Northern Virginia Zero-Emission Bus Strategic Plan

Northern Virginia Transportation Commission

January 2024

1964-2024 60th NVTC ANNIVERSARY

Table of Contents

Acronyms

- APTA – American Public Transportation Association
- ART – Arlington Transit
- BEB – Battery electric bus
- CBA – Cost-benefit analysis
- CNG – Compressed natural gas
- CTB – Commonwealth Transportation Board
- CUE – City of Fairfax City-University Energysaver
- DASH – Alexandria Transit Company
- DDOT – District Department of Transportation
- DOE – U.S. Department of Energy
- DRPT – Department of Rail and Public Transportation
- EPA – U.S. Environmental Protection Agency
- EV – Electric vehicle
- FCEB – Fuel cell electric bus
- FTA – Federal Transit Administration
- FY – Fiscal year
- ICE – Internal combustion engine
- IIJA – Infrastructure Investment and Jobs Act
- IRA – Inflation Reduction Act
- kW – Kilowatts
- kWh – Kilowatt hours
- LCT – Loudoun County Transit
- MTA – Maryland Transit Administration
- MWCOG – Metropolitan Washington Council of Governments
- NVTA – Northern Virginia Transportation Authority
- NVTC – Northern Virginia Transportation Commission
- OEM – Original equipment manufacturer
- P3 – Public-private partnership
- PRTC – Potomac and Rappahannock Transportation Commission
- RFI – Request for information
- RFP – Request for proposal
- SAE – Society of Automotive Engineers
- TPB – Transportation Planning Board
- UP – Unsolicited proposal
- USDOT – U.S. Department of Transportation
- VDOT – Virginia Department of Transportation
- WMATA – Washington Metropolitan Area Transit Authority
- ZEB – Zero-emission bus

Executive Summary

Transit providers in Northern Virginia, like those across the country, are in various stages of transitioning their fleets to zero-emission buses (ZEB). The Northern Virginia Transportation Commission's (NVTC) Northern Virginia Zero-Emission Bus Strategic Plan accounts for the diversity of transit agencies in Northern Virginia and presents six strategies rooted in agencies' shared opportunities and challenges. Actions, or steps, are described for each strategy and are categorized into a five-year implementation plan. The NVTC-led actions complement and leverage individual agencies' ZEB transition plans and broader regional ZEB initiatives.

The six strategies are:

1. Serve as a Regional ZEB Forum
2. Advocate for Consistent and Supportive ZEB Standards and Policies
3. Provide Regional ZEB Funding Coordination
4. Support Development of Shared BEB Charging Infrastructure
5. Evaluate Opportunities for Private Partnerships Related to ZEBs
6. Support ZEB Workforce Training and Education

The implementation strategy includes three phases:

Quick Wins (Year One)	**Short Term** (2-3 Years)	**Long Term** (3+ Years)
Actions that are relatively small in scale and therefore do not require major resource increases.	Actions which build upon lessons learned from year one and require additional resources.	Actions which require longer lead times, a greater degree of coordination and/or additional investment.

The Strategic Plan concludes with potential funding sources that NVTC could access to deliver the actions listed in the plan.

1. Introduction

Context and Background

Transit providers in Northern Virginia, like those across the country, are in various stages of their transition to zero-emission buses (ZEBs). Converting to ZEBs such as battery-electric buses (BEB) or hydrogen fuel cell electric buses (FCEB) requires considerable investment in vehicles and supporting infrastructure. The Northern Virginia Transportation Commission (NVTC) recognizes that the region's transit systems are at various stages of transitioning to ZEBs and that there is an opportunity to better coordinate ZEB planning and share best practices among them. This Northern Virginia Zero-Emission Bus Strategic Plan outlines how NVTC can support the ZEB transition among Northern Virginia transit agencies. This plan establishes six strategies for NVTC to pursue over the next five years, along with guidance on phasing and implementation of these strategies.

Alignment with NVTC Mission

ZEB regional coordination and collaboration furthers NVTC's mission of "bringing the region together to plan, coordinate and secure funding for transit systems that are financially sustainable and high performing." Taking a regional approach to ZEB investments supports capacity building at transit agencies and increases the competitiveness of future state and federal grant requests. To create strong alignment with the Commission's mission, this plan's recommendations are guided by NVTC's strategic goals.

NVTC's Strategic Goals

Increase the capacity of the regional transit network by expanding and improving the quality, coverage and frequency of new and existing systems, including Washington Metropolitan Area Transit Authority (WMATA), Virginia Railway Express (VRE) and new transit services.

Improve access and mobility throughout Northern Virginia by connecting the regional and local transit systems.

Promote safe, reliable and financially sound performance and management of regional transit systems.

2. Background

This section summarizes a series of technical papers prepared for NVTC including an overview of ZEBs, a snapshot of Northern Virginia transit agencies' ZEB transition processes and a briefing on industry trends.

Overview of Zero-Emission Bus Technology

The two primary zero-emission bus technologies available and on the road today are BEBs and FCEBs. ZEBs differ from traditionally fueled buses in that they produce zero tailpipe emissions.

Battery Electric Buses and Charging Infrastructure

BEBs use onboard batteries to store and distribute power to an electric motor and other onboard systems and must be charged to be operational. BEBs are sometimes categorized into two groups based on range: long/extended range BEBs with larger battery packs (250-660 kWh) and fast charge BEBs with smaller battery packs.[1] Long-range BEBs are typically intended to be charged once or twice a day, whereas fast charge BEBs are designed to receive more frequent high-powered charges (e.g., through on-route charging or for use as electric school buses). Battery ranges vary by manufacturer and are further impacted by environmental, topographic and load variables. They cannot travel the same distance as internal combustion engine buses on a single charge, which means that some routes cannot be replaced by a BEB on a 1:1 basis without on-route charging.

Due to the diverse marketplace and continuing maturation of charging technology, transit agencies need to proactively coordinate with EV charging manufacturers, transit bus original equipment manufacturers (OEMs), and local utilities when planning their charging infrastructure.

There are three primary types of electric charging equipment: plug-in, overhead and inductive (described in further detail in Figure 1). Plug-in chargers are best fit for overnight charging at the depot, whereas overhead charging is being deployed for both fast on-route charging and overnight charging. Inductive charging is newest to the market and is being primarily deployed on-route.

[1] USDOT. (2023, May 4). Electric bus basics.
https://www.transportation.gov/rural/electric-vehicles/ev-toolkit/electric-bus-basics

Plug-in charging: Plug-in charging requires the bus to be manually plugged in and can be located on-route or in-depot. The SAE International standard for plug-in chargers is J1772.

Charging capacity: Plug-in charging power options range from 40 kW (slow) up to 350 kW (fast). Of note, 1 MW charging solutions are under development for heavy duty vehicles in Oslo, Norway.[2]

Overhead charging: Overheard charging relies on an overhead pantograph system to charge buses. Unlike plug-in charging, vehicles can automatically begin charging when positioned correctly. Overhead charging supports fast charging speeds. Facilities can be located along the roadway, within stations or in depots. The SAE standard for overhead charging is J3105.

Charging capacity: This charging method allows for high-power ratings of up to 600 kW.[2]

Inductive charging: Wireless or cordless charging involves installing an undercarriage-mounted power receiver on the bus and embedding a transmitter packaged within a ruggedized pad in the ground. As shown in the adjacent picture, when the bus stops above the plate, power is transmitted wirelessly to the bus. Inductive charging is less commonly used than plug-in or overhead charging for transit. The SAE standard for inductive charging, J2954-2, is still being adopted by inductive charging manufacturers.

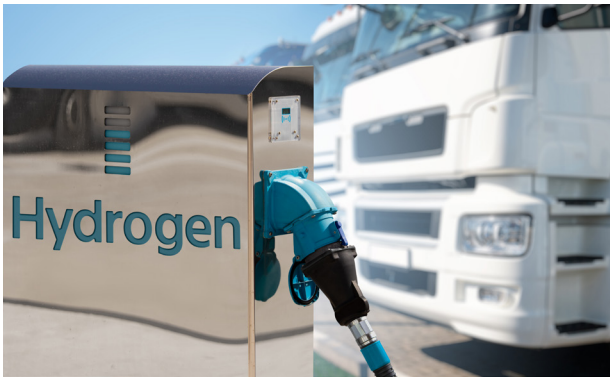
Charging capacity: 50 – 450 kW.[3]

FIGURE 1: Types of electric chargers

[2] U.S. Department of Transportation. (n.d.). E-Mobility Basics: Bus. Urban E-Mobility Toolkit. https://www.transportation.gov/urban-e-mobility-toolkit/e-mobility-basics/bus

[3] Electrive. (2018, April 19). Inductive 200 kW Charging System for Buses Ready. https://www.electrive.com/2018/04/19/inductive-200-kw-charging-system-for-buses-ready/

Hydrogen Fuel Cell Electric Buses and Fueling Infrastructure



Hydrogen FCEBs use hydrogen and oxygen to produce electricity through an electrochemical reaction to power the propulsion system and auxiliary equipment. Water is the only byproduct. Existing technology typically uses the fuel cell in conjunction with a battery to supplement the fuel cell's power during peak loads and to store electricity that is recaptured through regenerative braking. This system allows for better fuel economy, with FCEBs having an average range similar to that of conventional transit buses.

Market adoption of FCEBs is slower than BEBs. However, there is growing national and international interest in green hydrogen (hydrogen produced from renewable energy) as a zero-emission alternative to gasoline and diesel for transportation applications. Hydrogen is typically delivered (liquid or more rarely, gaseous) from steam methane reforming or produced on-site via water electrolysis.

Although hydrogen vehicles are more efficient than conventional fuel types, transporting and dispensing hydrogen is more expensive primarily due to the limited hydrogen infrastructure currently in place.

Notable financial barriers to implementing fuel cell technology include the upfront capital cost associated with physical infrastructure and rolling stock. It is important to note that FCEB capital costs have decreased as the adoption rate increases. FCEBs also become more cost competitive when implemented at scale, as shown in Figure 2.

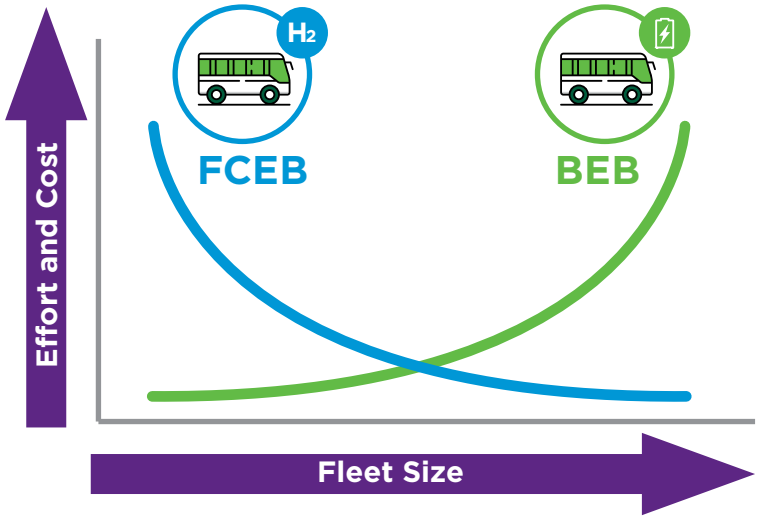


FIGURE 2: Cost competitiveness of BEB vs. FCEB

Source: TCRP Research Report 219: Guidebook for Deploying Zero-Emission Transit Buses; National Academies of Sciences, Engineering, and Medicine. 2021. Guidebook for Deploying Zero-Emission Transit Buses. Washington, DC: https://nap.nationalacademies.org/read/25842/chapter/6#56

State of ZEB Transition in Northern Virginia

Northern Virginia's transit agencies are in different phases of ZEB transition, each with specific goals and unique needs. These goals are driven by each jurisdiction's climate-related policies.[4] The information below summarizes the diverse operating characteristics that influence each agency's ZEB strategy, along with information on where each agency is in the implementation process. Figure 3 illustrates the ZEB transition timeline of the seven local agencies and highlights key milestones and transition points.

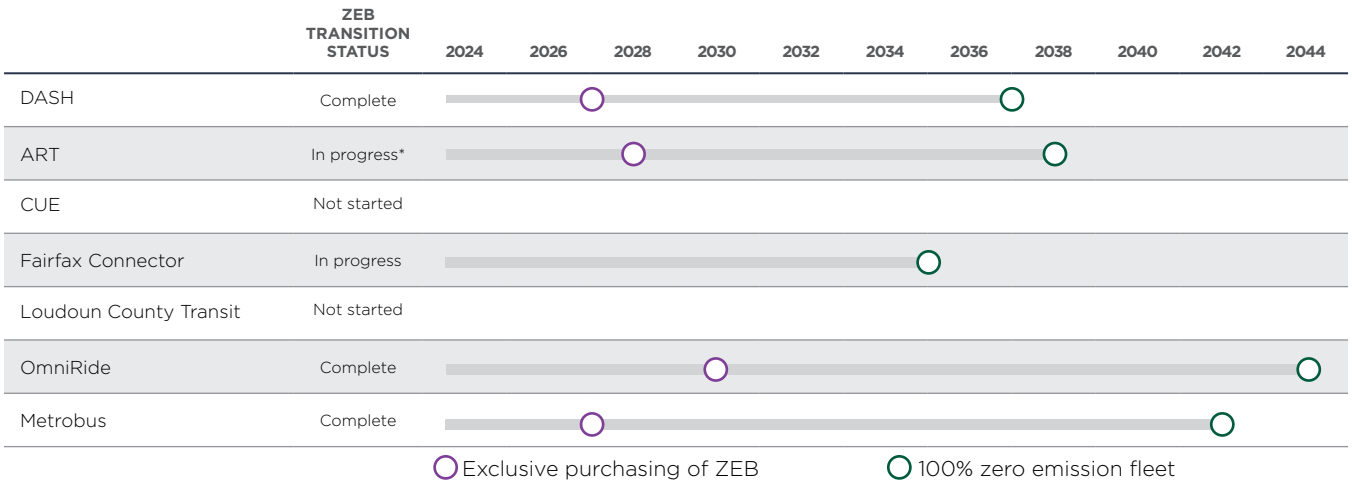


FIGURE 3: Local agency ZEB transition timeline as of November 2023. Dates subject to change as plans evolve. *Transition milestones are based on the final draft of the ART ZEB Feasibility Study provided by Kimley-Horn and are subject to change.

DASH

DASH is the City of Alexandria's 107-vehicle public bus system that operates 12 routes servicing Alexandria and surrounding areas. DASH is a zero-emission leader in the region, owning and operating 14 BEBs amid an otherwise diesel fleet. The agency intends to exclusively purchase ZEBs by 2027, leading to a one hundred percent zero-emission fleet by 2037.

In addition to the 14 BEBs currently deployed, DASH has secured funding from the Federal Transit Administration and the I-395 Commuter Choice Program to procure an additional 15 BEBs in the upcoming fiscal year. To serve its existing fleet of 14 BEBs, DASH has six plug-in chargers with 12 dispensers at its existing bus maintenance and storage facility. DASH and the City of Alexandria are in the process of building the DASH Facility Expansion project, scoped to be built as a make-ready BEB charging yard, with the opportunity to add up to 40 charge points to support the future fleet. This project is currently at 30% design and funded through Phase I, which includes an initial 20 new charge points. Phase II of this project (currently unfunded) will enclose the facility as an extension of the main facility and add the final 20 charge points.

[4] https://climatepartners.org/initiatives/local/

ART

Arlington Transit (ART) serves Arlington County exclusively with a fleet of 78 compressed natural gas (CNG) buses via 16 fixed routes, four of which are relatively high frequency (operating every 20 minutes or better). The system serves several high-priority corridors and critical connections between regional and local transit services.

ART is currently conducting a ZEB transition study. The agency has purchased four BEBs as part of a pilot and is considering both BEBs and FCEBs as part of its transition. The agency held two BEB demonstrations with different manufacturers in the fall of 2022 to obtain better knowledge of operating BEBs within ART's service area.

To support the growing and diversifying fleet, ART is constructing a new operations and maintenance facility. This facility will have the capability of charging up to 12 BEBs initially and is being constructed to charge up to 46 BEBs in the future.

Fairfax CUE

Fairfax City-University Energysaver (CUE) is the City of Fairfax's public transit service which operates a fleet of 12 diesel buses. Following its replacement plan, the agency replaces six buses every six years with the next bus procurement planned for 2027. A transition to electric buses (including supporting infrastructure) is under discussion because route and block lengths appear feasible given the existing BEB range, although a ZEB transition plan has not been initiated. The agency is studying the technology and following industry peers to analyze charging infrastructure, range and other fuel types.

Fairfax Connector

Fairfax Connector is the largest local bus system in Virginia, offering a mix of local services within Fairfax County and commuter routes serving approximately 29,000 daily passengers via 93 routes. Fairfax County maintains a network of transit centers with passenger amenities that can include parking, bicycle storage and commuter stores to support the Fairfax Connector, WMATA and Virginia Railway Express services.

Fairfax Connector's fleet is composed of 325 clean diesel buses, 8 hybrid buses and 12 BEBs. The ZEB transition plan is under development. A pilot program was launched in October 2023 with eight BEBs. The agency's goal is to transition the fleet to 100% ZEBs by 2035.

To support the BEB pilot program, four dual dispenser 150kW heavy vehicle chargers were installed at the West Ox Facility, and the Huntington Division will be upgraded with plug-in electric charging capabilities to support the next phases of the fleet transition. Overhead charging infrastructure is being considered to provide a more stable charging system for a full fleet transition. Fairfax County is also partnering with WMATA to operate BEBs out of WMATA's Cinder Bed Road facility, as described below.

Loudoun County Transit (LCT)

Loudoun County Transit has a fleet of 118 buses providing service via 83 local, commuter and Metro-Connection routes in the eastern part of the county.

Currently, Loudoun County does not have a ZEB transition plan in place. Loudoun County has ordered two 35′ BEBs for its longer route services, and these initial BEBs will allow the County to assess their performance within the transit system. The Loudoun County Board directed staff to purchase compressed natural gas (CNG) buses to replace local route diesel buses at the end of their service life. Staff has purchased six CNG commuter buses and will purchase 37 additional body-on-chassis buses using funds received from an FTA Low/No Emission grant.

OmniRide

OmniRide, operated by the Potomac and Rappahannock Transportation Commission (PRTC), provides multi-modal transportation options to Prince William County and the Washington, DC region, including commuter bus (OmniRide Express and Metro Express), local bus and ride-sharing services.

OmniRide operates a 100% diesel fleet composed of relatively new buses with much of their 12-year life span remaining. PRTC completed a Zero-Emissions Bus Study in February 2023 to support applications for FTA Low/No emission grant funding in future years. The plan recommends moving forward with BEBs, starting with the smaller fleet vehicles while still exploring the possibilities of the other propulsion types, particularly FCEBs. BEBs are recommended as a typical fixed-route option, and FCEBs are anticipated for long-haul routes.

OmniRide's Western Bus Operations and Maintenance Facility opened in 2021 and has designated space for BEBs. In addition to these existing spaces, there is undeveloped land on the same property that could be modified to support ZEB storage and maintenance, or even hydrogen storage if immediate needs arose.

WMATA Metrobus

Metrobus, WMATA's bus system, operates an extensive bus network throughout the Washington, DC, Maryland and Virginia region. With a fleet of nearly 1,600 buses, Metrobus is the sixth-largest bus network in the United States. WMATA completed its first ZEB Transition Plan in March 2023 and plans for a 100% zero-emission bus fleet by 2042.[5]

WMATA has two bus divisions in Northern Virginia – Cinder Bed Road and Four Mile Run – and leases space from Fairfax County at their West Ox bus division. Cinder Bed Road and Four Mile Run currently support revenue service vehicles, while West Ox is currently used for special projects while work on the bus network redesign determines future service needs. In summer 2023, WMATA received a $104 million grant from the FTA to support the conversion of Cinder Bed Road to a fully battery-electric bus facility; a portion of the facility is also planned to serve Fairfax Connector BEBs for their future Route 1 Bus Rapid Transit system. Four Mile Run is anticipated to be converted later in WMATA's transition to zero-emission buses.

[5] https://www.wmata.com/initiatives/plans/upload/WMATA-ZEB-Transition-Plan_March2023.pdf

Industry Trends Snapshot

Given the increased national and international interest in both BEBs and FCEBs, additional research and funding has been dedicated to these technologies. Advances in electric bus technology and a gradual decline in battery costs over recent years have made electric buses an increasingly viable option for many transit agencies. Increases in federal support for green hydrogen are also changing the feasibility of FCEBs. This section explores insights into emerging ZEB technologies and practices and discusses the implications on Northern Virginia transit agencies' ZEB transition plans.

Emerging Technologies and Practices

Solid-state batteries are a rechargeable energy storage system, similar in structure and operation to the lithium-ion battery but containing a solid electrolyte rather than a liquid electrolyte. They are lighter, have higher energy density, have greater range and recharge faster. They also reduce safety risks associated with lithium-ion batteries in BEBs. This technology should be monitored, as innovations in materials science continue and allow this technology to scale.

Typical EV batteries are estimated to retain 80% of their original capacity at the end of their useful service life, giving rise to the possibility for a "second life" in less intense use cases, like stationary storage. These systems have the potential to provide supplementary power supply to the electricity network, while providing sustainable solutions for reducing harmful waste. This approach can be applied to lithium-ion batteries in electric buses. Testing is currently being performed by companies in partnership with energy utilities. Results should be monitored.

Electric grid capacity is a critical component in the transition to sustainable public transportation systems. Transit systems may encounter several constraints when transitioning to electric vehicles and integrating them within the existing electrical grid, including grid congestion with other electric vehicles, siting and permitting, and compliance with other utility regulations. Overall, a coordinated effort between all stakeholders is essential to ensure that the electric grid can meet the needs of transit agencies, while limiting disruptions to service. Specific interventions that have been established to directly influence and reduce potential strain on the electric grid include.[6]

- Pursuing rates that meet the needs of electric transportation customers, including transit agencies.
- Getting creative with packaged charging solutions, including financing, make-ready investments, smart charging and incentives.
- Planning for large loads to minimize costs and potential constraints on the grid.
- Exploring novel solutions that address barriers to charging.

Bringing down the cost of hydrogen production is another emerging trend to track. In October 2023, the Department of Energy announced that seven regions had been selected for its Regional Clean Hydrogen Hubs Program (H2Hubs). The program will provide up to $7 billion to establish hydrogen hubs that will provide a foundation for future clean hydrogen supply. Although the local application from Connected DMV was not selected for the program, the

[6] Daniels, Lynn & Brendan O'Donnell, Seattle City Light: Transportation Electrification Strategy. (2019). Rocky Mountain Institute. https://rmi.org/insight/seattle-city-light

DC metropolitan area will still likely see increased hydrogen supply due to the Mid-Atlantic Hydrogen Hub (PA, DE and NJ) and the Appalachian Hydrogen Hub (WV, OH and PA). Additionally, there are hydrogen incentives through the Inflation Reduction Act (IRA) that have the potential to increase production of clean hydrogen in the United States.

Implications for NVTC ZEB Strategic Planning

The increasing awareness of the detrimental effects of traditional fossil fuel-powered vehicles on the environment, coupled with advancements in technology and supportive government policies, has fueled the adoption of ZEBs and the remarkable growth and transformative trends of the ZEB industry in recent years. Recurring themes and implications for transit agencies include:

1. **Cost Efficiency and Reliability:** Initial ZEB deployments have significant costs associated with new fueling and charging infrastructure, as well as the additional cost on a per-bus basis compared to diesel and CNG buses. BEB range limitations can also impact the number of buses needed to provide existing levels of service. That said, continuously improving bus technology has led to improved reliability and greater fuel economy, and the availability of federal funding mitigates some of the costs.

2. **ZEB Transition Planning:** Converting fleets to zero-emission vehicles requires new approaches to operations, maintenance and funding. It is important for agencies to complete ZEB transition plans to understand how infrastructure and service patterns might need to change. The transition plan is also a prerequisite for receiving federal funding for ZEBs, and it will be important to regularly update the plans as technology matures. NVTC's role is to identify ways the region can collaborate and share resources to ease the burden on individual agencies.

3. **Infrastructure Considerations:** Charging infrastructure plays a critical role in the success of BEB deployments. Coordinating software and hardware updates between chargers and buses helps ensure reliable operation. Early coordination with local power companies is also essential to assess and enhance grid capacity, avoiding potential challenges associated with long-term planning.

4. **Workforce Training:** New technology requires workforce (i.e., operators, mechanics, first-responders, etc.) education and training. Given the rapid pace of ZEB technological advancements, continuous education is necessary. The additional training is not an insignificant cost and will require thoughtful retraining of existing staff and hiring of new staff with the right skills.

5. **Rapidly Changing Technology:** Due to continuing technological innovation in the ZEB field, transit agencies should carefully consider the staging of upgrades to ensure their fleets and infrastructure are not over-reliant on outdated or proprietary technology. Additionally, when considering hydrogen deployment, costs and benefits should be carefully evaluated. While hydrogen presents a solution to range anxiety, its production and infrastructure costs remain significant barriers to scaling FCEBs. Consideration should also be given to centralized refueling facilities to minimize costs and optimize efficiency.

6. **Coordination and Partnerships:** System-wide coordination will contribute to a seamless transition to ZEB fleets and avoid service disruptions due to charging needs.

3. NVTC Actions to Support Regional ZEB Transition

NVTC is uniquely positioned to create a more efficient and collaborative path for Northern Virginia agencies in their ZEB transition. This section defines NVTC's support for regional ZEB transition in six broad strategies:

1. Serve as a Regional ZEB Forum
2. Advocate for Consistent and Supportive ZEB Standards and Policies
3. Provide Regional ZEB Funding Coordination
4. Support Development of Shared BEB Charging Infrastructure
5. Evaluate Opportunities for Private Partnerships Related to ZEBs
6. Support ZEB Workforce Training and Education

Within each strategy is a description of it, specific actions to be taken and considerations on coordinating initiatives. Each strategy concludes with a three-point scale to rate:

- **Level of Effort:** How complex and resource intensive is the strategy?
- **Return on Investment:** How does the impact of the strategy compare to its level of effort relative to other strategies?
- **Priority:** How critical is the strategy for the region's ZEB transition? Does the strategy align with NVTC's mission and goals?

Note these rankings are a qualitative assessment based on comparing attributes across the six strategies and are not meant to serve as a cost-benefit analysis (CBA).

Specific actions within each strategy are sorted into an implementation plan in the next section and are dispersed across all three time periods. There is not a direct correlation between the priority rating of each strategy and the implementation plan. Instead, actions are evaluated in greater detail, enabling quick wins from multiple strategies to be identified in year one.

Level of Effort	Return on Investment	Priority
Low Medium High	Low Medium High	Low Medium High

1. Serve as a Regional ZEB Forum

Description

ZEBs are an emerging technology that require transit agencies to reassess a myriad of considerations related to bus service, from length of blocks and service planning requirements to the considerations for new infrastructure required to charge and maintain ZEBs. For most agencies it is uncharted territory, and different agencies are at different steps in the transition process, including in Northern Virginia. Because ZEBs are an expensive transition (compared to conventionally fueled vehicles), agencies want to make sure they are making responsible decisions supported by data.

NVTC currently hosts a ZEB Working Group and will continue to do so. Serving as a regional ZEB forum allows agencies to have regular and structured contact with NVTC and each other as they work through ZEB challenges. This coordination facilitates knowledge and data-sharing among agencies, including information about important developments in the industry. As more agencies in the region deploy ZEBs, NVTC can help facilitate sharing operational data and findings, potentially through a portal or dashboard.

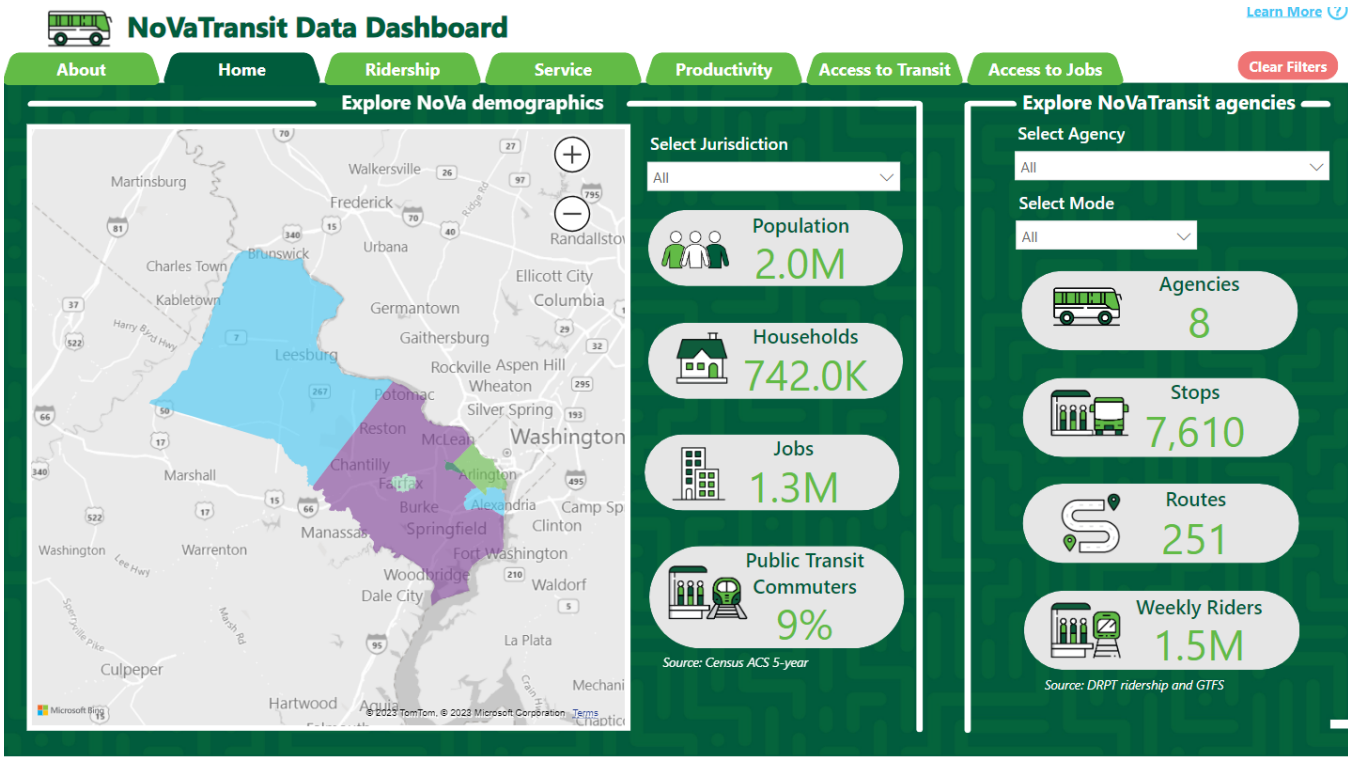


FIGURE 4: NVTC's data dashboard as an existing example of a dashboard NVTC built and hosted

NVTC Actions

1A - Continue to Facilitate ZEB Working Group: Continue to facilitate the NVTC ZEB Working Group and participate in regional and industry working groups. Coordinate on best practices for working with utilities, track technology advancements – including with hydrogen, and share lessons learned.

1B - Share Operational Data and Findings: Create a centralized clearinghouse where Northern Virginia agencies can share data on their ZEB transition and performance. Develop a dashboard to share operational data and findings among regional partners.

Coordinating Initiatives & Considerations

Some NVTC actions could be shared with WMATA's Regional ZEB Subcommittee.

Level of Effort	Return on Investment	Priority
Medium	**Medium**	**Medium**
Requires coordination of multiple agency and stakeholder priorities and schedules. A dashboard requires resources to maintain and update the data.	NVTC agencies could benefit from continued data sharing although other local initiatives and national best practices could negate the need for NVTC action.	While a low-hanging and obtainable strategy, it is not critical path to the regional ZEB transition.

2. Advocate for Consistent and Supportive ZEB Standards and Policies

Description

As the ZEB industry continues to mature, NVTC seeks to take lessons learned from the region's transit agencies and advocate for or educate external audiences on why Northern Virginia agencies are approaching the transition a certain way and how industry or government can ease transition issues. While standards exist in the ZEB industry, there are still integration issues that can arise when trying to integrate new technologies and vendors. Given the level of coordination that occurs among transit agencies in Northern Virginia, NVTC is in a good position to report multi-agency interoperability issues as they arise.

More generally, it is important to talk about ZEB challenges and opportunities to a wide variety of stakeholders so that there is greater understanding of what agencies need to do to convert their fleets to zero emissions.

NVTC Actions

2A – Educate Staff and Local Elected Officials: Ensure local elected officials and residents understand how the transition to ZEBs is progressing so they can advocate for policies that support zero-emission goals while also being realistic about financial and operational constraints.

2B – Advocate for Legislative Support: Support the zero-emission transition as part of the NVTC legislative agenda at state and federal levels.

2C – Encourage Interoperability: Through the ZEB Working Group, be a forum and repository for addressing ZEB interoperability issues and work with industry working groups, manufacturers, and suppliers to develop solutions and consistency.

Coordinating Initiatives & Considerations

The American Public Transportation Association (APTA), of which NVTC is a member, is one of the leading forums for standards and policy discussions. SAE has established standards for plug-in and pantograph chargers.

Level of Effort	Return on Investment	Priority
Medium	**Medium**	**Medium**
Significant level of effort to stay on top of industry standards and to coordinate with industry to create consistency.	Can avoid having to re-procure equipment due to interoperability issues.	Standards and policies support a regional approach to transition rather than piecemeal.

3. Provide Regional ZEB Funding Coordination

Description

Funding the transition to ZEBs will require a combination of local, regional, state and federal funding sources that will be different for each of the Northern Virginia agencies. Several, including DASH and Loudoun County Transit, were successful in securing discretionary grant funding from FTA to purchase low and no-emission vehicles. The very competitive nature of federal grant programs (see Figure 5 below) and of the Commonwealth's SMART SCALE program encourage the submittal of larger scale applications, which can demonstrate greater benefits on greenhouse gas reductions. This creates an incentive for agencies to apply jointly, or under the umbrella of NVTC. Further, the SMART SCALE program has a specific provision for regional entities like NVTC.

Opportunities for joint procurement across several agencies are likely to be more limited. Local agencies currently procure ZEBs and charging infrastructure through a statewide contract with timelines and prices that are more competitive than what agencies would be able to achieve on their own or as a small consortium. However, there could be opportunities for goods or services that are not covered by the statewide contract, such as software to manage the ZEBs and their integration in the fleet.

Developing and managing joint grant applications or procurements may require additional resources to NVTC to cover the additional staff time.

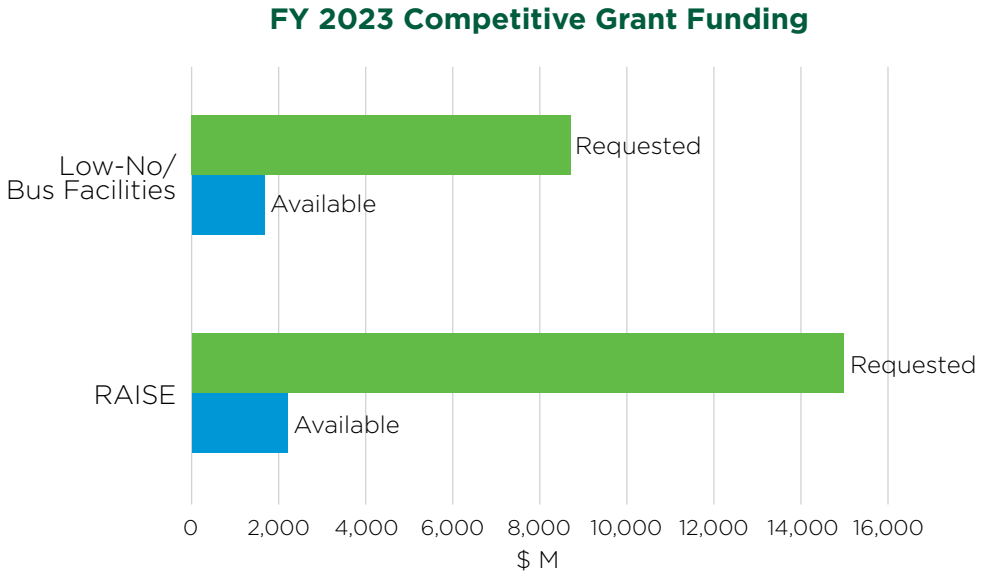


FIGURE 5: Demand for FY2023 competitive grant funding

NVTC Actions

3A – Create a ZEB Funding Strategy: Identify additional funding and resources to implement the recommendations of the strategic plan, such as through additional Virginia Department of Rail and Public Transportation (DRPT) technical assistance.

3B – Develop Multi-Agency ZEB Grant Applications: Develop proposals for multi-agency grant applications for federal or state funding and manage DRPT funding.

3C – Identify ZEB Joint Procurement Opportunities: Identify cost saving opportunities through joint procurement. Examples might include software such as telematics or charge management systems that improve interoperability.

Coordinating Initiatives & Considerations

Coordinate outreach to local and state elected officials, NVTA, the Commonwealth Transportation Board (CTB) and the Virginia Congressional delegation in support of grant applications. Document due dates of grants to prioritize and meet funding deadlines.

Level of Effort	Return on Investment	Priority
Medium	High	High
Additional staff time required but NVTC has experience with grants.	Key to ZEB funding.	Funding needs are high to continue regional ZEB transition.

4. Support Development of Shared BEB Charging Infrastructure

Description

Shared infrastructure can provide several benefits to the ZEB transition in Northern Virginia, in particular for BEBs. By identifying locations where multiple agencies can extend the range of their BEBs using on-route chargers, it is possible to improve reliability and lower infrastructure costs for BEBs. Procuring, implementing and testing on-route charging infrastructure as a region will help ensure that Northern Virginia agencies have compatible infrastructure and can identify interoperability issues early in the process. Additionally, given the limited undeveloped space inside Washington, D.C.'s Beltway, there are cost and feasibility reasons that support sharing the infrastructure. Finally, depending on the use case, a single on-route charger is likely to sit unoccupied for a significant portion of the day; increasing the number of buses that can use an on-route charger increases the return on investment and utility of the infrastructure.

As a regional body, NVTC is well positioned to lead a multi-agency effort to assess the feasibility of shared on-route charging infrastructure, identify potential barriers and risks, and create an actionable and phased implementation plan.

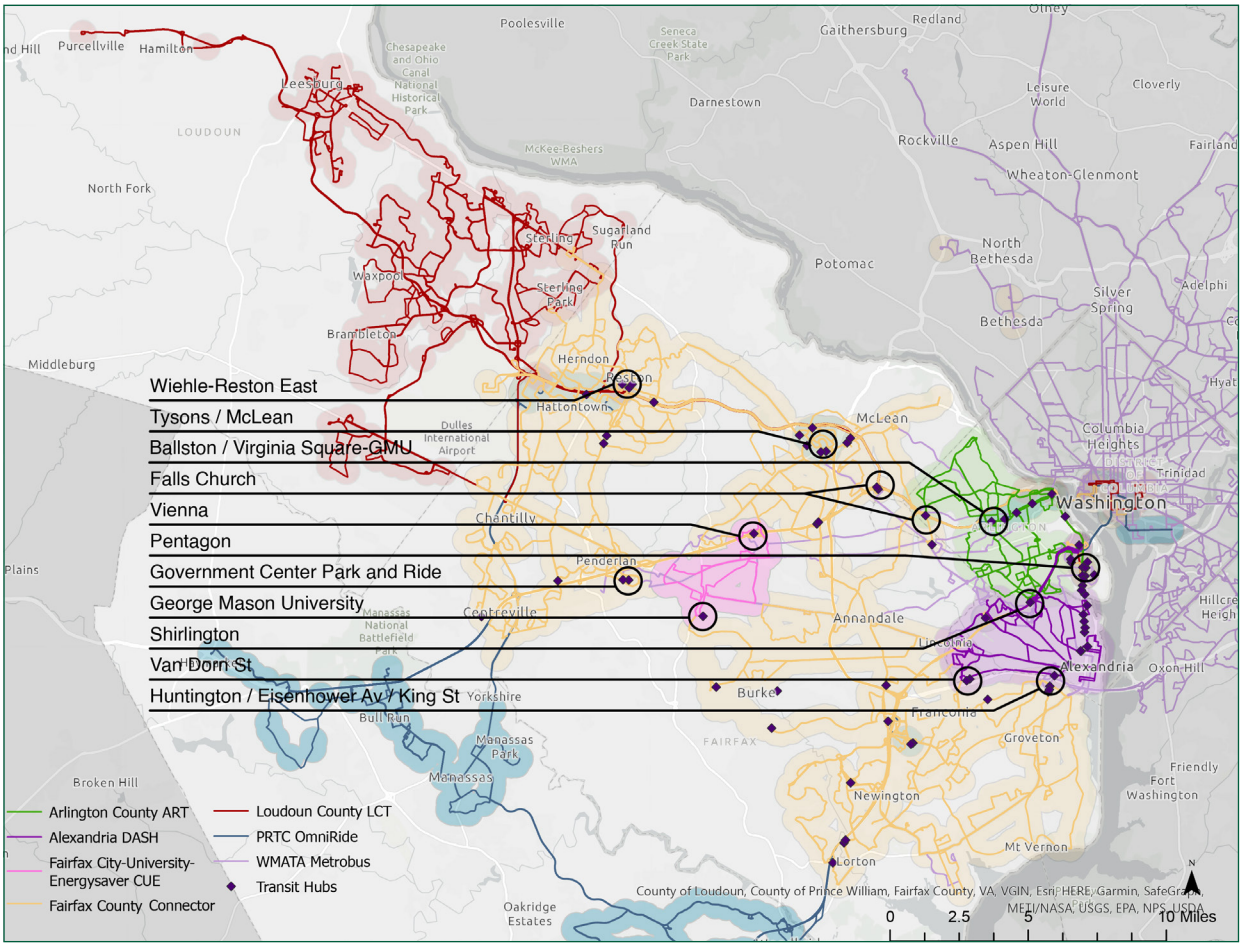


FIGURE 6: Network intersection and major transit hubs

NVTC Actions

4A – Conduct a Shared Charging Feasibility Study: Secure funding and conduct a feasibility study to identify potential locations, as well as construction, operations and maintenance considerations, for shared on-route charging infrastructure.

4B – Pilot Shared On-Route Charging Station: Work with operators and local utilities to pilot shared on-route charging infrastructure at one or more discrete locations. Document processes and create supporting templates for regional agencies to use over the course of the entire life-cycle of the project (i.e., multi-agency agreements regarding operations and maintenance, cost sharing agreements, utility coordination processes and documentation, evaluation and reporting).

Coordinating Initiatives & Considerations

Strategy 2 (Advocate for Consistent and Supportive ZEB Standards and Policies) supports the actions in this strategy. This strategy requires external grant funding to conduct these two actions.

Level of Effort	Return on Investment	Priority
High	**Medium**	**Medium**
High degree of effort up front.	Successfully piloting shared charging infrastructure could lead to cost efficiencies and charging redundancies for each agency.	Shared on-route charging infrastructure makes BEBs more feasible for all blocks, especially for commuter buses.

5. Evaluate Opportunities for Private Partnerships Related to ZEBs

Description

ZEBs bring significant technological risk, particularly related to charging and fueling infrastructure, which could potentially be better managed by the private sector under an alternative delivery structure. Bringing on a private partner involves private financing, which is fundamentally different from public funding. Because private sector financing is typically more costly than public-sector financing, it may be more appropriate for projects where the private sector can add more value than the difference in financing cost. The figure below outlines some key considerations for public-private partnerships (P3s) in the ZEB space. Private sector partners are typically more interested in larger scale transactions, so there would be an incentive for several, if not all, of the Northern Virginia agencies to join forces.

Alternative project delivery requires significant analysis upfront, in particular a comprehensive analysis of project risks. Additional potential pre-procurement efforts can deliver substantial benefits by bringing the private sector into the conversation early. These include unsolicited proposals (UPs) and Requests for Information (RFIs), which help determine the appropriate delivery approach for the project and gauge the industry's appetite for risk sharing, which in turn greatly influences the cost of private involvement. NVTC is well placed to initiate conversations with the private sector around ZEB transition.

Benefits	Drawbacks	Best Practices
• Private sector is nimbler, has greater experience with ZEB and charging technologies, and can better manage risks • Cost effective and performance-based operations and maintenance • Economies of scale	• Higher cost of private financing • Contractual complexity • Can be challenging to definitively determine added value from private sector • Requires greater agency and public buy-in than traditional procurement • Shifts costs from capital to operating budget	• Pre-procurement phase is critical to success • Assess private sector interest early and take feedback • Use quantitative tools to validate value of private participation and identify delivery model • Hire specialized advisors • Secure broad buy-in

FIGURE 7: Benefits, drawbacks and best practices for a potential Northern Virginia ZEB P3

NVTC Actions

5A – Host Industry Listening Sessions: Host listening sessions or industry days to learn more about ZEB infrastructure and technology vendors.

5B – Create Transit Technology Proposal Process: Develop a process through which vendors can propose solutions to demo with Northern Virginia transit agencies based on identified regional problems, starting with the ZEB transition.

5C – Develop ZEB Request for Information: Explore options for an RFI to assess private sector interest in working with Northern Virginia agencies. If RFI is successful, issue an RFP for a comprehensive ZEB solution across several agencies.

Coordinating Initiatives & Considerations

The Virginia Department of Transportation (VDOT) has extensive expertise with P3s and could be a resource for future RFPs.

Level of Effort	Return on Investment	Priority
High	**High**	**Medium**
Upfront planning for RFI. Could require hiring external advisors.	Well-designed P3 could result in better integration of ZEB infrastructure.	Need to determine industry interest and potential viability before individual agency transitions are too advanced.

6. Support ZEB Workforce Training and Education

Description

Agencies face a continued labor shortage and competition for skilled staff. As their fleets transition to ZEB, there is widespread need to attract new workers with new skills and retain existing workers who may be reluctant to up-skill. As such, it is imperative that transit agencies, planning organizations, OEMs and educators come together to address this issue.

Transitioning to ZEBs is complex. It requires substantial changes to the service and operations planning process, not just operations staff training. Potential issues include:

- Existing workers may start to share new responsibilities, e.g., having dispatch and operators monitor remaining range during service.
- Existing functions may incorporate new skills, e.g., planning staff using new operations data on range to prepare realistic block designs and schedules.
- Agencies have found that mechanics who work on internal combustion engines (ICE) may not want to work on ZEBs. Agencies must figure out how to utilize the skills and interests of workers during the transition.
- Operators and mechanics need hands-on experience and clear understanding of how operating procedures and practices may differ with a zero-emission vehicle.

Community colleges play an important role in training mechanics and operators. Agencies can take advantage of existing relationships with these institutions to train their workforce. Agencies can supplement outside instruction at community colleges or elsewhere with in-house hands-on training, such as an apprenticeship or mentorship program. Finally, transit agencies can work with community college advisory committees to develop more effective curriculum that meets future workforce needs.

NVTC can support workforce training by partnering with DRPT, NVTC-district transit agencies, regional partners (e.g., WMATA, PRTC, Transportation Planning Board, Maryland Transit Administration and District Department of Transportation), colleges and OEMs to develop strategies to improve the workforce pipeline, training, roles and coordination among all groups on this topic.

NVTC Actions

6A – Identify and Share ZEB Training Resources: Coordinate with regional partners and DRPT to understand existing regional efforts and initiatives. Track new training programs available through the Transit Workforce Center and APTA.

6B – Engage with Educational Institutions, Regional Partners and DRPT about ZEB Training Opportunities: As agencies or educational institutions develop their own training programs, coordinate among them to better understand training needs, capacity constraints, etc.

Coordinating Initiatives & Considerations

Explore feasibility of multi-state training program with partners in the District of Columbia and Maryland.

DRPT Modernizing Transit Fleets Project and subsequent initiatives.

Level of Effort	Return on Investment	Priority
Low	**High**	**Medium**
Low degree of staff time required to identify and coordinate about resources.	This should reduce the gap in skilled workforce and increase the expertise of the workforce.	A fundamental need and urgent matter to ensure the delivery of high-quality service.

4. Implementation Plan and Strategy

NVTC will work with a variety of stakeholders to implement the strategies in this plan, which allocates regional priorities over three time horizons and is meant to complement each agency's individual ZEB Transition Plan. For example, each agency's choice of ZEB technology informs industry discussions and impacts the potential scale of a regional ZEB public-private partnership. Conversely, the ability to secure funding at the regional level may enable individual agencies to accelerate their ZEB transition.

The Northern Virginia ZEB Strategic Plan is designed to be implemented gradually, starting with relatively small scale "quick wins" that can be delivered in year one. Larger scale initiatives follow as they require more time to plan and fund. They will also build upon the successes and lessons learned from the initial wave of projects.

The phased approach is also necessary to balance NVTC's available resources in the shorter term with the need to move fast to meet ZEB mandates, implement priority policy initiatives and keep pace with technology. The overall approach to the implementation strategy is shown in Figure 8.

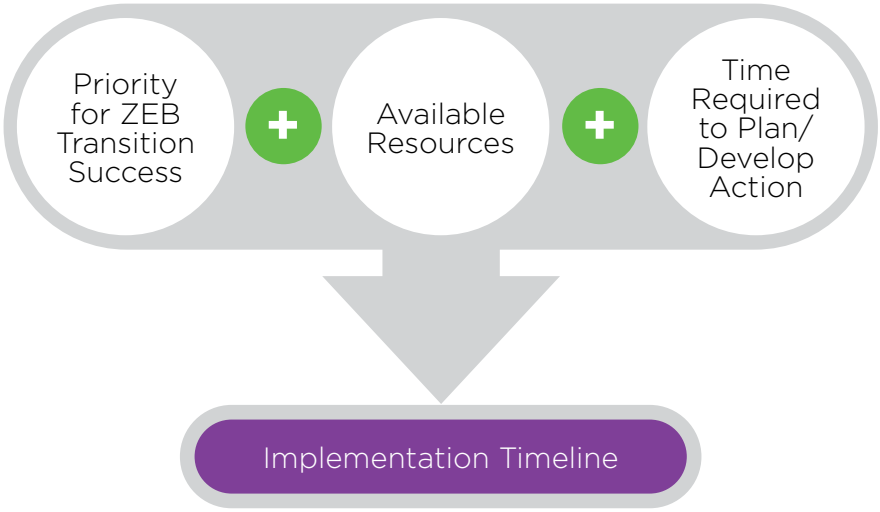


FIGURE 8: Northern Virginia ZEB Strategic Plan implementation strategy

Implementation Timeline

The implementation of the Strategic Plan is divided in three phases:

Quick Wins (Year One)	Short Term (2-3 Years)	Long Term (3+ Years)
Actions that are relatively small in scale and therefore do not require major resource increases.	Actions which build upon lessons learned from year one and require additional resources.	Actions which require longer lead times, a greater degree of coordination and/or additional investment.

Quick wins are actions that are relatively small in scale and therefore do not require major resource increases or lengthy procurement timelines. These actions will have a positive impact on the region's adoption of ZEBs by encouraging data sharing and studying the feasibility of innovative approaches like shared facilities and P3s. They are also building blocks for future initiatives.

Once the quick wins have been realized in the first year, actions identified for the two-to-three year timeframe are larger in scale and build upon year one lessons learned and successes. These actions require more resources and planning than quick wins and are also expected to have a greater impact on regional ZEB transition.

After the initial three years of implementation, NVTC and its partners will deliver the final phase of actions that build upon the activities completed to-date and support the full-scale transition to ZEBs in the region.

NVTC has identified six strategies in support of Northern Virginia transit agencies' zero-emission bus transitions.	**Quick Wins** (Year One)	**Short Term** (2-3 Years)	**Long Term** (3+ Years)
Strategy 1 - Serve as a Regional ZEB Forum			
1A - Continue to Facilitate ZEB Working Group			
1B - Share Operational Data and Findings			
Strategy 2 - Advocate for Consistent and Supportive ZEB Standards and Policies			
2A - Educate Staff and Local Elected Officials			
2B - Advocate for Legislative Support			
2C - Encourage Interoperability			
Strategy 3 - Provide Regional ZEB Funding Coordination			
3A - Create a ZEB Funding Strategy			
3B - Develop Multi-Agency ZEB Grant Applications			
3C - Identify Joint ZEB Procurement Opportunities			
Strategy 4 - Support Development of Shared BEB Charging Infrastructure			
4A - Conduct a Shared Charging Feasibility Study			
4B - Pilot Shared On-Route Charging Station			
Strategy 5 - Evaluate Opportunities for Private Partnerships Related to ZEBs			
5A - Host Industry Listening Sessions			
5B - Create Transit Technology Proposal Process			
5C - Develop ZEB Request for Information			
Strategy 6 - Support ZEB Workforce Training and Education			
6A - Identify and Share ZEB Training Resources			
6B - Engage with Educational Institutions, Regional Partners and DRPT about ZEB Training Opportunities			

FIGURE 9: NVTC ZEB Strategic Plan implementation strategy

Stakeholder Involvement

NVTC has primary responsibility for the implementation of the actions listed in this Plan, but numerous other stakeholders will play an important part in the successful transition to ZEBs in Northern Virginia. NVTC jurisdictions, Northern Virginia transit agencies, regional bodies and other entities such as utilities and universities are called upon to support action implementation (e.g., with human resources, financially or through complementary initiatives). Figure 10 below presents the universe of stakeholders that will be consulted and/or active in the implementation of the ZEB strategies.

 **NVTC Jurisdictions**	 **Northern Virginia Transit Agencies**	 **Regional/Statewide Bodies**
▪ Arlington County ▪ City of Alexandria ▪ City of Falls Church ▪ City of Fairfax ▪ Fairfax County ▪ Loudoun County	▪ ART ▪ CUE ▪ DASH ▪ Fairfax Connector ▪ Loudoun County Transit ▪ OmniRide ▪ WMATA Metrobus	▪ DRPT ▪ MWCOG TPB ▪ NVTA ▪ VDOT ▪ WMATA ZEB Subcommittee
 **Utilities/Energy Organizations**	 **Training/Education**	 **Industry**
▪ Connected DMV ▪ Dominion Energy ▪ Washington Gas	▪ APTA ▪ Northern Virginia Community College, Local Universities ▪ Transit Workforce Center	▪ Transit Bus OEMs ▪ Charging Station Manufacturers ▪ Energy Management/Charge Management Vendors ▪ Telematics Vendors ▪ Software Providers

FIGURE 10: Stakeholder engagement matrix

Funding Strategies

Potential funding sources available to support the implementation of the Northern Virginia ZEB Strategic Plan are summarized below. They are extracted from a more comprehensive list of federal, state, local and private sources of funding and financing compiled for infrastructure projects and vehicle procurements, most of which are not applicable to the implementation strategies in this Strategic Plan.

At the federal level, limited funding is available for ZEB planning activities such as the ones included in this Strategic Plan. The FTA Low-No discretionary grant program does not provide funding for feasibility studies or demonstration projects. The highly competitive nature of multi-modal discretionary grant programs such as the Multi-modal Project Discretionary Grant (MPDG) and Rebuilding American Infrastructure with Sustainability and Equity (RAISE) programs makes them a better fit for ZEB deployment than for planning and data sharing projects. The Strengthening Mobility and Revolutionizing Transportation (SMART) discretionary grant program, which is funded at $100 million annually through 2026, lists system integration projects among eligible activities. There could also be opportunities under agencies other than USDOT such as the Environmental Projection Agency (EPA) and the Department of Energy (DOE), both of which have grant programs targeting zero-emission fuels and decarbonization projects.

State discretionary grant programs administered by DRPT are a better fit for the actions recommended in this Strategic Plan. These include the Technical Assistance grant and the Demonstration Project Assistance grant program Type 2, which funds up to 80% of costs for technology and innovation projects. The case could be made that the sharing of on-route charging facilities is an innovation. To be eligible, the on-route charging project would need to be included in the local transit system's Transit Development Plan (TDP), Transit Strategic Plan (TSP) or Transportation Demand Management (TDM) plan.

Local funds are necessary to leverage federal and state grant funds. NVTC and its local jurisdictions will need to coordinate to program funds in transit agency transportation budgets towards the delivery of the actions listed in this Strategic Plan. While many of the quick wins can be implemented within NVTC's existing budgets, larger projects such as the shared charging infrastructure pilot program will require additional local funding.

Private funding is unlikely to be available for the large majority of the actions listed in this plan, with the potential exception of the transit technology proposal process, which could attract interest from a technology provider.

	ZEB Transition Planning	Demonstration Projects	ZEB Deployment
Federal Funding Programs			
SMART		●	
RAISE		●	●
MPDG		●	●
FTA Low-No			●
State Funding Programs			
Technical Assistance	●	●	
Demonstration Project Assistance		●	
Capital Assistance			●

FIGURE 11: Select federal and state funding eligibility

5. Conclusion

NVTC's Northern Virginia Zero-Emission Bus Strategic Plan provides guidance for the Commission to support the region's transition away from fossil-fuel powered transit vehicles. The six strategies provide value to all agencies by considering the diversity present in the region. For example, the state of ZEB transition varies widely among transit providers in Northern Virginia. While some providers have already incorporated ZEBs into operations and are building charging facilities, others have yet to initiate their transition to ZEBs. In addition, the operating environment among transit providers in Northern Virginia is also very diverse, from systems like Loudoun County Transit that operate long-distance commuter bus service, to DASH and ART that operate more compact, higher frequency systems.

The Strategic Plan recommendations define NVTC's role in supporting the region's ZEB transition. The actions outlined in this document align with the Commission's mission and goals by facilitating closer coordination and knowledge sharing among providers, supporting more effective funding and procurement strategies, and helping establish regional solutions for considerations like equipment standards and workforce development.

Many of these recommendations could be accomplished at a larger scale than just Northern Virginia; for example, FTA could define interoperable charging standards for electric transit buses or Virginia, Maryland and the District of Columbia could come together to develop a region-wide workforce development and training strategy. NVTC welcomes any practical solutions and partnerships that go beyond just Northern Virginia. Transitioning to ZEBs will require extensive investment, operational changes, experimentation and learning. NVTC hopes to support these changes and ensure Northern Virginia is a model of inter-agency collaboration.