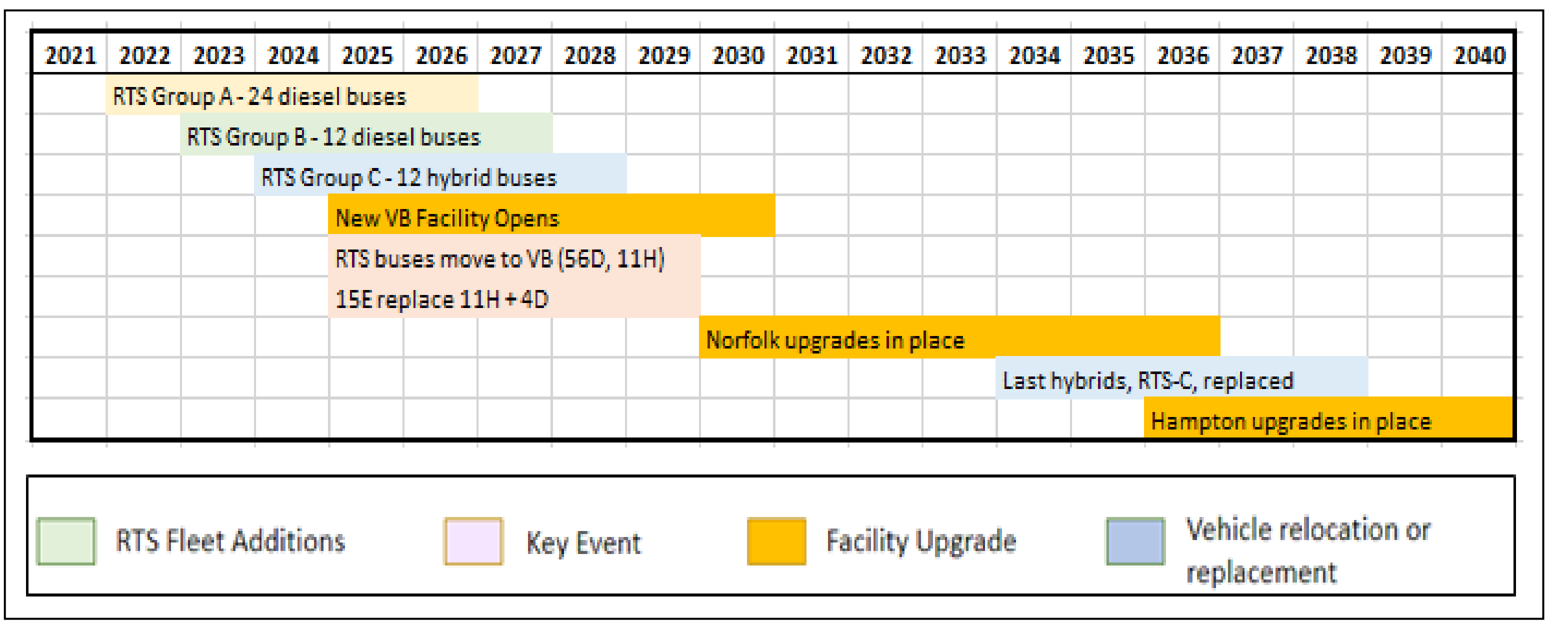
A detailed layout of HRT's fleet conversion to 100 percent BEBs is displayed in Figure 7-2. The proposed bus replacement schedule will be conducted over a 20-year period. To meet a 100 percent BEB fleet by 2040 goal, at least 329 BEBs will need to be purchased at a pace of about 20 buses per year (from 2025 through 2040, plus an extra bus in one of those years). The New Southside Facility is planned to open in 2026 with the Norfolk facility converting afterwards in 2030 and the Hampton Facility converting last in 2035.

Figure 7-2: Future HRT Bus Fleet Composition



This schedule was developed using the assumptions shown in Figure 7-3. These assumptions include RTS fleet additions, key events, facility upgrades, and vehicle relocations or replacements. If the timeline of these assumptions differs from the current plan, the overall fleet transition plan may need to adapt.

Figure 7-3: HRT Fleet Transition Assumptions



Past and Future BEB Feet Procurements

As mentioned in Section 3, HRT's began piloting BEBs in its fleet in December 2020. Six electric buses were deployed initially on Route 20, the busiest route in the Commonwealth. HRT plans to procure more BEBs starting in 2025 or sooner as federal dollars are made available to assist with the transition. HRT is looking to complete 100 percent BEB conversion of its fleet by 2040.

BEBs and Batteries Cost Estimates

The current cost estimates for a 40-foot BEB is estimated to be $1,000,000. The Hampton facility is planning to purchase 107 BEBs which will be installed over a period of 5 years from 2036 to 2040. The estimated total BEB cost at the Hampton facility is $147,300,000. The estimated total BEB cost at the Norfolk/18th Street facility, with 141 BEBs over a 7-year acquisition period from 2030-2036, is $167,900,000 and at the New Southside Facility, with 81 BEBs over the span of six years from 2025-2030, is $89,800,000. Each BEB has an average lifespan of 12 years, which will require the replacement of some BEB procurements over the transition period. 6 BEBs will need to be replaced from the Norfolk/18th Street Facility and 60 will need to be replaced from the new Southside Facility.

Figure 7-1 provides a summary of the BEB cost estimates per facility, including the installation periods. A more in-depth cost spreadsheet is in Appendix B.

Table 7-1: BEB Cost Estimates Per Facility

Facility Name	Number of BEBs Purchased	Replacement BEB Procurements	Installation Time Period	Estimated Cost ($)
Hampton Facility	107	0	2036-2040	$152,450,000
Norfolk/18th Street Facility	141	6	2030-2036	$181,340,000
New Southside Facility	81	60	2025-2030	$179,070,000
Total	**329**	**66**	**15 years**	**$512,860,000**

8 Facilities and Infrastructure Modifications

Facility Upgrades

HRT's transition to BEB technology will require several modifications and changes to existing infrastructure and operations. This would include the eventual decommissioning of diesel equipment, enhancements to and expansions of electrical equipment, additional electrical supply, and the installation of BEB chargers, dispensers, and other components. The HRT BEB Transition Roadmap (Figure 7-1) details a timeline of expected BEB charging equipment. The expected schedule includes 40 chargers by 2025, 100 by 2030, 220 by 2035, and 340 by 2040 to accommodate HRT's BEB fleet.

Table 8-1 provides an overview of the existing and future HRT facilities which would be outfitted with electrical infrastructure to support BEB vehicles.

Table 8-1: Existing and Future Bus Facilities Summary

Facility Name	Address	Main Functions	Fuel Type	Total Buses	Requires Upgrades
Northside Facility	3400 Victoria Boulevard, Hampton, VA 23661	O&M	Diesel CNG	126 buses	Yes
Southside Facility	509 East 18th Street, Norfolk, VA 23504	O&M	Diesel, Electric	146 buses and 14 trolleys	Yes No[1]
Virginia Beach Trolley Facility*	1400 Parks Avenue, Virginia Beach, VA, 23451	O&M	Diesel		No, will be decommissioned once New Southside Facility is built
New Southside Facility*	Corporate Landing Parkway, Virginia Beach, VA, 23454	O&M	Diesel, Electric	100 buses and 15 trolleys	Will be operational in 2026 to accommodate electric fleet (level of electrification will depend on awarded federal money)

Notes: *New Southside Facility planned at Corporate Landing Parkway to be operational in early 2026. [1] The New Southside facility is under construction and assumed to be built out with pending grant funds to a degree where all buses hosted in the facility would have electric chargers upon opening day. In this scenario, no further electric charging infrastructure would be required on-site. If the grant funds are not awarded, the New Southside facility would require further upgrades after it opens to accommodate electric charging infrastructure.

In-Route Charging

HRT is not precluding the possibility of implementing in-route charging to supplement electric charging equipment at its maintenance facilities. In-route charging can help maintain appropriate state of charge on BEBs while carrying out revenue operations, as well as assist in spreading the power demand of the bus fleet away from maintenance facilities, thereby reducing the total power demand per facility.

In-route charging infrastructure generally includes pantographs, charging cabinets, gantries to support pantographs, and similar improvements. There are other technologies such as induction charging as well.

Best practices related to installation of in-route charging include choosing locations with space owned or managed by HRT and generally away from the street (such as transit centers or terminals), where operators currently have layovers, providing built-in time for charging with minimal effects to route operations. Additionally, it is best practice to choose locations along routes that are unlikely to change from network redesigns, because of the cost of relocating in-route charging infrastructure once installed.

Cost Estimates

Necessary improvements for the electrification of facility infrastructure and maintenance include the electrification of maintenance bays, electrification of bus parking lots, and charging equipment. The added estimated costs of necessary equipment are included in Table 8-2 and a detailed list of specific equipment required per facility is included in Appendix B.

Table 8-2: Facility Electrification Infrastructure Estimated Costs

Facility	Number of Buses	Number of Parking Stalls	Year of Expenditure Dollars
Hampton Facility	107	111	$54,888,000
Norfolk/18th Street Facility	141	146	$39,387,000
New Southside Facility	81	115	$35,992,000
Total	**329**	**372**	**$130,267,000**

Construction Implementation

HRT will consider all health and safety concerns, required permits, infrastructure construction (i.e., site and building construction) and traffic management considerations associated with facility construction efforts.

The engineer of record for the construction will ensure compliance with all applicable codes and regulations.

During the construction phase, the equipment supplier and design firm will be included to identify any potential solutions and approve design changes.

Additionally, HRT will ensure that all fueling infrastructure is to be installed and functional before any buses are delivered to preserve the ability to test and utilize buses.

Charging Logistics

Charging equipment will be installed in advance of all BEB deliveries. Plug-in chargers will be used inside maintenance facilities and the existing plug-in chargers acquired in HRT's bus electrification pilot program will also be utilized. All other charging equipment is anticipated to be pantograph chargers.

Pantograph charging equipment will be installed in each facility. The number of pantograph chargers will exceed the proposed BEB fleet size to allow for future growth and acquisitions. A summary of proposed pantograph charger installations by facility is displayed in Table 8-3.

Table 8-3: Proposed Number of Pantograph Chargers by Facility

Facility	Number of Pantographs
Hampton Facility	111
Norfolk/18th Street Facility	146
New Southside Facility	115
Total	**372**

Maintenance Needs

While reduced fuel costs are the key financial benefit of electrification, reduced maintenance costs are a close second. BEB propulsion systems utilize much simpler propulsion systems with fewer moving parts that require less frequent service intervals. The baseline conventional bus preventive maintenance interval employed by HRT is 6,000 miles which is predominantly driven by engine oil service requirements. Depending on the bus OEM and specific subcomponent supplier requirements, recommended baseline BEB service intervals are generally pushed out from 6,000 miles to 15-20,000 miles. Although BEBs have some fluid and filter replacements that are comparable to conventional diesel bus requirements, they do not require fuel filters, engine air filters, or crankcase filter replacements. The majority of BEBs available in the marketplace also use a direct-drive traction motor arrangement, which removes the need for transmission, and the fluid, filters, and costly rebuilds associated with maintaining that component. BEBs also utilize regenerative braking to increase efficiency of operation, resulting in a significant reduction of brake wear as compared to conventional buses. Factoring in these key differences in vehicle equipment and associated maintenance requirements, industry experience has shown that maintenance costs for supporting BEBs can be reduced by as much as 40 percent when compared to conventional buses.

Maintenance Cost Estimates

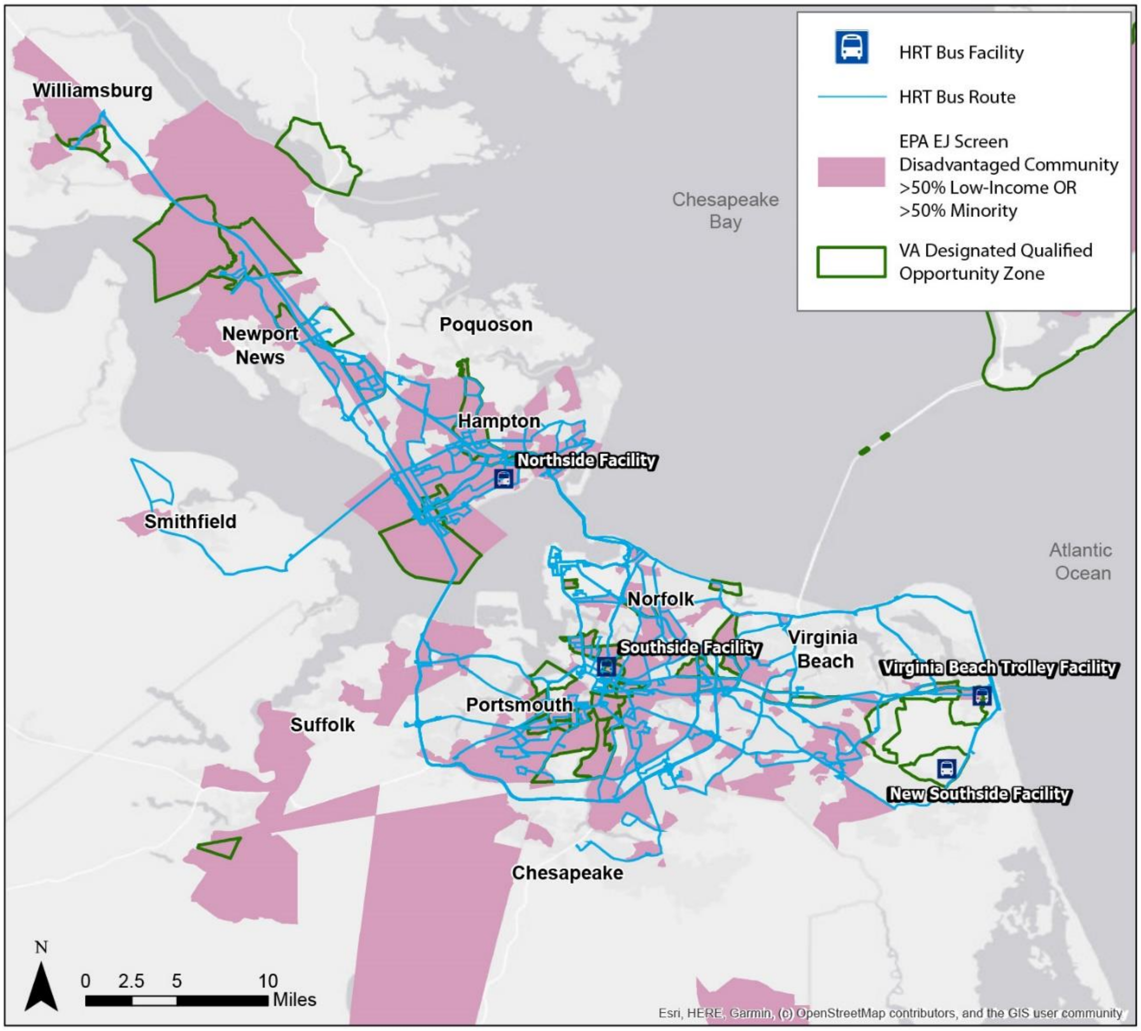
Based on HRT's operating data from 2019 (prior to any service impacts from COVID-19) available in the FTA National Transit Database, conventional bus maintenance cost is calculated at $1.42 per revenue mile. Whereas total Vehicle Maintenance costs in 2019 were reported at $14.9 million, for a comparable fleet of BEBs requiring less frequent servicing with fewer fluids and consumable items, and longer brake life through regenerative braking, maintenance costs are estimated to be reduced to approximately $9 million, annually. Over time, the reduced maintenance requirements of a BEB fleet are expected to significantly offset the large infrastructure expenditures that will be required throughout HRT's transition to electrification.

9 Service to Disadvantaged Communities

The Hampton, existing Norfolk/18th Street, and Virginia Beach Trolley facilities are either directly in, or immediately adjacent to, disadvantaged communities, while the planned new Southside facility is in an opportunity zone and will be in within a 3 mile radius of disadvantaged communities. This transition plan identifies disadvantaged communities as those where 50 percent or more of households are low-income, or where 50 percent or more of households consist of minority population. The conversion of existing ICE operations to BEB operations will directly benefit the communities in the vicinity of these divisions by way of a reduction in noise and emissions.

To locate disadvantaged communities, indicators, such as areas where at least 50 percent of the population earn low incomes and 50 percent or more of the population identify as minorities, are identified using the Environmental Protection Agency's EJSCREEN tool at the Census Tract level. Based upon these indicators, HRT serves 153 low-income Census Tracts and 428 minority Census Tracts. Excluding trolley routes, all HRT bus routes pass through disadvantaged communities at least once during service. Figure 9-1 highlights the location of disadvantaged communities in the HRT service area.

Figure 9-1 Disadvantaged Communities in Hampton Roads Region



Source: EPA, 2022, State of Virginia, 2022

Once facilities are electrified, BEBs can be prioritized for routes which primarily service disadvantaged communities. Though all HRT bus routes pass through disadvantaged communities, not all routes pass through equal lengths or densities of disadvantaged communities, so there remains a framework for route transition prioritization.

Residents of disadvantaged communities are generally among the most vulnerable populations. They often rely on public transit, are more likely to be impoverished, and are more frequently exposed to harmful emissions and pollutants that result in negative health outcomes. Implementing BEB service in disadvantaged communities is an opportunity for HRT to contribute to local and regional equity.

10 Workforce Training

To operate a zero-emission bus system, HRT is deploying training to how to manage, operate and maintain the new technology. HRT is focusing on training current transit employees and stakeholders by providing them with skills that will support job retention for years to come.

Workforce Development Plan

Training is required with all new and updated equipment that utilizes new technology. It is critical that HRT provides a workforce development program that equips all staff members with the necessary skills to properly use all new technology, including diagnostic software support. To achieve this goal, HRT will identify skills and credential gaps to generate long-term support and seeks to invest in a workforce development plan that will be necessary to deploy this long-term transition successfully. During the pilot program, a workforce development plan is provided by Proterra on-site. Future workforce development programs will be administered by manufacturers based on corresponding BEBs.

A detailed overview of each workforce development plan is listed below. Each plan are developed following the FTA's workforce evaluation tool.

Required Training for Proposed Fleet

The following provides a list of personnel and positions that will need to be retrained upon further adoption of BEBs (this list is not exhaustive):

Bus Operators

Bus operators will need to be familiarized with the BEBs, safety, bus operations, and charging operations. BEB operators should be trained on how to understand and use readings such as battery SOC, remaining operating time, estimated range, and other system notifications that may occur during operation. Operators should confirm with the OEM how SOC will be reported in monitoring services to ensure adequate charging for services. The FTA recommends training on concepts, working principles, and details of regenerative braking (specifically the differences between regenerative braking and conventional braking), mechanical braking, hill holding, and roll back.

Facilities Maintenance Staff and Maintenance

Facilities staff will need to be familiarized with scheduled and unscheduled repairs, high-voltage systems, and the specific maintenance and repair of equipment.

Emergency Service Providers and First Responders

HRT's Department of Security and Emergency Preparedness maintains partnerships with Public Safety and Emergency Management partners in its member cities. HRT's Emergency Management Specialist coordinates regularly with Directors of Emergency Preparedness and Response and Fire Marshall. These relationships include hazards-based communications to discuss events (planned or unplanned) that may impact HRT as a critical infrastructure entity operating within the region's cities. HRT's Emergency Management Specialist is actively invited to participate as a Liaison Officer (LNO) with multiple Preparedness and Response entities in the region, HRT's Department participates in table-top as well as full-scale exercises for emergency conditions and engages Public Safety and Emergency Management partners in joint-response to incidents where HRT is either directly or indirectly impacted. These partnerships will become increasingly important as HRT transitions to a BEB fleet.

Tow Truck Service Providers
Tow truck providers will need to be familiarized with the new buses and proper procedures for towing BEBs.

Body Repairers
Body repairers will need to be familiarized with the safety-related features and other components of BEBs.

Instructors
For both bus operations instruction and maintenance, instructors will need to understand all aspects of BEBs to train others.

Service Attendants
Service attendants will become familiarized with proper charging and servicing protocols and procedures that are BEB-specific.

Management Staff
All management staff (supervisors, directors, etc.) will be familiarized with BEB operations and safety procedures.

Current Skills and Impacted Employees
Training has already begun through HRT's pilot BEB program. Additionally, because HRT operates light rail, an inhouse workforce currently exists with experience with electric vehicles. This group, and the operators going through training in the pilot BEB program, are well-positioned to assist in the transition of HRT's current maintenance workforce.

Proterra currently trains HRT's existing workforce on operations and maintenance protocols for Proterra buses and sub-system. This has worked well for HRT's fleet of Proterra buses. Going forward, HRT will partner with vocational schools (e.g., Tidewater Tech and Automotive Technology Institute) to conduct classroom workshops to make sure its workforce is trained specifically on electrical and electronic technology. This will allow HRT's workforce to be able to maintain the electrical fleet regardless of the bus manufacturer.

Skill Gaps Mitigation Strategy
HRT will assess and identify the skills gaps of the existing workforce using each individual employees Position Qualification Standard (PQS). Approximately 10 percent of existing employees may be impacted by the transition to BEBs as a result of new skills requirements. In tandem with the transition to a 100 percent BEB fleet by 2040, HRT is developing a roadmap to transition its current workforce to prepare to service an all-electric fleet. This roadmap includes working with existing partners, such local vocational schools Tidewater Tech and Automotive Technology Institute. HRT will also utilize classroom training sessions, equipped with simulators to train employees on BEB operations.

Training Program Partners
The transition to BEBs will alter HRT's service and operations. Converting to BEBs from diesel is an arduous endeavor and will impact all ranks of the organization. This will require extensive change for management and training, some of which will be provided by the original equipment manufacturer (OEM) and others by HRT and outside organizations. HRT is committed to retaining and training current staff. HRT bus operators and mechanics are represented through the Amalgamated Transit Union, Local 1177 (ATU

1177). ATU 1177 represents roughly 600 HRT employees and HRT is committed to working with ATU 1177 to ensure all employees experience a smooth transition to a BEB fleet.

Training for New Hires and Steps to Avoid Workplace Displacement

Training resources will be supporting the recruitment, training, and development of new workers. These resources include a pre-employment assessment. This assessment will be used to identify and create a training plan for each individual and his or her identified skill gaps. These same assessments will be given to the existing workforce to ensure non-displacement. In addition, the vocational schools mentioned above will also be utilized to develop any skills needed for existing employees.

Workforce Engagement in Transition Planning

To avoid displacement, measures were taken to encourage workforce engagement in the transition planning process. These steps include:

- Encouragement of collaboration from the current workforce to establish commitment and buy-in.
- Utilization of existing employees as the basis of new employee training methods.
- Inclusion of existing workforce in pilot program for BEB training.

Current workers will be consulted in finalizing any plans and training to meet the needs of this transition.

Funding for Training

HRT is applying for funding to support training efforts through workforce development grants. In addition, at least 5 percent of the project budget for the transition will be allocated to workforce development training initiatives.

Other Initiatives

Through its innovative Drive Now Program, HRT partners with local cities, Tidewater Community College, Automotive Technology Institute, and other technical and vocational institutions to offer a helping hand to urban residents who require additional workplace readiness training. The main goal of this program is to provide Commercial Driver's License training, customer service and workplace skills, and professional appearance enhancement opportunities. HRT's Drive Now Program is designed to help participants achieve self-sufficiency through education to support the development of work skills and experience. Further, participants in this program have increased job readiness and skills to aid in supporting families to achieve economic independence.

HRT has implemented local hiring agreements to invest in the Hampton Roads area and provide employment opportunities to citizens. Additionally, HRT offers apprenticeship programs with local technical colleges including Advance Technical Institute (ATI) to develop well-trained employees and skilled mechanics.

Other opportunities HRT currently offers its employees include:

- Leadership Education and Development Program (LEAD), which offers HRT employees development and leadership training opportunities not offered through typically assigned training
- GoSkills, offering over 90 classes
- Online University, providing over 340 classes with certificates upon class completion

Additionally, HRT developed the Diversity Committee, which aims to work collaboratively to help establish a supportive and welcoming workplace environment in which employees of all backgrounds and demographic characteristics can work together. As a transit agency, the Diversity Committee provides equitable access to public transportation. The goals of the Diversity Committee include:

- Relating diversity and inclusion to HRT's mission, vision, and values.
- Outlining key diversity and including goals and actionable steps to achieve them for employees, customers, and our community.
- Helping institutionalize policies that support equity for all employees and customers.
- Focusing workforce recruitment and promotion/retention.

The Diversity Committee evaluates the effectiveness of ongoing efforts and adapt as needed. The BEB transition's delivery and implementation will create good-paying jobs with free and fair choice to join a union, such as ATU 1177. The implementation will provide greater access to jobs (upwards of 312,000 jobs, as described in section New Southside Bus Operating Division Facility), thereby creating more opportunities for income advancement. Additionally, as the popularity of BEB fleets increases among transit agencies, the retraining efforts of current employees regarding BEB operations will equip them with advanced skillsets that sets them apart from their counterparts.

11 Capital Improvement Plan

HRT's Capital Improvement Plan (CIP) (December 2021) is a blueprint for future capital investments. The CIP outlines how HRT will fund the replacement and expansion of agency infrastructure, including BEB acquisitions. It covers a ten-year planning horizon and is updated annually. The FY2023-FY2032 CIP is focused on the investments required to both maintain and improve upon HRT's existing and RTS transit network. These are key updates and observations for this year's CIP:

- HRT's ten-year capital program totals $382 million, distributed across 61 projects.
- HRT consulted closely with the Virginia Department of Rail and Public Transportation (DRPT) so HRT can enhance project applications for potential state funding. DRPT's Making Efficient and Responsible Investments in Transit (MERIT) grant program is the largest source of capital funding in HRT's CIP. The agency has worked with DRPT to constrain its MERIT funding requests based on anticipated state resources and to gather state input on which types of projects and funding applications are most successful based on MERIT's competitive criteria.
- HRT plans to aggressively pursue available federal funding opportunities. This year's CIP includes placeholders for future federal discretionary funding. The bipartisan Infrastructure Investment and Jobs Act (IIJA) was passed and signed into law by President Biden shortly after the completion of this year's CIP funding program. The IIJA will open significant new potential discretionary funding sources for the agency, in addition to formula-based allocations. HRT's success in obtaining future federal grants may help offset the capital program's use of state, Hampton Roads Regional Transit Fund (HRRTF), and local dollars.
- The CIP includes 10 projects related to RTS implementation that support investments in technology, rolling stock, passenger facilities, bus stop amenities, and operating facilities. Between FY23 and FY32, HRT plans to allocate $81.5 million in funds to the RTS network; this amount is in addition to the $46 million in RTS funds allocated in FY2021 and FY2022.

While the CIP consists of 61 individual projects, a handful of major projects represent a large share of the agency's future capital needs. A detailed profile of major projects is presented in Chapter Four of the CIP, in the section entitled "Major Projects". These projects are:

- Parks Avenue Replacement: This project will replace the existing Parks Avenue bus storage and maintenance facility with a new southside garage and maintenance facility. The new facility will allow for year-round operations, something the current facility cannot handle. This new facility will allow maintenance work to be completed locally in Virginia Beach and accommodate the growing and changing HRT fleet. The project will require funding from a wide variety of sources and HRT is seeking a multi-year funding agreement from DRPT to support the project. The replacement facility is required in order to accommodate the expanded RTS fleet at HRT and to support electrification efforts to provide more efficient and frequent service.
- Fleet Investments: Bus replacement, repower, and expansion make up the largest share of HRT's capital budget. HRT is expanding service through the RTS program and will procure a total of 48 new buses by FY2025.
- Light Rail State of Good Repair: Light rail investments are the second largest investment category. HRT utilizes a separate planning effort to identify light rail capital needs over a 30-year horizon (FY2021-FY2050), which the CIP team relied upon to group State of Good Repair needs into a set of capital projects for the CIP. Over the next 10 years, HRT expects to fully fund all light rail state-of-good repair needs based on projected funding.
- Human Resource Management System (HRMS): The current software reached the end of its support in 2018, is outdated, and no longer meets agency needs. This project will replace the aging software with a new system.
- Bus Stop Amenity Program: As part of the implementation of RTS, HRT is upgrading over 600 stops with new passenger amenities such as shelters, seating, and lighting. This project represents the single largest investment in bus stop assets in the agency's history.
- Evelyn T Butts Transfer Center and Robert Hall Transfer Center: These two facilities, in Norfolk and Chesapeake respectively, are slated to be replaced with larger and higher-quality transfer centers as part of RTS implementation.

12 Funding Sources

There are several potential federal, state, and regional funding and financing sources at HRT's disposal. To date, HRT has applied for and been awarded three grants, two Federal and one state, for the pilot BEB program. A comprehensive list of all funding sources can be found below in Table 12-1.

State and Regional

The Virginia Department of Environmental Quality (VA DEQ) provides funding through the Clean Air Communities Program.

The Virginia Department of Rail and Public Transportation (DRPT) provides funding through the Making Efficient and Responsible Investments in Transit (MERIT) program.

The MERIT program also offers the Clean Transportation Voucher Program which provides grants to transit agencies to help offset the costs of transitioning and developing ZEB infrastructure. This program is funded by Virginia's portion of the Volkswagen Environmental Mitigation Trust, which has made funding available to all 50 states, Puerto Rico, and the District of Columbia for programs that focus on replacing transit vehicles.

Federal

Multiple funding programs are offered by the FTA to offset the costs of transitioning. These programs include the Metropolitan & Statewide Planning and Non-Metropolitan Transportation Planning program, the Urbanized Area Formula Grants, the State of Good Repair Grants, the Flexible Funding Program – Surface Transportation Block Grant Program, the Low and No Emissions Program, the Bus & Bus Facilities Competitive Program, and the Capital Investment Grants – New/Small Starts program.

The EPA offers the Environmental Justice Collaborative Program-Solving Cooperative Agreement Program and the Diesel Emissions Reduction Act (DERA) National Grants.

The FHWA provides the Congestion Mitigation and Air Quality Improvement Program.

The USDOT offers the RAISE Grant, a competitive grant that can cover the costs associated with infrastructure. USDOT also offers two other grants, the Charging and Fueling Infrastructure Competitive Grants and the National Electric Vehicle Formula Program.

The U.S. Department of Energy provides the Energy Infrastructure Federal Financial Assistance Program, Smart Grid Matching Grants, and the Carbon Dioxide Transportation Infrastructure and Innovation (CIFIA) Loan Program.

Other Sources

Innovative financing mechanisms can also be utilized, such as Charging as a Service (CaaS). This consists of turn-key project management services for the construction and installation of infrastructure and the deployment of smart charging. The company then owns, operates, and maintains the infrastructure and the transit operator typically pays the company per kWh or per mile (ex. Amply, Invenergy, In-Charge).

HRT's utility provider, Dominion Energy, offers a Smart Charging Infrastructure Pilot (SCIP) program. The SCIP program offers rebates for ZEV charging stations, charging infrastructure, and charging installation.

Table 12-1: Funding Opportunities

Agency	Name	Competitive	Vehicles	Infrastructure
	Federal			
FTA	Metropolitan & Statewide Planning and Non-Metropolitan Transportation Planning		X	X
	Urbanized Area Formula Grants (5307, 5339)		X	X
	State of Good Repair Grants		X	X
	Flexible Funding Program – Surface Transportation Block Grant Program			X
	Low and No Emissions Program	X	X	

Agency	Name	Competitive	Vehicles	Infrastructure
	Bus & Bus Facilities Competitive Program	X	X	X
	Capital Investment Grants – New/Small Starts	X		X
EPA	Environmental Justice Collaborative Program-Solving Cooperative Agreement Program	X	X	X
	Diesel Emissions Reduction Act (DERA) National Grants	X	X	
FHWA	Congestion Mitigation and Air Quality Improvement Program			
USDOT	Charging and Fueling Infrastructure Competitive Grants	X		X
	National Electric Vehicle Formula Program			X
	Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Grant	X		X
US Energy	Energy Infrastructure Federal Financial Assistance Program	X		X
	Smart Grid Matching Grants			X
	Carbon Dioxide Transportation Infrastructure and Innovation (CIFIA) Loan Program			X
		State		
VA DEQ	Clean Air Communities Program	X	X	
DRPT	Making Efficient and Responsible Investments in Transit (MERIT)	X	X	X
		Local/Regional		
Dominion Energy	Smart Charging Infrastructure Pilot (or "SCIP") Program			X

13 Start-up and Scale-up Challenges

HRT has identified several challenges and opportunities associated with purchasing and transitioning to BEB technology, including:

- **High vehicle capital costs**: While lifecycle costs may be lower with BEBs than ICE buses, initial capital costs are high due to BEB vehicle market price. HRT will need to ensure the transition to BEBs does not affect existing service. HRT will explore the option of leasing buses or batteries, both of which are options provided by BEB manufacturers, to determine best financial practices for capital and operations costs of a BEB fleet.
- **Procurement phasing/timing**: Transition to BEBs requires careful coordination across routes and facilities to ensure new BEBs can meet service and route requirements, including having charging infrastructure in place prior to receiving BEBs for service. BEB production demand is also rising, and HRT will need to work with manufacturers to ensure delivery schedule expectations are clear and worked into HRT bus fleet management.
- **Facility infrastructure constraints, cost and construction schedule**: Existing bus facilities must be upgraded with electric charging equipment for BEBs. The addition of pantographs, gantries, charging cabinets, and other equipment must be designed, accommodated, and built in structures which may or may not have been designed to accommodate such features. The capital cost of this construction must be understood and planned for, and its schedule closely coordinated with Dominion Energy and the HRT bus operations department.
- **Multi technology operations during transition**: Buses, which may currently be utilized flexibly across routes or housed at different facilities depending on operation's needs, will no longer be 'interchangeable" as the fleet transitions to BEBs. HRT will need to closely monitor which routes will utilize BEBs, where the home facility of those BEBs are located, and the availability of BEB and combustion engine bus parking as each facility undergoes upgrades, to ensure BEBs do not run out of charge while away from the facilities due to service changes, deadheading, or other operation's needs. Additionally, HRT staff will need to be trained in both conventional and BEB-supportive maintenance skills while the fleet is in transition.
- **Power demand management and uncertainty**: Currently, bus operation is tailored toward service needs (e.g. AM/PM peaks). With a BEB fleet, charging costs fluctuate throughout the day based on utility provider rates, with charging costs generally higher during high-demand periods. HRT will need to consider how to manage charging to reduce peak demands and utilize power cost-efficiently. This will require close coordination with Dominion Energy.
- **Utility company dependency & needed upgrades**: The availability, consistency, and expansion of power needs is dependent on Dominion Energy, which is the sole utility provider in the HRT service area. The ability of HRT to upgrade facilities with charging infrastructure and operate a BEB fleet is dependent on the ability of Dominion Energy to provide the necessary electrical connections and infrastructure required to maintain reliable BEB service. HRT may explore options to reduce dependency such as outfitting facilities with solar photovoltaic panels to generate on-site energy. HRT is currently exploring solar photovoltaic panels over vehicle parking stalls at the New Southside Facility.
- **Technological adaptation**: The BEB market is rapidly evolving. Today's projections are based on existing BEB vehicles and battery range available, which may be outdated in the near or mid-future. HRT will need to remain alert to changes in battery technology and BEB market products while looking to meet FTA or other grant deadlines.
- **IT Infrastructure cost/challenge**: BEBs have different software requirements and outputs and will need to be integrated into existing HRT information technology systems. This will involve new partnerships, new training, and new monitoring and evaluation processes.
- **Funding challenges**: HRT may not have sufficient funds from its existing budget to implement a BEB transition on its own and will likely seek grant opportunities where possible. Successful grant

applications may keep a transition on target but rejected grant applications may delay a fleet transition.

- **Resiliency and emergency response**: HRT will need to consider the different implications of running BEBs compared to combustion engine buses. This could include changes in service as a result of COVID-19, or whether there are different safety, hazards, or fire risks if a flood, hurricane, excessive heat, or other natural disaster impacts a facility with large amounts of electric charging equipment.
- **Training and outreach activities**: The existing workforce will likely need retraining to manage BEBs, while opportunities for a new generation of BEB technicians can provide outreach and economic development opportunities to the communities of the HRT service area. However, the availability of such a workforce will be a factor in the success of the transition.
- **PPP opportunities**: The emergency of public-private partnerships as an increasingly common way to provide infrastructure or services will be closely monitored to identify areas which can optimize service or lower costs of purchasing and maintaining a BEB fleet.

14 Next Steps

The process to transition to BEBs should and will be iterative to minimize risk, and to accommodate new developments in a rapidly evolving market. HRT will use the information outlined in this document to refine and determine the following:

- Address incomplete service blocks
- Refine costs
- Explore collaboration opportunities
- Engage utilities

This analysis is a living document. HRT will update the plan as the agency procures BEB technology, learns from the pilot program and current roll out strategy, and designs and builds the needed infrastructure.

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Appendix A - PEER Report

Appendix B - Facility Electrification Spreadsheet

[Facility Improvements] Hampton - 107 Buses; 111 Parking Stalls								
	Phase 1 - Electrify Maintenance Bays							
		Shop Charger	8	EA	50,000	400,000	2035	670,000
		Switchgear + Disconnects	8	EA	2,000	16,000	2035	30,000
		Overhead Crane	1	EA	25,000	25,000	2035	40,000
		High Voltage PPE	1	LS	5,000	5,000	2035	8,000
		High Voltage Diagnostic Too	2	SET	15,000	30,000	2035	50,000
		Tie in to Command Center	1	LS	10,000	10,000	2035	17,000
	Phase 1 - Electrify Bus Parking Lot - Initial Buildout							
		Bus Canopy	68,300	SF	100	6,830,000	2035	11,400,000
		Concrete Pads (Equip)	4,300	SF	10	43,000	2035	70,000
		Electrical Service (Site Conn	1	EA	16,000	16,000	2035	30,000
		Service Extension Allowance	1	LS		-	2029	-
		Switchgear Building	8000	SF	125	1,000,000	2035	1,700,000
		Medium Voltage Switchgear	1	LS	2,225,000	2,225,000	2035	3,700,000
		SCADA System	1	LS	100,000	100,000	2035	170,000
		Electrical Meter	1	EA	6,000	6,000	2035	10,000
		Conduit + Wire (Service)	150	LF	80	12,000	2035	20,000
		Conduit (Service - Spare)	150	LF	50	7,500	2035	10,000
		Conduit + Wire (Distribution	2470	LF	70	172,900	2035	290,000
		Conduit (Distribution - Spar	2470	LF	50	123,500	2035	210,000
		Electrical Manhole	2	EA	19,000	38,000	2035	60,000
		Pullboxes	7	EA	19,000	133,000	2035	220,000
		Pavement Trenching	740	LF	50	37,000	2035	60,000
		Trench Fill & Pavement Patc	740	LF	20	14,800	2035	20,000
		Charge Management System	111	EA	1,900	210,900	2035	350,000
	Phase 1 - Charging Equipment							
		Charging Assembly	1	EA	2,450,000	2,450,000	2035	4,100,000
		Pantograph	20	EA	35,000	700,000	2035	1,200,000
		Emergency Stop	20	EA	125	2,500	2035	4,000
	Phase 2 - Charging Equipment							

Phase 2 - Charging Equipment								
	Charging Assembly	1	EA	2,450,000	2,450,000	2036		4,200,000
	Pantograph	20	EA	35,000	700,000	2036		1,200,000
	Emergency Stop	20	EA	125	2,500	2036		4,000
Phase 3 - Charging Equipment								
	Charging Assembly	2	EA	2,450,000	4,900,000	2037		8,800,000
	Pantograph	40	EA	35,000	1,400,000	2037		2,500,000
	Emergency Stop	40	EA	125	5,000	2037		10,000
Phase 4 - Charging Equipment								
	Charging Assembly	1	EA	2,450,000	2,450,000	2038		4,600,000
	Pantograph	19	EA	35,000	665,000	2038		1,200,000
	Emergency Stop	19	EA	125	2,375	2038		4,000
Phase 5 - Electrify Bus Parking Lot - Secondary Buildout								
	Bus Canopy	11,800	SF	100	1,180,000	2039		2,300,000
	Concrete Pads (Equip)	400	SF	10	4,000	2039		8,000
Phase 5 - Charging Equipment								
	Charging Assembly	1	EA	2,450,000	2,450,000	2039		4,800,000
	Pantograph	12	EA	35,000	420,000	2039		820,000
	Emergency Stop	12	EA	125	1,500	2039		3,000
						SUB-TOTAL - Hampton	**$**	**54,888,000**

[Facility Improvements] 18th Street - 141 Buses; 146 Parking Stalls								
	Phase 1 - Electrify Maintenance Bays							
		Shop Charger	10	EA	50,000	500,000	2029	660,000
		Switchgear + Disconnects	10	EA	2,000	20,000	2029	30,000
		Overhead Crane	1	EA	25,000	25,000	2029	30,000
		High Voltage PPE	1	LS	5,000	5,000	2029	7,000
		High Voltage Diagnostic Toc	2	SET	15,000	30,000	2029	40,000
		Tie in to Command Center	1	LS	10,000	10,000	2029	13,000
	Phase 1 - Electrify Bus Parking Lot - Initial Buildout						2029	
		Bus Canopy	0	SF	100	-	2029	-
		Concrete Pads (Equip)	2,400	SF	10	24,000	2029	30,000
		Electrical Service (Site Conn	1	EA	16,000	16,000	2029	20,000
		Service Extension Allowance	0	LS	0	-	2029	-
		Switchgear Building	9400	SF	125	1,175,000	2029	1,500,000
		Medium Voltage Switchgear	1	LS	2,425,000	2,425,000	2029	3,200,000
		SCADA System	1	LS	100,000	100,000	2029	130,000
		Electrical Meter	1	EA	6,000	6,000	2029	10,000
		Conduit + Wire (Service)	660	LF	80	52,800	2029	70,000
		Conduit (Service - Spare)	660	LF	50	33,000	2029	40,000
		Conduit + Wire (Distributior	2850	LF	70	199,500	2029	260,000
		Conduit (Distribution - Spar	2850	LF	50	142,500	2029	190,000
		Electrical Manhole	2	EA	19,000	38,000	2029	50,000
		Pullboxes	8	EA	19,000	152,000	2029	200,000
		Pavement Trenching	920	LF	50	46,000	2029	60,000
		Trench Fill & Pavement Patc	920	LF	20	18,400	2029	20,000
		Charge Management Systerr	146	EA	1,900	277,400	2029	370,000
	Phase 1 - Charging Equipment							
		Charging Assembly	1	EA	2,450,000	2,450,000	2029	3,200,000
		Pantograph	20	EA	35,000	700,000	2029	920,000
		Emergency Stop	20	EA	125	2,500	2029	3,000
	Phase 2 - Charging Equipment							

	Phase 2 - Charging Equipment								
		Charging Assembly	2	EA	2,450,000	4,900,000	2030		6,700,000
		Pantograph	40	EA	35,000	1,400,000	2030		1,900,000
		Emergency Stop	40	EA	125	5,000	2030		10,000
	Phase 3 - Charging Equipment								
		Charging Assembly	2	EA	2,450,000	4,900,000	2032		7,300,000
		Pantograph	40	EA	35,000	1,400,000	2032		2,100,000
		Emergency Stop	40	EA	125	5,000	2032		10,000
	Phase 4 - Charging Equipment								
		Charging Assembly	1	EA	2,450,000	2,450,000	2033		3,800,000
		Pantograph	20	EA	35,000	700,000	2033		1,100,000
		Emergency Stop	20	EA	125	2,500	2033		4,000
	Phase 5 - Charging Equipment								
		Charging Assembly	1	EA	2,450,000	2,450,000	2034		3,900,000
		Pantograph	26	EA	35,000	910,000	2034		1,500,000
		Emergency Stop	26	EA	125	3,250	2034		10,000
						SUB-TOTAL - 18th Street		**$**	**39,387,000**
[Facility Improvements] New Southside Facility - 81 Buses; 115 Parking Stalls									
	Phase 1 - Electrify Maintenance Bays								
		Shop Charger	12	EA	50,000	600,000	2024		650,000
		Switchgear + Disconnects	12	EA	2,000	24,000	2024		30,000
		Overhead Crane	1	EA	25,000	25,000	2024		30,000
		High Voltage PPE	1	LS	5,000	5,000	2024		5,000
		High Voltage Diagnostic Too	2	SET	15,000	30,000	2024		30,000
		Tie in to Command Center	1	LS	10,000	10,000	2024		11,000
	Phase 1 - Electrify Bus Parking Lot - Initial Buildout								
		Bus Canopy	76,300	SF	100	7,630,000	2024		8,300,000
		Concrete Pads (Equip)	2,400	SF	10	24,000	2024		30,000
		Electrical Service (Site Conn	1	EA	16,000	16,000	2024		20,000
		Service Extension Allowance	0	LS	0	-	2024		-

		Service Extension Allowance	0	LS	0	-	2024		-
		Switchgear Building	8000	SF	125	1,000,000	2024		1,100,000
		Medium Voltage Switchgear	1	LS	2,225,000	2,225,000	2024		2,400,000
		SCADA System	1	LS	100,000	100,000	2024		110,000
		Electrical Meter	1	EA	6,000	6,000	2024		10,000
		Conduit + Wire (Service)	3825	LF	80	306,000	2024		330,000
		Conduit (Service - Spare)	3825	LF	50	191,250	2024		210,000
		Conduit + Wire (Distribution	1500	LF	70	105,000	2024		110,000
		Conduit (Distribution - Spar	1500	LF	50	75,000	2024		80,000
		Electrical Manhole	5	EA	19,000	95,000	2024		100,000
		Pullboxes	6	EA	19,000	114,000	2024		120,000
		Pavement Trenching	0	LF	50	-	2024		-
		Trench Fill & Pavement Patc	0	LF	20	-	2024		-
		Charge Management System	115	EA	1,900	218,500	2024		240,000
	Phase 1 - Charging Equipment								
		Charging Assembly	1	EA	2,450,000	2,450,000	2024		2,600,000
		Pantograph	20	EA	35,000	700,000	2024		760,000
		Emergency Stop	20	EA	125	2,500	2024		3,000
	Phase 2 - Charging Equipment								
		Charging Assembly	1	EA	2,450,000	2,450,000	2025		2,800,000
		Pantograph	20	EA	35,000	700,000	2025		790,000
		Emergency Stop	20	EA	125	2,500	2025		3,000
	Phase 3 - Charging Equipment								
		Charging Assembly	2	EA	2,450,000	4,900,000	2026		5,700,000
		Pantograph	40	EA	35,000	1,400,000	2026		1,600,000
		Emergency Stop	40	EA	125	5,000	2026		10,000
	Phase 4 - Charging Equipment								
		Charging Assembly	2	EA	2,450,000	4,900,000	2028		6,200,000
		Pantograph	35	EA	35,000	1,225,000	2028		1,600,000
		Emergency Stop	35	EA	125	4,375	2028		10,000
						SUB-TOTAL - New Southside		**$**	**35,992,000**

[Rolling Stock] Hampton									
Initial BEB Procurements									
Electric Buses	14	EA	$	1,000,000	$	14,000,000	2036	$	18,500,000
Electric Buses	24	EA	$	1,000,000	$	24,000,000	2037	$	32,300,000
Electric Buses	24	EA	$	1,000,000	$	24,000,000	2038	$	32,900,000
Electric Buses	24	EA	$	1,000,000	$	24,000,000	2039	$	33,600,000
Electric Buses	21	EA	$	1,000,000	$	21,000,000	2040	$	30,000,000
Initial BEB Service Packages									
12-Year Battery Warranty	14	EA	$	35,000	$	490,000	2036	$	650,000
12-Year Battery Warranty	24	EA	$	35,000	$	840,000	2037	$	1,100,000
12-Year Battery Warranty	24	EA	$	35,000	$	840,000	2038	$	1,200,000
12-Year Battery Warranty	24	EA	$	35,000	$	840,000	2039	$	1,200,000
12-Year Battery Warranty	21	EA	$	35,000	$	735,000	2040	$	1,000,000
SUB-TOTAL - Hampton	**107**				**$**	**110,745,000**		**$**	**152,450,000**
[Rolling Stock] 18th Street									
Initial BEB Procurements									
Electric Buses	6	EA	-		-		Existing	-	
Electric Buses	11	EA	$	1,000,000		11,000,000	2030	$	12,900,000
Electric Buses	24	EA		1,000,000		24,000,000	2031	$	28,700,000
Electric Buses	18	EA		1,000,000		18,000,000	2032	$	21,900,000
Electric Buses	24	EA		1,000,000		24,000,000	2033	$	29,800,000
Electric Buses	24	EA		1,000,000		24,000,000	2034	$	30,400,000
Electric Buses	24	EA		1,000,000		24,000,000	2035	$	31,000,000
Electric Buses	10	EA		1,000,000		10,000,000	2036	$	13,200,000

Initial BEB Service Packages							
	12-Year Battery Warranty	11	EA	$ 35,000	385,000	2030	$ 450,000
	12-Year Battery Warranty	24	EA	$ 35,000	840,000	2031	$ 1,000,000
	12-Year Battery Warranty	18	EA	$ 35,000	630,000	2032	$ 770,000
	12-Year Battery Warranty	24	EA	$ 35,000	840,000	2033	$ 1,000,000
	12-Year Battery Warranty	24	EA	$ 35,000	840,000	2034	$ 1,100,000
	12-Year Battery Warranty	24	EA	$ 35,000	840,000	2035	$ 1,100,000
	12-Year Battery Warranty	10	EA	$ 35,000	350,000	2036	$ 460,000
Replacement BEB Procurements							
	Electric Buses	6	EA	$ 1,000,000	6,000,000	2032	$ 7,300,000
Replacement BEB Service Packages							
	12-Year Battery Warranty	6	EA	$ 35,000	210,000	2032	$ 260,000
	SUB-TOTAL - 18th Street	**141**			**$ 145,935,000**		**$ 181,340,000**
[Rolling Stock] New Southside Facility							
Initial BEB Procurements							
	Electric Buses	15	EA	$ 1,000,000	$ 15,000,000	2025	$ 15,900,000
	Electric Buses	15	EA	$ 1,000,000	15,000,000	2026	$ 16,200,000
	Electric Buses	15	EA	$ 1,000,000	15,000,000	2027	$ 16,600,000
	Electric Buses	15	EA	$ 1,000,000	15,000,000	2028	$ 16,900,000
	Electric Buses	15	EA	$ 1,000,000	15,000,000	2029	$ 17,200,000
	Electric Buses	6	EA	$ 1,000,000	6,000,000	2030	$ 7,000,000
Initial BEB Service Packages							
	12-Year Battery Warranty	15	EA	$ 35,000	$ 525,000	2025	$ 560,000
	12-Year Battery Warranty	15	EA	$ 35,000	525,000	2026	$ 570,000
	12-Year Battery Warranty	15	EA	$ 35,000	525,000	2027	$ 580,000
	12-Year Battery Warranty	15	EA	$ 35,000	525,000	2028	$ 590,000
	12-Year Battery Warranty	15	EA	$ 35,000	525,000	2029	$ 600,000
	12-Year Battery Warranty	6	EA	$ 35,000	210,000	2030	$ 250,000

Replacement BEB Procurements								
Electric Buses	15	EA	$	1,000,000	$	15,000,000	2037	$ 20,200,000
Electric Buses	15	EA	$	1,000,000		15,000,000	2038	$ 20,600,000
Electric Buses	15	EA	$	1,000,000		15,000,000	2039	$ 21,000,000
Electric Buses	15	EA	$	1,000,000		15,000,000	2040	$ 21,400,000
Replacement BEB Service Packages								
12-Year Battery Warranty	15	EA	$	35,000	$	525,000	2037	$ 710,000
12-Year Battery Warranty	15	EA	$	35,000		525,000	2038	$ 720,000
12-Year Battery Warranty	15	EA	$	35,000		525,000	2039	$ 740,000
12-Year Battery Warranty	15	EA	$	35,000		525,000	2040	$ 750,000
SUB-TOTAL - New Southside	**81**				**$**	**145,935,000**		**$ 179,070,000**