Modernizing Transit Fleets

A Guidebook to Low- and Zero-Emissions Transit Buses

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Prepared for:

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Peer State Agencies | Four state agencies across the United States participated in one-on-one interviews about similar statewide guidebooks.

Introduction and Guidebook Purpose

Overview and Purpose

The purpose of this Modernizing Transit Fleets: A Guidebook to Low- and Zero-Emissions Transit Buses (“Guidebook”) is to equip interested Virginia transit agencies (“agencies”) with resources to assist with transitioning their fleets to low- and zero-emissions vehicles. This Guidebook provides high-level technical guidance to make the pursuit of modernizing transit fleets—by means of cleaner propulsion technologies—easier to achieve. The Commonwealth of Virginia and the Department of Rail and Public Transportation (DRPT) recognize that providing guidance on low- and zero-emissions fleet transitions is a key component of modernizing travel in Virginia by keeping pace with emerging technology in the public transportation industry.

Planning, Policy, and Governance

This Guidebook builds on, and is a direct product of, the analysis conducted through the ***Virginia Transit Equity and Modernization Study***. That study was realized in 2021, when the Virginia General Assembly passed ***House Joint Resolution 542***, directing DRPT to conduct a needs assessment on transit equity and modernization in the Commonwealth. The study explored topics such as transit, accessibility, technology, electrification, safety, engagement, representation, and infrastructure.

This Guidebook directly addresses six outcomes and recommendations of that study relating to low- and zero-emissions buses, consisting of the following:

- **Establish statewide goals for zero-emissions transit vehicles and a transition plan to convert agency fleets**
- **Conduct recurring assessments of innovation in the zero-emissions transit vehicle industry**
- **Develop implementation resources for agencies to assist with their fleet transition planning**
- **Establish guidance for on negotiating technology contracts**
- **Align MERIT (Making Efficient and Responsible Investments in Transit) program funding with zero-emissions goals**
- **Expand opportunities for technology funding and implementation assistance**

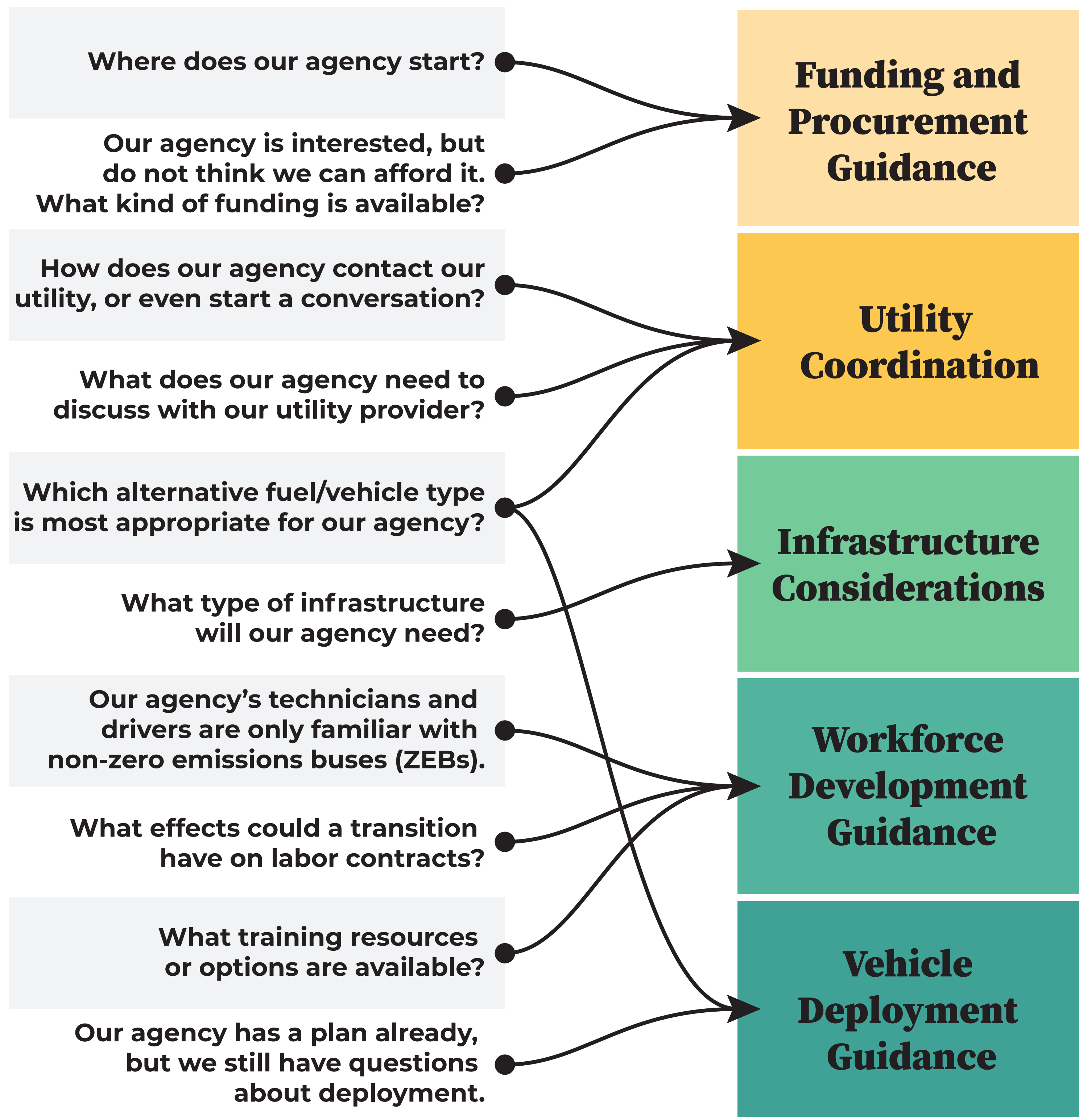
While there are many and varied efforts throughout Virginia toward sustainability in the forms of vehicle electrification, carbon reduction, etc., they are not guided by established guidelines, policies, or priorities at the statewide level. Currently, there are no officially adopted statewide targets, actions, or deadlines for vehicle electrification, carbon reduction, or overall resiliency. Therefore, DRPT allows agencies the autonomy to make their own choices regarding the adoption of low- or zero-emissions transit vehicles.

While there are no clear directives from the Commonwealth that require agencies to transition their fleets by a specified date or achieve a certain emissions reduction goal, the purpose of this Guidebook is to assist agencies in being poised to act strategically, swiftly, and in advance of any state requirements.

How to Use This Guide

This Guidebook can be used in the order of topics presented, or in the order deemed most relevant to an agency's needs or transition progress. If the agency is unsure of where to start, consider referencing the chart at right, which outlines the sections addressing various key questions the agency may be asking at this time.

This Guidebook is organized by key topics and should not be interpreted as a step-by-step guide, nor should it be interpreted as preferring or specifying which propulsion technology/technologies should be selected by agencies. Although there is an implicit and necessary chronology of various steps involved in fleet transitions, agencies across the Commonwealth are currently in varying stages of pursuit of transitioning to low- or zero-emissions fleets. In addition, fleet propulsion technologies should not be viewed as one-size-fits-all and should be tested and selected according to each agency's unique service and needs.



Funding and Procurement Guidance

How to Pursue Funding

Identifying Funding Sources

A. RESEARCH AND TRACK POTENTIAL FUNDING SOURCES

Agencies intending to pursue funding opportunities for low- or zero-emissions vehicle transition and deployment efforts should establish a standardized process for tracking public funding sources. To do so, agencies should designate staff to identify funding opportunities and facilitate proposal writing efforts. Upon determining the larger strategic goals for the agency and how the low- or zero-emissions transition would fit within these larger goals, designated staff should begin to identify funding sources at the federal, state, and local levels.

B. ORGANIZE POTENTIAL OPTIONS

It is helpful to identify potential funding sources that may release opportunites that are supportive of an agency's zero-emission efforts. These sources can be collected and organized into a matrix of potential public funding sources. An agency may find it helpful to use software platforms such as Microsoft Excel and Smartsheets to document relevant information, such as deadlines, eligibility criteria, available funding, match requirements, and other items of interest. Where necessary, the agency should provide software

training to enable more effective collaboration between project teams and proposal writers in drafting and submitting applications.

Funding opportunities of interest may include rebates, incentives, grants, utility programs, and more. In conducting funding searches, emphasis should be placed on which elements of funding announcements are clearly within the agency's capabilities, and which elements would require additional assistance.

C. DETERMINE APPROPRIATE SOURCE

For low- or zero-emissions funding opportunities of interest, an agency will need to confirm it is an eligible applicant and has an eligible project to pursue. This may require review by legal and/or other agency staff. Designated proposal staff should familiarize themselves with the solicitation documents and communicate with appropriate staff to verify that the agency is eligible and able to pursue the funding opportunity. To maximize the chances of being awarded funding, agencies should decide if their needs would be best met through the pursuit of smaller, localized opportunities or larger and more competitive solicitations.

Preparing a Grant Application

A. DEVELOP WORKFLOW PROCESSES

After committing to pursue an opportunity, the agency should identify an internal project team based on expertise and availability. Roles for drafting technical content, budgets, project schedules, contract modifications, and other required sections should be clearly delineated. Timelines shared with internal staff should be realistic, with enough time allotted to receive approval from the agency's governing body, in addition to proofread, fix formatting errors, and make sure the project scope is fully addressed in the proposal narrative.

Legal staff should be tasked with reviewing legal terms and should be given sufficient time to review contract documents and submit contract modifications (if allowed by the solicitation). Similarly, financial staff will need time to review and provide feedback on payment-related requirements. If an agency is required to obtain management and/or board approvals to pursue an opportunity and/or submit an application, that should be factored into the timeline. Additional requirements, including collaboration with a disadvantaged business enterprise (DBE), may need input from multiple staff and will need to be noted while developing proposal workflows. The designated proposal writer will be responsible for guiding internal staff through this process by identifying content within the solicitation that will need additional review.

Emphasis should also be placed on opportunities to join pre-proposal webinars or ask questions to the funding organization to better understand a solicitation. Due to a multitude of factors, funding opportunities may have unclear language. Although the responsiveness of the funding agency to questions may vary, gaining clarity on solicitation language and requirements can help make an agency's proposal more competitive and increase chances of being awarded funding.

B. DRAFTING A PROPOSAL NARRATIVE

The agency may consider using the solicitation as a reference to make a template or outline for the proposal narrative, especially if the funding opportunity includes a rubric for how proposals will be evaluated. In drafting a grant proposal, designated proposal writers should collaborate closely with the agency staff who would manage the project if awarded so that the agency fully addresses how it will meet solicitation requirements. Depending on the solicitation requirements and complexity, the agency may need to build out a larger team.

C. PROJECT PARTNER CONSIDERATIONS

In applying for projects, agencies should consider their capacity to meet the technical needs of the project, including access to technical and managerial project staff with the bandwidth to fully support the project. If an agency does not have such staff, they should consider naming a partner organization with the required credentials to submit a competitive application, if allowed by procurement guidelines of the agency and the funding organization. Proposed project team members from each organization should meet to negotiate project roles and proposal responsibilities as early in the proposal writing process as possible. Partner organizations should also be available to help agencies address questions related to project priorities that are included in the funding application.

Another approach to working with other organizations for a project proposal involves utilizing consultants to facilitate the proposal writing process. If an agency is interested in pursuing multiple funding opportunities within a given timeframe, they may benefit from leveraging resources available through a bench contract to draft the proposal as a service. This approach may allow an agency to pursue a proposal in instances where the agency has the technical capabilities to complete a project without having available designated staff to coordinate the proposal writing process.

D. ADDITIONAL REQUIREMENTS

Solicitations will often ask for references to verify the experience of applicants. Designated proposal staff should prioritize selecting references similar in scope to that of the solicitation. Additionally, the selected reference organizations should have a good working relationship with the applying agency as well as staff who will be responsive to outreach from the funding agency.

Achieving equity as a project benefit has also become an increasingly important factor in submitting proposals. Examples of this include a requirement of collaboration with a disadvantaged business enterprise, focusing the project activities on disadvantaged communities, working with diverse partners, and/or including content addressing the triple bottom-line (environmental, social, and economic) equity associated with the proposed project—all of which may set an agency apart from competitors when applications are being evaluated.

Lastly, agencies should consider any and all technical difficulties that may arise prior to submitting a proposal. Factors that regularly affect timely submission of a proposal include the mode of submission (digital or physical), the time zone of submission, the number of signed forms needed to submit a complete application, notary requirements, and acknowledgment of solicitation addenda. After submission, the designated proposal writer and project staff should (depending on the solicitation) prepare for a potential interview with the funding organization. Through comprehensively addressing the scope content and addressing questions, an agency may successfully transition from being an applicant to being a funding recipient.

Funding Sources for Low- and Zero-Emissions Transit

Transitioning to a low- or zero-emissions bus fleet increases overall fleet costs because of the incremental cost of zero-emissions buses, the installation of new infrastructure, and required modifications to maintenance facilities. The average cost of a forty-foot (40') electric bus purchased in Virginia since 2020 is $930,000, which is 71 percent more expensive than an equivalent diesel bus purchased during the same time period.[1] Additionally, the necessary infrastructure to support these buses adds to the financial burden of transitioning to a low- or zero-emissions fleet. Sources of funding for transitioning to low- or zero-emissions vehicles are available at all levels of government in the Commonwealth. These funding sources, while competitive, can help provide agencies with the purchasing of specific transition needs related to both vehicles and infrastructure. They help alleviate the amount of local funds needed to complete procurement. Below are some examples of low- and zero-emissions funding at the regional, state, and federal level.

Regional Funding Sources

Regional funding for low- and zero-emissions fleet transition differs from state funding in its focus on addressing specific regional transportation needs and challenges. While state funding may have broader goals and criteria, regional funding tends to be more tailored to the unique circumstances and priorities of a particular area. Typically, regional funding takes the form of make-ready programs or a regional fund from a regional agency or other public agency funding.

MAKE-READY PROGRAMS

Make-Ready Programs typically involve infrastructure development and upgrades to support the widespread adoption of zero-emissions vehicles, such as electric vehicles (EVs). The term "make-ready" refers to the process of preparing or "making ready" a location for the installation of charging infrastructure, such as electric vehicle charging stations. This funding is typically provided by utility providers within a region and has been offered in Virginia previously, including through Dominion Energy. Note, Dominion Energy had previously included Make-Ready funds as part of its Smart Charging Infrastructure Pilot (SCIP) Program, which ended on December 31, 2022. For future Make-Ready programs, regional utility providers, such as Dominion Energy, Appalachian Power Company, or Kentucky Utilities, may offer funding to support EVs.

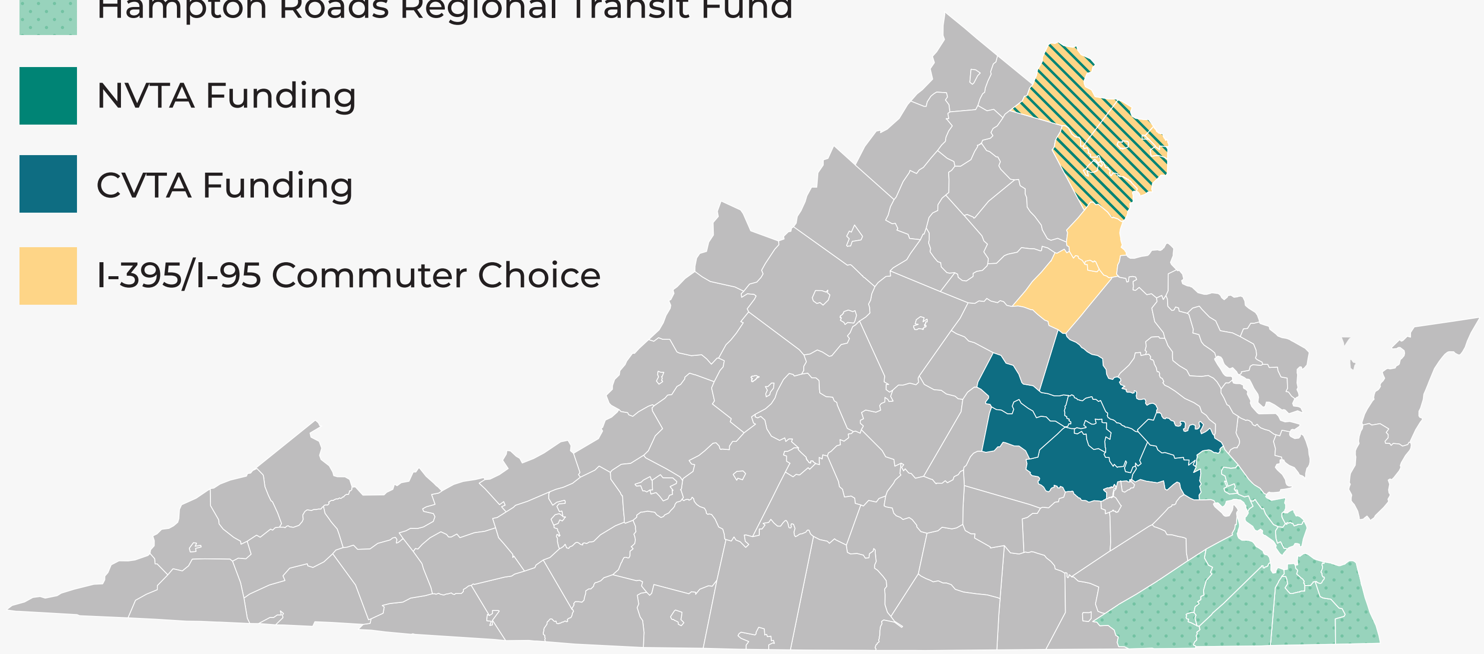
1 *This comes from the vehicle purchase price reported in TransAM from 2020 to Fall of 2023.*

REGIONAL FUNDING PROGRAMS

In Virginia, different agencies offer regional funding programs, such as the **Hampton Roads Regional Transit Fund**, a resource designated to support transit-related projects and initiatives within the Virginia Beach region. It aims to improve public transportation services, infrastructure, and accessibility in the area. Additionally, **Northern Virginia Transportation Authority (NVTA)** funding exists to serve agencies within the Northern Virginia region, therefore allowing agencies within that region to qualify for funding, though it excludes those outside of the region. Furthermore, the following includes other regional funds available to specific regions of the state:

- **I-395/I-95 Commuter Choice** *(Applicable to I-66 and I-395/95 corridors in Northern Virginia)*
- **Central Virginia Transportation Authority (CVTA) Funding** *(Applicable to Richmond, VA region)*

Figure 1. Regional Funding Opportunity Coverage



State Funding Sources

In addition to federal and regional funding, the State of Virginia offers funding for any agency in the state. These funds typically come from the Virginia Department of Transportation (VDOT) and the DRPT. State Funding sources that agencies can consider include:

MERIT GRANTS (DRPT)

MERIT (Making Efficient and Responsible Investments in Transit) is a statewide grants program that provides financial assistance to support public transportation services throughout the state. Under the program, there are several different individually administered grant programs, including:

- **Operating Assistance:** DRPT provides funding for operating expenses for eligible public transportation services and uses a performance-based methodology to determine the specific allocation of operating assistance funds to each operating agency. The program funds no more than 30 percent of all operating expenses borne by public transportation operators.[2]
- **Capital Assistance:** DRPT allocates funding for capital projects and investments based on the following categories: (1) State of

2 https://drpt.virginia.gov/our-grant-programs/making-efficient-and-responsible-investments-in-transit-merit/

Good Repair, (2) Minor Enhancement, and (3) Major Expansion. Applicants that are eligible for federal public transportation grant programs may combine federal and state capital assistance grant funds to decrease the local match needed for each project. A minimum four percent local match is necessary for all projects.

- **Demonstration Project Assistance:** DRPT administers the Demonstration Project Assistance grant program, which is a competitive grant program that supports local efforts to improve transit reliability, access to housing and employment centers, and public transportation mobility options.
- **Technical Assistance:** DRPT's Technical Assistance grant program supports studies, plans, research, data collection, and evaluation projects to help improve public transportation services. This includes providing technical analysis and guidance on operations, service delivery, customer service, expansions of service, and program delivery.
- **Public Transportation Workforce Development Program:** DRPT provides this grant program to cover eligible expenses including wages, fringe benefits, training, and travel for apprenticeships in public transportation operations such as mechanics, operators, dispatchers, and operations supervisors. This includes both post-collegiate apprenticeships and pre-graduate training. This program is not for staff augmentation and requires an open recruitment process to select qualified individuals

For Fiscal Year 2025, DRPT began accepting applications on December 1, 2023. Agencies can apply for this funding in several ways, such as applying for capital assistance for bus purchases during the procurement stage. Alternatively, agencies could also apply for technical assistance funding to fund studies related to zero-emissions transition studies and route modeling studies.

SMART SCALE (VDOT)

The SMART SCALE grant program, managed by VDOT, prioritizes transportation projects based on a data-driven approach to maximize efficiency and effectiveness in infrastructure investment. Projects are evaluated and scored using a set of objective criteria aligned with statewide transportation goals, including reducing congestion, improving safety, enhancing accessibility, and supporting economic development and environmental sustainability. The SMART SCALE process involves rigorous analysis and public engagement to ensure transparency and accountability in project selection. Funding decisions are made based on the project's ability to deliver measurable benefits and achieve strategic objectives, fostering a more equitable and resilient transportation system across Virginia.[3] SMART SCALE only funds projects that result in transit expansion, so it is not intended for projects focused purely replacing existing fleets. Agencies can use this grant in the case of expanded service or expanded facilities such as a bus depot to support a larger fleet. SMART SCALE projects are evaluated on five categories, of which environmental quality is only 10 percent, so this funding only makes sense for projects that also address safety, congestion mitigation, accessibility, and/or economic development

3 https://smartscale.org/

SMART SCALE projects follow the following schedule and application process:

- **Call for Applications:** VDOT announces the opening of the SMART SCALE application period, inviting localities, regional entities, and transportation agencies to submit project proposals.
- **Application Submission:** During this phase, interested parties prepare and submit project applications according to the guidelines provided by VDOT. Applications typically include detailed information about the proposed projects, such as scope, cost estimates, expected benefits, and alignment with SMART SCALE criteria.
- **Evaluation and Scoring:** VDOT evaluates each project application based on a set of objective criteria, including factors like congestion reduction, safety improvement, accessibility enhancement, economic development impact, and environmental considerations. Projects are scored and ranked based on their anticipated performance against these criteria.
- **Public Review and Input:** VDOT provides opportunities for public review and input on the proposed projects and their scores. This ensures transparency and allows stakeholders, including community members and local officials, to provide feedback on the prioritization process.
- **Funding Allocation:** After completing the evaluation and review process, VDOT allocates funding to the highest-scoring projects based on available resources and strategic priorities. Funding decisions aim to maximize the overall benefit to the transportation system and the state.
- **Implementation:** Once funding is allocated, selected projects move into the implementation phase, where planning, design, and construction activities take place. VDOT works closely with project sponsors to ensure that SMART SCALE-funded projects are successfully delivered on time and within budget.

Pre-applications for SMART SCALE started on March 1, 2024, and closed on April 1, 2024. Full applications open on June 1, 2024, and are due by August 1, 2024. As part of the pre-application process, applicants must clear three “Readiness Gates” during the application development process to ensure that support documentation is completed in a timely manner. The three gates are: 1. pre-application submission, 2. pre-application to full application conversion, and 3. full application submission.

STATE CONTRACTS AND PROCUREMENT

In conjunction with the statewide funding sources, the Commonwealth of Virginia holds a state procurement contract that includes diesel-fuel buses, CNG buses, hybrid-electric buses, battery electric buses (BEBs), and fuel cell electric buses (FCEBs). It should be noted that the state procurement contract can be difficult to navigate, therefore, agencies are recommended to engage with original equipment manufacturers (OEMs) and/or DRPT about procurement if necessary. It should be noted that Virginia has an open cooperative agreement for their state contract, which allows agencies in other states to procure using the Virginia state contract. The following manufacturers of low- or zero-emissions buses—ranging from 29' to 60' vehicles—are included on the state contract:

- **Gillig:** 35'-40' Battery Electric Buses, 29'-40' CNG Buses, 35'-40' Hybrid Buses
- **New Flyer:** 35'-60' Hybrid Buses, 35'-60' Battery Electric Buses, 40'-60' FCEBs, 35'-60' CNG Buses
- **ENC:** 32'-40' CNG Buses, 40' Battery Electric Buses, 40' FCEBs

In addition to 29' to 60' buses, the Commonwealth also holds state contracts for the following low- and/or zero-emissions smaller vehicle types:

- **Raised Roof Vans:** Battery Electric
- **BOC / Cutaway:** Soon updated to include CNG, Propane, and Hybrid
- **Low Floor BOC / Cutaway:** Battery Electric

Not all low- and zero-emissions bus manufacturers sell the associated charging infrastructure for their vehicles, which means compatibility between charging/fueling equipment with alternative fueled vehicles should be verified by manufacturers.

Federal Funding Sources

The federal government funds transit primarily through the Federal Transit Administration (FTA), but agencies can also access funds through the Federal Highway Administration (FHWA), Department of Energy (DOE), and Environmental Protection Agency (EPA). The FTA provides annual formula funds as well as competitive grant programs. FTA funds can generally only be applied to capital expenses except in specific cases such as rural transit and for maintaining compliance with the Americans with Disabilities Act and the Clean Air Act. Federal funding sources agencies should be considering include:

LOW OR NO EMISSION (LONO) VEHICLE PROGRAM (FTA)

The LoNo Vehicle Program (49 U.S.C. 5339(c)) is a competitive grant that funds the modernization of aging fleets with low- to no-emissions buses, renovation and/or construction of bus facilities, and supports workforce development. The federal share is up to 80 percent of the total cost of the project; thus, agencies must demonstrate the source of the remaining 20 percent of funding, which can include:

- Cash from non-government sources other than revenue from providing public transit services
- Sale of advertising and concessions
- Funding received under service agreement with a state/local social service agency or private social service organization
- Revenue from value capture finance mechanisms
- Funds from an undistributed cash surplus
- Replacement/depreciation cash fund or reserve
- New capital
- In-kind contributions
- Transportation development credits or in-kind match (must be documented in the application)
- Other non-federal funds

The LoNo Vehicle Program can provide a significant source of funding for agencies in initiating its transition to a cleaner fleet. In the Federal Fiscal Year 2023, the grant provided nearly $1.7 billion from the Bipartisan Infrastructure Law that supported 130 projects across 46 states/territories.

GRANTS FOR BUSES AND BUS FACILITIES PROGRAM (FTA)

The Grants for Buses and Bus Facilities Competitive Program (49 U.S.C. 5339(b)) makes federal resources available to agencies to replace, rehabilitate, and purchase buses and related equipment and to construct bus-related facilities, including technological changes or innovations to modify low- or no-emissions vehicles or facilities. Funding is also provided through formula allocations. Like the LoNo Vehicle Program, applicants must submit a Zero-Emission Transition Plan if the fund is to be used toward purchasing ZEBs and supporting infrastructure.

DOE FUNDING

The DOE frequently offers funding for electrification or other clean-energy projects related to transit and transportation. Previously, the DOE selected 16 projects totaling $32.5 million to advance technology integration in areas critical to achieving net-zero greenhouse gas emissions in the transportation sector, which focused on expanding EV deployment and supporting EV charging infrastructure by reducing installation costs, educating consumers, and implementing regional deployment. Future funding opportunities may become available from the DOE.

NATIONAL ELECTRIC VEHICLE INFRASTRUCTURE PROGRAM (NEVI)

The National Electric Vehicle Infrastructure Program (NEVI) is a funding initiative administered by the DOE through the Alternative Fuel Infrastructure Grant Program. The program aims to accelerate the adoption of EVs by supporting the development of EV charging infrastructure across the United States. The funding is allocated to states based on a formula that takes into account population and EV registration data. States then distribute these funds to eligible entities, such as local governments, businesses, and non-profits, to install EV charging stations in strategic locations. The program is intended to expand access to charging infrastructure and encourage the widespread adoption of electric vehicles, thereby reducing greenhouse gas emissions and dependence on traditional fossil fuels. The FHWA is responsible for allocating funds from the NEVI Program Formula Program annually until Fiscal Year 2026. This allocation ensures that each state receives an amount determined by the FHWA funding formula outlined in 23 U.S. Code 104. In order to qualify for funding, states must submit plans to both the FHWA and the Joint Office of Energy and Transportation on an annual basis.

This program requires chargers to be publicly available or available to multiple commercial carrier companies and prioritizes FHWA-designated Alternative Fuel Corridors (AFCs). Therefore, this funding is not available for typical bus depot charging but could be used for supplemental on-route charging at a public charging location; for example, providing on-route charging for paratransit vehicles at points of interest like a shopping center or medical facility.

Other Federal Funding Sources and Programs

The **Formula Grants for Rural Areas** initiative furnishes financial aid, including capital, planning, and operational support, to states in order to bolster public transportation systems in rural regions with populations under 50,000. These areas typically have a significant portion of residents dependent on public transit for their travel needs. Additionally, the program allocates funds for state and national training as well as technical assistance through the Rural Transportation Assistance Program.

The United States Department of Transportation's (USDOT) **Rebuilding American Infrastructure with Sustainability and Equity (RAISE) Discretionary Grants**: USDOT offered grants for projects that achieved significant reductions in diesel emissions and exposure, particularly from fleets operating in areas designated by the USDOT Administrator as poor air quality areas. The program closed in 2023, but future funding may be available.

Transportation Infrastructure Finance and Innovation Act (TIFIA) Rural Project Initiative (RPI): The RPI, through USDOT, is a loan program designed to improve transportation and transit infrastructure in rural communities. Eligible projects include transit systems, including infrastructure, bus stations, and facility improvements.

Table 1. Summary of Applicable Funding Source

Funding Opportunity Name	Administer of Funding	Funding Applicability				
		Low- or Zero-Emissions Vehicles	Facilities	Workforce Development	Charging Equipment	Feasibility/ Implementation Plan
FEDERAL						
Federal Grants for Buses and Bus Facilities Competitive Program [5339(b)]	FTA	✦	✦			
Federal Low or No Emission Vehicle Program [5339(c)]	FTA	✦	✦	✦	✦	
Congestion Mitigation and Air Quality (CMAQ) Improvement Program	FHWA/FTA	✦			✦	
RAISE Discretionary Grants	USDOT	✦	✦		✦	
Capital Investment Grants (CIG) Program	FTA	**Only applicable to new or extended bus rapid transit (BRT) separated guideways**				
STATE						
Capital Assistance (MERIT)	DRPT	✦	✦			
Carbon Reduction Program (CRP)	VDOT	✦	✦		✦	
Demonstration Project Assistance (MERIT)	DRPT	✦			✦	
Technical Assistance (MERIT)	DRPT					✦
SMART SCALE	Virginia Commonwealth Transportation Board (CTB)	✦[a]	✦[a]		✦[a]	
Public Transportation Workforce Development Program (MERIT)	DRPT			✦		
Operating Assistance (MERIT)	DRPT					
REGIONAL						
I-395/I-95 Commuter Choice	Northern Virginia Transportation Commission (NVTC)	✦[b]	✦[b]		✦[b]	
General NVTA Funding	NVTA	**Not specified**				
Hampton Roads Regional Transit Fund	Hampton Roads Transportation Accountability Commission (HRTAC)	✦	✦		✦	
Central Virginia Transportation Authority (CVTA) General Funding	CVTA		✦		✦	✦

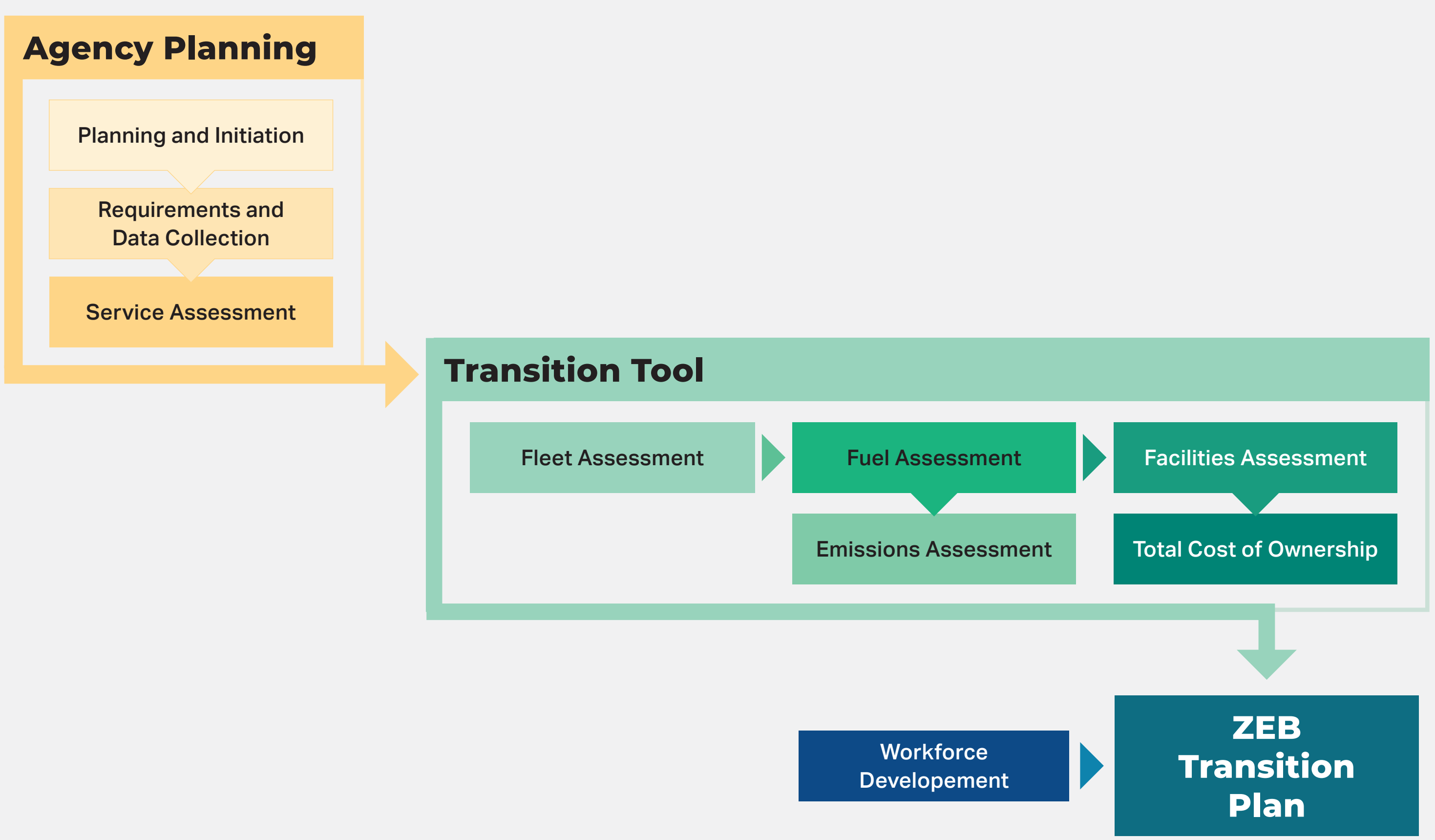
[a] *Applicable to capacity expansion only*
[b] *Applicable to service enhancements only*

Fleet Transition Template and Tool

In the previous section, there is guidance pertaining to how to pursue funding and what those funding sources are that may be applicable to a particular agency. In this subsection, the agency will be provided information that aids in their understanding of the specific needs for low- or zero-emissions transition. This section will outline the planning tool needed to initiate short- and long-term low- or zero-emissions transition planning. This section will detail the Transition Plan Data Input Tool ("Tool"). This Tool is instrumental in helping the agency understand operational and financial needs as they work through a phased approach to introduce new technology to their fleet.

The Tool is a Microsoft Excel spreadsheet comprised of a comprehensive set of worksheets that are designed to guide the agency as they work through development of their low- or no-emissions vehicle long-term transition plan. The Tool was developed primarily based on the Center for Transportation and Environment's (CTE) Transition Planning Methodology, which is a complete set of analyses used to inform agencies in converting their fleets to zero-emissions. The methodology consists of data collection, analysis, and assessment stages; these stages are sequential and build upon findings in previous steps. For this tool, CTE collaborated with Arcadis to incorporate an "Emission Calculations Output" tab that aids in estimating emissions per year, infrastructure cost projections, and total cost of ownership inputs. Steps specific to this tool are outlined in **Figure 2**.

Figure 2. ZEB Transition Plan Methodology



Agency Planning

It is important for the agency to follow the sequential steps outlined in the ZEB Transition Plan Methodology. These phases are designed to help agencies understand ZEB technologies and how to plan for successful deployments.

Upon completion of these phases, agencies should have all information required to complete their Low- or Zero- Emission Transition Plan Report. The eight phases of the methodology are outlined below for additional context.

PLANNING AND INITIATION

During the planning and initiation stage, agencies should conduct initial meetings with applicable stakeholders to understand important aspects to consider pertaining to the ZEB transition plan. Stakeholders to consider may be planning, procurement, operations, IT, maintenance, and facilities staff. The following questions should be considered during the planning stage:

- Has the agency collected or have access to relevant data and information to support analyses needed for Low- or ZEB Transition Planning?
- Has the agency set fleet transition planning goals based on local priorities, constraints, and regulatory requirements?
- Has the agency initiated or completed a discussion with the appropriate utility provider or hydrogen supplier?
- Has the agency identified funding sources to support the procurement of Low- or ZEBs and fueling infrastructure?
- Has the agency begun working on the following activities pertaining to Workforce Development?
- Have the agency contacted transit agencies and/or reviewed published lessons learned from transit agencies that have deployed or are deploying Low- or ZEBs?

REQUIREMENTS AND DATA COLLECTION

In the Planning and Initiation phase, the agency will confirm it has collected or has access to the relevant data and information required to support the analyses needed for low- or ZEB transition planning. In the Requirements and Data Collection phase of this process, the agency will gather required data that will be used as inputs for the Tool. The list below are examples of the data that agencies should review prior to starting the inputs for the Tool.

- Route and blocking data (e.g., required vehicle type, schedules, mileage)
- Fleet information (e.g., asset type, retirement schedule, annual average mileage, operational costs, maintenance costs). A final wrap-up session to present and discuss findings from each individual group.
- Facilities information (e.g., available power, site constraints, number of depots to be considered)
- Available ZEB models and fueling infrastructure (i.e., BEB chargers and fuel cell electric bus [FCEB] hydrogen fueling infrastructure) and any market constraints that may limit the type of bus or fueling infrastructure deployed
- Maintenance costs (baseline cost per mile, overhaul costs/frequency)

The "Instructions" tab in the Tool defines where the information above will serve as inputs in the Microsoft Excel spreadsheet to produce the results (or outputs) of each assessment also referenced above.

SERVICE ASSESSMENT

The Service Assessment evaluates the expected energy needs for each bus to determine whether zero-emissions technologies have sufficient range to replace current buses on a 1:1 basis and complete every scheduled service day or route assignment. This phase also builds off the Planning and Initiation phase discussed earlier in this section. The results from the Service Assessment are used to guide ZEB procurements in the Fleet Assessment and determine energy requirements for the Fuel Assessment.

For this transition plan guide, agencies should have a basic understanding of the expected energy needs for each bus to determine whether the proposed technology has sufficient range to replace the current technology at a 1:1 basis. If the ration is greater than 1:1, then the agency should consider alternative solutions such as alternative charging locations (e.g., on-route charging), re-blocking, or multiple ZEBs for challenged routes.

Daily energy needs are dependent on many factors, some quantifiable like vehicle size and others with more variation like driving style. The two biggest factors for a high-level estimate are tractive load (energy needed to drive the vehicle, which is a function of distance) and heating, ventilation, and cooling (HVAC) loads (energy needed for cabin and battery thermal conditioning, which is a function of time in service). Unlike conventional gasoline or diesel-powered vehicles that have a large amount of waste heat from combustion engines to heat the cabin in cold weather, BEB propulsion systems generally operate above 90 percent efficiency, generating very little waste heat. As a result, cabin heating in cold conditions draws heavily from the battery and consume energy that could otherwise be used for driving. This concept is key for BEB planning – transit operators need to consider the ambient temperature as a key input to vehicle range.

Note that these values are estimates and planning specific to service and climate are needed for more precise analysis. This information does not consider all locally unique variables, like terrain, driving style, traffic, high passenger loading, or slippery road conditions where regenerative braking is disabled. For a more specific local analysis, agencies may consider working with a specialized industry consultant, looking for resources from the National Renewable Energy Lab (NREL), and joining the Zero Emission Bus Resource Alliance (ZEBRA) professional organization for transit agencies to share ZEB adoption experiences and real-world BEB performance data on a dashboard.

Long term data of a large number of transit agencies shows 40' BEB energy consumption can be estimated around 2.1kWh/mi. In moderate HVAC use days around 65F, agencies will often see well under 2.0mi/kWh and approaching 1.5kWh/mi. In hot weather, where maximum Air Conditioning load is required, energy use may approach 3.0kWh/mi in conditions of 95F. In winter, heating requires more energy than Air Conditioning, energy use can exceed 3.5kWh/mi at 20F if a diesel heater is not in use. Other technology like heat pumps may be available after publication of this guide and their improved energy efficiency is likely to reduce cold to moderate weather range loss. This is based on a state of the market in 2024 and does not consider other technologies that exist but are not in the US market like lighter weight buses, more energy efficient glass, or heated floor panels. Urban areas will often see more energy consumption due to higher passenger loads, more aggressive stop-and-go driving, and more time spent idling at traffic lights.

A cutaway operating in cold winter conditions of around 20F will see 2.5kWh/mi, compared to 2.2kWh/mi around 95F. Around 65F when little to no HVAC is required, cutaways can expect to see around 1.1kWh/mi or even better if conditions are optimal. Diesel heaters can be considered for climates that routinely experience below freezing temperatures in winter to mitigate range loss.

When working with utilities, agencies will need to know their daily energy use and power demand. In today's market, BEB energy storage is often not enough to complete the longest or most challenging routes. A good assumption for predicting energy needs is that no more than 80 percent of a bus's usable battery capacity will be used on a daily basis. For demand, a 150kW charger is adequate to charge two 40' BEBs fully overnight with the batteries on the market today. A 60kW charger can charge two cutaways overnight as their batteries are significantly smaller than full size transit buses as of 2024. Block schedules, parking layouts, and utility time of use rate tables are unique at every transit agency and require specific analysis to determine if the above generalization apply and allow each bus to be fully charged by pull-out time.

ZEB Transition Planning Tool

The Tool was developed to aid agencies in the creation of their specific transition plans that fulfill the requirements for the FTA's LoNo Vehicle Program with a minimum amount of pre-existing knowledge. The Tool's key outputs are the fleet procurement schedule, fleet composition over time, total cost of ownership, and emissions reductions associated with the transition to low- or zero-emissions technologies.

The Tool allows the agency to define their own transition timeline and technology split for a given year. When using the Tool, agencies can adjust the timing of their transition based on their available budget, route feasibility, infrastructure, personnel, or any other constraints that is relevant to the plan. The tool also allows the agency to select the technology that best suits their needs at any given time, which could include a split between battery electric and fuel cell purchases, or a slow phasing-in of a new technology to gain familiarity over time

FLEET ASSESSMENT

The objective of the Fleet Assessment is to evaluate fleet composition over the transition period. This includes all ZEB transition scenarios based on the agency's current procurement cycles. It is important that the agency has access to their baseline fleet data. This data will be used as inputs for the Tool's "Fleet Input" tab.

The Fleet Assessment analyzes the capabilities of current ZEB technologies to meet an agency's service requirements. The existing fleet information is comprised of the number of vehicles used for an agency's operation that include in-service and spare vehicles, the current fuel types of vehicles used in an agency's operation (gas, propane, diesel, biodiesel, compressed natural gas [CNG], etc.), and criteria like vehicle identification number, vehicle length, and annual mileage.

Figure 3. Example of Fleet Inputs

About the Agency	
Average Cost of options for buses:	
Average Cost of options for Cutaways:	
Tax rate for bus purchases:	

Current Bus Fleet Data									
Depot	Bus Length	Bus Series or Bus ID	Fuel Type	First Service Year	Expected Last Service Year	Standard Service Life [years]	Quantity	Annual Mileage Per Vehicle	Fuel Consumption (GGE)
Example	40'	1234	Diesel	2015	2027	12	2	40000	1000

Vehicle Procurement Cost		
Fuel Type and Length	Cost (EXCLUDING Cost of options and applicable taxes)	Source
Bi-Fuel Gas and PropaneCutaway	$ 389,000	Agency Data

ZEB Purchase Percentage			
Year	Battery Electric Purchase Percentage	Fuel Cell Electric Purchase Percentage	ZEB Percentage
2024			0%

Fleet Expansions									
Depot	Bus Length*	Bus Series or Bus ID	Fuel Type	First Service Year	Expected Last Service Year	Standard Service Life [years]	Quantity	Annual Mileage	Fuel Consumption (GGE)

BEB Specifications			
BEB Length	BEB Efficiency	BEB Capacity	BEB Capacity Source
Cutaway			
30'			
35'			
40'			
45'			
Articulated			
Commuter			

The analysis will project the timeline for replacement of existing buses with BEBs and FCEBs. The Fleet Assessment also includes an assessment of projected fleet procurement costs over the transition lifetime.

Agency Data

The agency will input average costs of options for their buses and/or cutaways. The tax rate for the bus purchases will be added here if applicable.

Vehicle Procurement Cost

The agency will input vehicle procurement costs that exclude the cost of options. These costs will align with fuel type and length of the buses. A list of fuel types and lengths are populated but can be edited if necessary.

Current Bus Fleet and Fleet Expansion Data

Fleet data is collected for the specific depot, bus length, bus series or bus identification, fuel type, first service year, expected last service year, standard service life in years, quantity of buses, annual mileage per vehicle, and fuel consumption measured in gasoline gallon equivalent (GGE).

ZEB Purchase Percentage

The ZEB Purchase Percentage section outlines the percentage of the zero-emissions technology by year over the transition timeline. For each year of the transition, the agency should input the percentage of the specified technology.

BEB Specifications

The agency will input specifications for the desired BEB length. Specific inputs include BEB efficiency, capacity, and capacity source.

FUEL ASSESSMENT

The Fuel Assessment uses the outputs from the Fleet Assessment to create a projected timeline for the replacement of current vehicles consistent with an agency's existing fleet replacement plan. Technology constraints and alternative fleet compositions determined by the Service Assessment are considered in the creation of this projected timeline, and the agency makes sure the timeline is in alignment with the agency's sustainability and transition goals.

FACILITIES ASSESSMENT

The Facilities Assessment defines the requirements for charging and hydrogen fueling infrastructure, including operational impact and utility service requirements. The agency develops estimates for equipment and infrastructure, design, construction, and installation costs, space and sitting requirements. The agency evaluates the requirements for upgrading its facilities to be compatible with battery electric and hydrogen fuel cell bus technology and determines the requirements for any hydrogen refueling stations or charging equipment needed to support the fleet, depending on its composition.

The Tool uses assumptions (noted in the "Instructions" tab) and known costs that will be auto populated. The agency can adjust assumptions and costs as applicable (see **Figure 4** for an example).

EMISSIONS ASSESSMENT

The emission assessment will be conducted through use of the Agency Emissions Reduction tool. The agency emissions tool utilizes the EPA's Motor Vehicle Emissions Simulator (MOVES) tool to calculate pollutants at a selected area of operation. The agency will input data for the Agency Emissions Reduction tool from sources including the TransAM platform and default EPA data. Additional information and a more detailed explanation of the data inputs will be provided in the emissions tool section of this Guidebook.

TOTAL COST OF OWNERSHIP

The Total Cost of Ownership Assessment summarizes: the costs of annual bus procurements; annual fuel cost; annual

Figure 4. Example of Infrastructure Inputs

Infrastructure Inputs	
General	
Inflation Rate	*3%*
Existing Conditions	
Number of CNG Maintenance Bays	*3*
Number of Non-CNG Maintenance Bays	*3*
Existing Electrical Power (kW)	*2000 kW*
Fuel Cell Electric Bus Infrastructure Assumptions	
Delivery Type	*Hydrogen Not Used*
Battery Electric Bus Infrastructure Assumptions	
On-Route Chargers	*0*
Dispensers per Charger	*2*
Buses per Charger	*2*
Cutaway Charger Power	*20 kW*
Bus Charger Power	*120 kW*
Costs	
Bus Charger Cost	*$75,000*
Bus Charger Installation Cost	*$5,000*
Cutaway Charger Cost	*$8,000*
Cutaway Charger Installation Cost	*$2,000*
Dispenser Cost	*$2,500*
Dispenser Installation Cost	*$1,000*
Planning Project Cost	*$75,000*

maintenance costs; the costs of charging equipment, supporting infrastructure, facility upgrades; and design, construction, and installation over the transition period. The total cost of ownership assessment uses the fuel type, annual mileage, and fuel consumption of each bus to help determine annual costs.

LONG-TERM TRANSITION PLAN REPORT

Upon completion of the analyses, the agency will have information that will aid in completing a Low- or Zero-Emissions Fleet Transition Plan that adheres to the guidelines set as a part of the Modernizing Transit Fleets project (MTF) and the requirements of 49 U.S.C. 5339(c)(3)(D) Bus and Bus Facilities Competitive Program (BBF). A report template will be available for the agency to complete. This template can be used as a guiding basis for the agency to outline their short- or long-term low- or zero-emissions plans. The plan is divided into six sections, addressing each of the following elements outlined by the FTA:

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

Financial Analysis and Emissions Reduction Tools

As part of the toolkit and guidebook, Financial Analysis and Emissions Reductions tools were created to model costs and emissions related to zero-emission vehicle transitions at both the agency level and state level. The Agency Financial Tool allows an agency to enter information about its current fleet and its desired transition fuel type (i.e., BEB, FCEB, or Mixed-Fleet) and target transition year. The agency also has an opportunity to either use default infrastructure assumptions or input their own data related to vehicle costs or facility costs (note: where possible, entering agency specific data is always preferred). Using those inputs, a projected procurement schedule and fleet inventory by year until 2040 is created. Using that projected fleet inventory and procurement schedule, new capital costs and operating costs are created. Operating costs are also based on factors like fuel cost/mile, which were assembled by evaluating data from DRPT TransAM as well as industry experience. As with infrastructure inputs, however, an agency can always modify those unit prices based on a quote or other knowledge. The resulting output features total cost broken into four major categories: (1) fleet, (2) infrastructure, (3) fuel, and (4) maintenance.

Visualizations are automatically produced to help the agency visualize cost by year for their transition scenario. These graphics can be copied into Low- or Zero-Emissions Fleet Transition Plans or grant applications and play a crucial role in projecting resources for the duration of the transition.

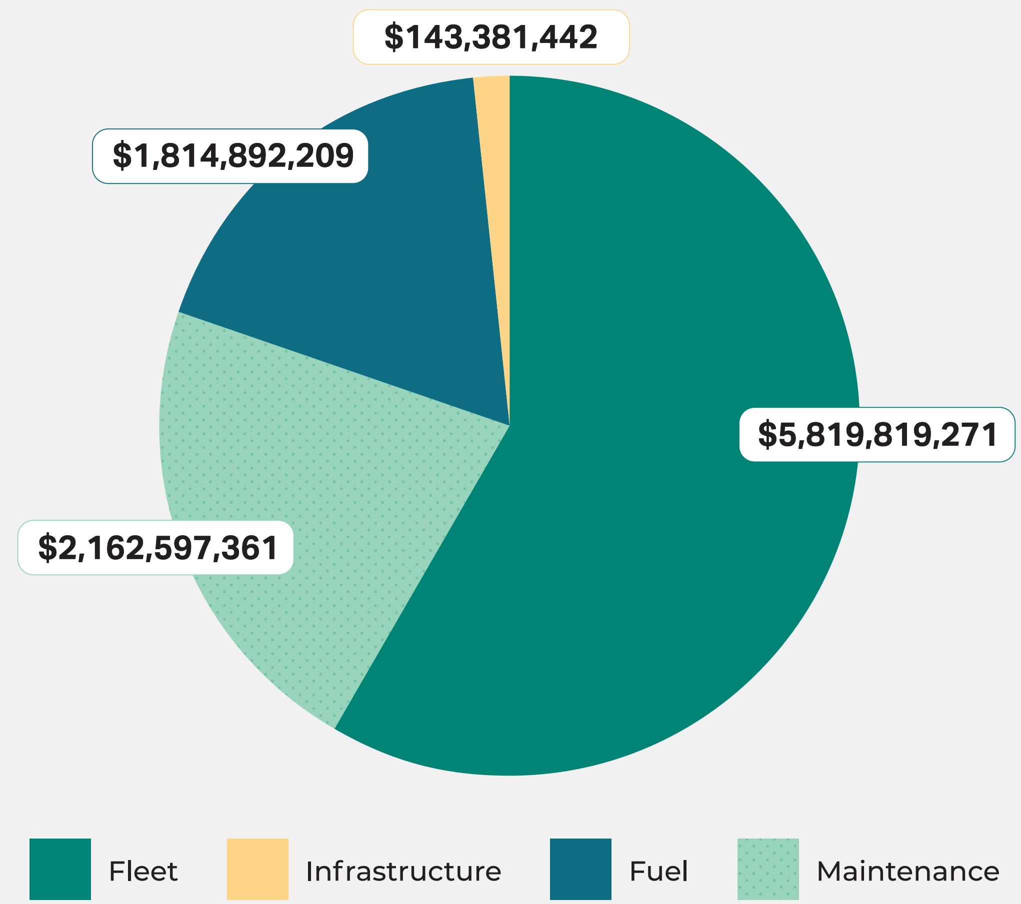
To compare costs across scenarios, agencies can simply alter their target transition fuel type or target year to evaluate the differences in cost. For each scenario that is entered, new graphics would be produced.

Like the Agency Financial Analysis tool, the Statewide Financial Analysis tool uses regional data on vehicle quantities and costs, alongside other sources such as U.S. Energy Information Administration (EIA) fuel estimates and DOE research to estimate the total costs of transitioning the fleet statewide. To use the tool, DRPT (or other users) would simply enter in the desired transition percentage that should be completed by a given year. For example, an agency might input that they want to see the total costs of a 75 percent transition to BEBs statewide by 2035. Using a similar framework as outlined in the agency financial tool, the model would then calculate and output the projected overall costs of transitioning 75 percent of all vehicles by 2035 and provide accompanying graphics as well.

As with the Agency Financial Analysis tool, the Statewide Financial Analysis tool makes default assumptions to assist with evaluating costs automatically. These variables include inputs such as the number of chargers typically needed for each bus or inflation rate. There are additional inputs for adjusting the procurement approach and for adjusting any future legacy fuel vehicle purchases to be cleaner than diesel purchases. These costs can always be modified based on revised information and resulting outputs would reflect those changes as they are made. **Figure 5** shows an example of the visualizations that are produced from the financial tools and includes the cost breakdown by category.

The Agency Emissions Reduction tool and Statewide Emissions Reduction tool utilizes the EPA's MOVES tool to calculate pollutants at a selected area of operation, including at the state level, regional level, or at a smaller, project level. For the agency emissions tool, the procurement tool includes existing MOVES outputs on pollutant rates for CO_2, NOx, $PM_{2.5}$, PM_{10}, and So_2 emissions for gas, diesel, CNG, and electric transit buses. For other types of vehicles, pollutant rates were calculated based on research. These pollutant rates are the imported into the Agency Emissions Reduction tool and Statewide Emissions Reduction tool. In both of these tools, these pollutant rates are then multiplied by mileage statistics, as calculated by the procurement tool based on fleet input. To simulate different scenarios, such as 25 percent BEB scenarios or 75 percent BEB scenarios, agency users can manipulate fleet inputs in the procurement tool to change mileage calculations, which then feed into emissions calculations. Outputs of emission rates and percent changed based on mileage are represented in both tabular and graphical formats.

Figure 5. Example Total Transition Costs by Category



Utility Coordination

Overview of Low- and Zero-Emissions Propulsion Technologies

Battery Electric Buses (BEBs)

BEBs are zero-emissions vehicles (ZEVs) that use electricity as their fuel source and are powered by lithium batteries. Buses "refuel" at electric charging stations and usually run a couple hundred miles before returning to charge again. The lithium battery in the vehicle powers a motor, as opposed to an engine, which provides mechanical force for the vehicle's movement. The battery also powers the vehicle's onboard electronic and air conditioning (A/C) systems. Lithium batteries are large and heavy and will add some weight to the vehicle. They are usually installed in an area that does not reduce passenger count, such as the top or bottom of the vehicle.

FUEL UTILITY

EVs have the most independence from how their fuel is produced. Any form of power plant-producing electricity is producing fuel for BEBs. This means upstream emissions are entirely dependent on how the local grid is powered. Populated areas such as cities and suburbs will have the ability to supply a bus charging station. Rural areas may have some difficulties and require improvements to the local grid.

COMPARATIVE INFORMATION[4]

The range of different buses can vary, but an agency can expect a 200-mile-distance capability for electric buses. Electric buses have less mileage than the other fuel options available. Part of the reason for this shorter distance is that auxiliary functions, such as heating or cooling, draw from the same power source as the vehicle's movement. Special considerations should be taken during planning if the route that the bus is responsible for will be used in more extreme climates.

The charging times of BEBs are extremely dependent on the model of bus and charger being used for the fleet. Overhead conductive charging can recharge buses in as little as 10 minutes. Plug-in charging can be anywhere from two to eight hours. Electric buses have the longest potential "refuel" time of any ZEV or low-emissions vehicle (LEV) option. Electric buses are heavier than their diesel counterparts. This should be taken into consideration when choosing a ZEV or LEV option for transit routes with weight limits. EVs do boast the most efficient energy conversion of LEV and ZEV fuel types from well to wheel. EVs have no tailpipe emissions to be concerned about. Unlike their diesel and CNG counterparts, there is no byproduct from a combustion engine.

4 *Vehicle metrics given are general estimates. Specific vehicle specifications should be used for analysis and decision-making purposes.*

Fuel Cell Electric Buses (FCEBs)

FCEBs are powered by hydrogen gas (H2). The gas is stored in a tank on the bus at 5,000 to 10,000 pounds per square inch (psi). The fuel is passed through the fuel cell power module to produce electricity, and that electricity is stored in a battery to run the vehicle during operation. The electricity is used for an electric motor, which powers the vehicle mechanically. The power goes from the motor to the transmission to the wheels. The vehicle's fuel cell uses oxygen from the air and the hydrogen gas to produce electricity, with water as a byproduct.

FUEL UTILITY

Production

There are currently different methods of generating hydrogen. It can be captured from natural gas or produced using electrolysis. Producing H2 from natural gas is cheaper but still has an environmental impact. Producing H2 using electrolysis is the cleanest method, and most of its emissions are going to be upstream emissions.

Steam methane reformation is the more popular method of creating H2. Natural gas (mostly methane) and steam are input into the process. Carbon monoxide and carbon dioxide as well as hydrogen are produced as outputs. These output emissions can be captured; however, this method still produces more emissions than electrolysis, even when the byproducts are captured.

State of the Supply Chain

Hydrogen is currently the least available of the fuel sources. There are efforts into making H2 hubs around the U.S., but as it stands, the availability of the fuel can be a non-starter. Better options for H2 should become available within the next 10 years.

There are approximately 1,600 miles of hydrogen pipelines actively being used in the U.S. These pipelines are between large production facilities and large hydrogen consumers. They are not established for commercial use. Transit fleets, unless located close to a hydrogen producer, will need to have hydrogen delivered by truck. There are currently no large hydrogen suppliers in the state of Virginia. However, there are out-of-state suppliers that can be used to import hydrogen for pilot programs. Furthermore, there is a high level of interest in hydrogen in Virginia. The Virginia Tech Research Center in Newport News as well as the Energy DELTA Lab in Wise County are both positioned to provide research and testing for different hydrogen technologies. There are also plans for a Green Energy Center in Surry that will include a hydrogen production facility. There is a trend of hydrogen generation facilities being planned near green energy production. This creates a dedicated chain of green energy production to hydrogen generation. These plans are usually created around energy-demanding structures such as data centers or factories.

COMPARATIVE INFORMATION[5]

The range of hydrogen FCEVs are slightly less than their diesel counterparts. Buses can have ranges up to 370+ miles. Their refuel time is 10 to 15 minutes—faster than electric vehicles and comparable to diesel buses. The batteries in FCEBs are not as large as those on BEBs; this means that FCEBs tend to be slightly lighter than BEBs, but still heavier than their diesel counterparts. Furthermore, they have no carbon emissions at tailpipe.

5 *Vehicle metrics given are general estimates. Specific vehicle specifications should be used for analysis and decision-making purposes.*

Natural Gases Infrastructure

Compressed Natural Gas (CNG) buses are fueled by natural gas. The main ingredient in this natural gas is methane, and there are some small amounts of other gases mixed in. It is compressed to less than one percent of its volume at atmospheric pressure. It is stored at a high pressure and a regular temperature.

Buses powered by CNG keep it stored in a tank at 3,000 to 3,600 psi. The gas is passed through a high-pressure regulator and sent to the fuel injection system. From there, it is passed off to the internal combustion engine, and the vehicle is powered and operates by the same mechanisms that a diesel vehicle would.

Some vehicles use this gas in its liquid form, called **Liquid Natural Gas (LNG)**. LNG is cooled to -260 degrees Fahrenheit for storage and use. This liquid is stored on a tank at low pressure; however, it requires heavy thermal insulation and the ability to vent gas buildup should the liquid get too warm. While LNG is an option for vehicle fuel, this state is much more commonly used for the transportation of natural gas.

FUEL UTILITY

Natural gas can be obtained from drilling or from natural gas distilleries. Natural gas distilleries decompose biowaste and other materials to produce the gas. This gas is referred to as **Renewable Natural Gas (RNG)**.

Natural gas is already used as a fuel source in many places. What primarily determines whether an area is beneficial for CNG fueling stations is the pressure available on the local gas utility. The higher pressure the service line is, the less money that needs to be invested in compressors at the fueling station, and the less energy it takes to compress the gas.

COMPARATIVE INFORMATION

CNG buses have reduced emissions at tailpipe. Their emissions are only 20 percent that of their diesel counterparts. CNG buses have slightly less range than their diesel counterparts by about 10 percent. Fast refill stations for CNG can refill in comparable times to diesel fuel pumps at about five to ten minutes. Time-fill stations with smaller compressors can take longer to refill fleets but can be created at a lower price..

Moving Forward: BEBs

BEBs

Coordination with local electric utilities will be key for successful utility coordination during the transition process. Below is a list of suggestions for successful coordination with utility companies and providers.

- Engage them early and often.
- Make sure the grid at desired locations can support supplying a bus fleet with the energy it will need.
- Calculate power needs of the fleet ahead of time so that an insightful conversation can be had with the utility.
- Ask about off-peak hours charging and see if it is necessary or incentivized.
- Ask about lead times on equipment such as transformers and make sure parts are ordered early enough that they do not impact the project timeline.

Moving Forward: FCEBs

FCEBs

Finding out if there is currently any interest in hydrogen production in areas where fleet conversion is desired will be key in moving forward with a transition process to FCEBs. Below is a list of suggestions for transit agencies looking to take the beginning steps in the FCEB transition process.

- Look for partners in those regions that may be looking to produce hydrogen or generate green energy that can be used for hydrogen production.
- Make sure hydrogen suppliers meet the agencies standards for green energy production.
- Keep connected with facilities and ventures that have high levels of interest in hydrogen fuel or green energy production.
- Ask hydrogen suppliers what their future plans may be for moving into the market in Virginia.

Moving Forward: Natural Gases

NGs

Below is a list of suggestions for transit agencies looking to take the beginning steps in the natural gas transit bus transition process.

- Contact gas utilities in the desired fleet conversion locations.
- Ask about the pressure of their supply lines and see if it is feasible to build a refueling station at that inlet pressure.
- Investigate to see if there are any local suppliers of RNG.
- Coordinate with the supplier and utility to purchase RNG from that facility.
- Reach out to the regional wastewater authority and see if they have any plans for RNG production.
- If LNG is a consideration, make sure there is a production facility close enough that supplies it, and that proper storage facilities can be constructed.

Infrastructure Considerations

An agency's capacity to procure, install, and maintain the necessary infrastructure is as important to the successful deployment as the vehicles themselves. Depending on the chosen fuel type, the necessary infrastructure can be remarkably different from the infrastructure required to fuel traditional gas and diesel vehicles. Understanding the specific infrastructural needs of a fuel type and the agency's capacity to support these needs is imperative before beginning a fleet transition.

While each fuel type has its own unique infrastructural needs, there are external factors which influence the implementation of a fleet transition which agencies should consider throughout the process:

- **Weather:** The outside ambient air temperature and severe weather can affect the efficiency of and even damage alternative fueling infrastructure. Agencies located in areas of Virginia which experience frequent high temperature, multiple days in freezing temperatures, and/or severe weather like flooding, high winds, strong thunderstorms, earthquakes, tornadoes, etc. should take extra steps in planning their transition to be weather resilient. Agencies should conduct further analysis on whether additional infrastructure, such as additional cooling capacity, is needed to successful deploy their alternative fleet.
- **Fleet:** The size of an agency's fleet and the type of vehicles within its fleet will have significant influence on the infrastructural needs for the transition. The fueling infrastructure for some alternative fuels require large upfront capital investment but becomes more cost-efficient for larger fleets, while other alternative fuels require a set amount of infrastructure per vehicle, which is cost-effective with smaller fleets but can become less cost-effective as the fleet expands. Agencies, especially those with either exceptionally large or small fleets, should be aware of the cost-effectiveness of their chosen alternative fuel type so that the capital costs associated with procuring the necessary infrastructure does not exceed their funding capacity.
- **Fleet Composition:** The composition and type of vehicles in an agency's fleet is also an important consideration. Depending on the chosen alternative fuel type, the infrastructure needed for a cutaway bus could differ from the infrastructure needed for a 40' low-floor bus. Additionally, the maturation of alternative fuel types differs based on the type of vehicle. A less developed fuel type for use in transportation may result in higher capital costs in procuring the alternative infrastructure or the infrastructure not being as efficient as other alternative fuels. Additionally, some alternative fuels and/or alternative fuel practices may not be available for specific vehicles. Agencies should evaluate their fleets and their applicability to the different alternative fuel types before transitioning.
- **Facility:** Agencies should be aware of the space and utility capacity of their facilities while planning for their fleet transition. An agency's chosen fuel type(s) and its necessary infrastructure could require additional space or utility requirements beyond their facility's current capacity. Agencies should assess the space, power/utility, and installation requirements for an alternative fuel during the transition and long-term to evaluate the feasibility of integrating the fuel type onto their facility(s).

- **Redundancy/Resiliency:** Transitioning to alternative fuels shifts an agency's operations to be dependent on the new fuel and related production and procurement methods associated with the alternative fuel. Each fuel type has its weaknesses, which could disrupt operations. Developing the necessary methods to counteract unpredicted setbacks is critical in maintaining consistent operations; this may require the procurement of additional infrastructure to increase the resiliency of the agency's operations and/or create redundancies, which dampen the negative effects from an accident or system failure.
- **Possibility for Collaboration:** Agencies are often one part of a jurisdiction's overall fleet of vehicles. Many jurisdictions have separate fleets of vehicles for non-public transportation purposes, such as city works and school buses. Transit agencies should coordinate with their jurisdiction(s) to evaluate whether these fleets are also transitioning to alternative vehicles and whether there are opportunities for coordination and collaboration. A partnership with another one of a jurisdiction's departments could help to reduce the barriers to alternative fuel deployment while also increasing the operational and cost-efficiency of said deployment.

BEB Infrastructure

Charging Infrastructure

Charging or "refueling" BEBs is unique from refueling traditionally and other alternatively fueled vehicles due to the process' time requirements. Charging a battery takes longer than refueling a tank, and to recharge large batteries like ones needed to power BEBs, this process can take hours. As a result, two main charging strategies were developed:

- Depot charging
- On-route charging

While these two strategies differ in specific applications of similar infrastructure, BEB charging shares common infrastructural needs. BEB charging typically requires the following elements:

- Transformer
- Switchgear
- Charger
- Dispenser

The size of an agency's fleet, the number of distinct charging locations, and an agency's recharging strategy will determine the needs for the listed elements.

DEPOT CHARGING

Depot charging refers to the process of recharging BEBs at the agency's depot/storage facility when not in service. This process is typically done overnight but can be performed anytime during the day when a bus is not in service. Depot charging is most commonly performed using plug-in chargers. Some plug-in chargers can charge at a low kilowatt (kW) rate, which preserves a BEB's battery's capacity, saving money in the long-term. Additionally, plug-in chargers have lower procurement, installation, and maintenance costs than higher-powered chargers.

Plug-in chargers are classified into three categories based on their power output.

- **Level One** (120 volts alternating current [AC], 1.3-2.4 kW)
- **Level Two** (240 volts AC, 4-16.8 kW)
- **Level Three**, also known as direct current (DC) fast chargers (50-600 kW)

Level One and Level Two chargers both use AC and differ in the amount of electrical power they can supply; Level Two chargers can supply greater power than a Level One charger and thus have faster charge rates.

Level Three use DC to charge electric vehicles and recharges vehicles faster than the AC chargers. Due to their high-power output, Level Three DC chargers typically stop "fast charging" once a vehicle's battery hits 80 percent charge. The DC fast charger will then either charge the remaining 20 percent at non-fast charging speeds or stop charging altogether. This 80-percent threshold on fast charging is a safety measure to slow the degradation of the

vehicle's battery. While Level Three chargers such as pantographs and induction chargers can supply up to 600kW of electrical output, not all BEBs can take advantage of the power output due to limitations in their max charge rate.

Depot charging can also use Level Three plug-in chargers, pantographs, and induction chargers, also known as "fast chargers." Fast chargers have high charge rates, which significantly reduce the recharging time for a BEB; one fast charger has the ability to recharge multiple BEBs at the same time it takes a Level One or Two charger to recharge one BEB. The specific time it takes to recharge a BEB using a fast charger is dependent on the BEB's max charge rate; some buses cannot be charged at the max rate advertised by fast chargers. Additionally, while fast chargers can reduce recharging times, higher charge rates degrade a battery's lifespan faster than a slower charger. Fast chargers are also more expensive to purchase and install than slower chargers and also incur higher maintenance costs and electricity rates due to their high energy demand. Additionally, fast chargers are also less efficient than lower-level plug-in chargers.

Within depot charging, there are multiple charging strategies, which have their advantages and disadvantages when it comes to space and cost requirements. Depot charging using slow chargers will require a 1:1 or 1:2 vehicle-to-charger ratio, depending on the selected equipment. A 1:1 vehicle-to-charger ratio requires additional facility space but are often the more reliable depot charging strategy, especially for agencies without much experience with battery electric vehicles (BEVs) (when compared to multi-dispenser or fast charging). Using fast chargers or a charger with multiple dispensers can reduce the amount of space and capital needed as less chargers are needed to charge the fleet. However, depot charging with a higher vehicle-to-charger ratio is more prone to service impacts from charger malfunctions. Alternatively, fast charging at a depot requires staff time to monitor charge states and move vehicles as they are recharged.

Depot charging is typically less expensive than on-route charging: the chargers are cheaper, require less costly installation and maintenance, and charge during non-peak hours. However, depot charging can become costly with larger fleets. BEB charging differs from fueling traditional and other alternative fuels, as the charging/refueling process is decentralized. Typically, one charger is procured for each new vehicle added to the fleet, which increases the overall infrastructure costs per vehicle. The costs associated with charger procurement, installation, and maintenance are shown in **Table 2**.

ON-ROUTE CHARGING

The second charging strategy is on-route charging. On-route charging uses high-powered chargers to refuel a BEV while it is in service, instead of taking the vehicle out of service and returning it to a depot. Pantographs and induction chargers are commonly used for on-route charging. On-route charging is usually employed in conjunction with depot charging as a range extension strategy. An on-route charging-only strategy uses the on-route fast chargers as the only fueling infrastructure, and it requires fast chargers at strategic points in a vehicle's route to fully recharge a near-depleted vehicle multiple times through its operational run. A strategy using both on-route and depot charging will use an on-route charger once or twice per a vehicle's operational run to "top off" its battery so that the vehicle can complete its run. For the greatest efficiency, on-route chargers should be placed where multiple routes overlap and at stations to maximize the range extension benefits of the on-route charger.

Currently, on-route charging technology is the most applicable to agencies running service with full-sized transit buses. Fast charging technology and techniques for body-on-chassis (BOCs)/cutaways, coach buses, and vans are not as developed they are for transit buses: there are no pantographs for available for smaller vehicles, most models of transit vehicles are not capable of using induction charging, and smaller

Table 2. BEB Charger Cost Assumptions

Charger Type	Charge Rate	Paratransit Vehicle Recharge Time	40' BEB Recharge Time	Hardware Price	Installation Price	Maintenance Costs
Level 1	1.3-2.4 kW	50 hours	Infeasible	$380	$300	$250
Level 2	16.8 kW	7 hours	0.9 hours – 4.2 hours	$2,500	$7,000	$250
Level 3	50 kW	2.4 hours	8 hours	$27,900	$62,700	$2,790
Level 3	150 kW	48 minutes	2.5 hours	$87,800	$75,500	$8,780
Level 3	300 kW	24 minutes	1.3 hours	$139,000	$138,200	$13,900

Source: Argonne National Laboratory

vehicles typically have lower charge rates as well. If an agency chooses to include fast charging as part of their operations, the agency needs to procure vehicles with batteries capable of accepting the charge rate of the fast charger.

Land ownership is an important factor for on-route charging. It is best practice to place on-route chargers on parcels of land owned by the agency or another related public entity, allowing for reliable accessibility and operations. A high-powered on-route charger requires extensive utility work to obtain the necessary electrical power to operate; such extensive renovations are potentially infeasible on leased parcels of land.

DEPOT CONSIDERATIONS

A transition to BEBs will impact other aspects of an agency's depot beyond the fueling infrastructure. Agencies looking to transition to BEBs should consider the following aspects and how they might affect the operations and physical infrastructure of their depots:

- **Vehicle Weight:** BEBs are significantly heavier than their diesel and gasoline counterparts due to their batteries. A 40' BEB is approximately 2 times heavier than a 40' diesel bus. Agencies should evaluate their mechanical lists and hoists to see if they are rated to handle a BEB.
- **HVAC/Ventilation:** BEB charging equipment produces heat as a byproduct through the process of charging BEBs with higher-powered chargers, producing more heat in their operations. Depending on the location of an agency's charging equipment, the heat produced from recharging their fleet could overload their depot's ventilation system.
- **Fire Protection:** Due to the metals and chemical compositions in a BEB's lithium-ion battery, different fire suppression methods are needed in a depot to maintain a safe working environment. BEB fires are typically more intense, last longer, and burn hotter than traditional vehicle fires, and some traditional extinguishing methods, like water, are ineffective and—in some cases—even counterproductive in fire suppression. Agencies should learn about the fire risks associated with BEBs and upgrade their depots with fire suppression equipment capable of handling BEBs.

FCEB Infrastructure

Fueling Infrastructure

The infrastructural needs for hydrogen fuel cell vehicles are like those of other gaseous- and liquid-based fuels. The infrastructural needs to support a FCEB fleet pivots on two main decisions:

- Will the FCEBs use liquid or gaseous hydrogen?
- Will the agency produce hydrogen on-site or get its hydrogen fuel delivered?

Hydrogen fuel comes in two physical states: liquid hydrogen (LH2) and gaseous hydrogen (GH2). The two states of hydrogen fuel require many of the same infrastructural components but need different equipment due to their physical differences: to keep it in its liquid state, LH2 needs to be stored at sub-zero temperatures, so specialized insulated equipment such as cryogenic storage tanks will need to be procured. GH2 is like CNG in that it needs to be compressed when stored and used on the vehicle. As a result, a compressor and a chiller will need to be procured so the gaseous fuel can be compressed and stored. Safety and ventilation equipment will also need to be upgraded to match the safety requirements associated with the chosen state of hydrogen fuel. **Table 3** lists the common and specific elements of a hydrogen fueling station.

On-Site Production

Agencies can procure hydrogen fuel through either truck deliveries from a commercial hydrogen provider or producing it on-site. Delivered hydrogen will require significantly fewer capital costs than constructing an on-site steam methane reformation (SMR) or electrolysis plant, but on-site production of hydrogen fuel through either SMR or electrolysis will reduce the per-kilogram (kg) cost of hydrogen fuel, especially with large quantities. Agencies should consider their daily usage of fuel and their capital and operation budgets when deciding where to obtain their hydrogen fuel. The cost assumptions of constructing a hydrogen refueling station are shown in **Table 4**.

There are two main methods for producing hydrogen fuel: SMR and electrolysis. Both methods can be performed in smaller processes located at an agency's facility. The SMR process requires methane-based natural gas as a feedstock, while electrolysis uses electricity for its power sources. Installing an SMR or electrolysis refueling station on-site will require additional coordination with the transit agency's gas or electrical utility provider, respectively.

Depot Considerations

FCEBs, like BEBs, contain lithium-ion batteries. While smaller than their BEB counterparts, the batteries in FCEBs lead them to share

Table 3. Hydrogen Fueling Station Elements

Common Elements	LH2 Station Specific Needs	GH2 Station Specific Needs
Storage tanks	Cryogenic storage	Compressor
Hose/dispenser	Liquid pump or vaporizer	Chiller
Safety systems		
Control and monitoring system		
HVAC/ventilation		

Table 4. Hydrogen Fueling Station Elements

Station Aspect	Financial Assumption
Total Station Cost	$14.36 x Dispensing Rate (kg/year) + $1,353,400.68
Annual Operations and Maintenance (O&M)	6.1% of Total Station Cost
Installation Cost	33% of equipment cost
Site Preparation and Design	23% of equipment + installation costs
Costs for a Mid-Size Transit Fleet*	
Total Station Cost	$7,905,150
Annual O&M	$482,214

* *Assumes a fleet of 50 40' FCEBs using 25 kg of hydrogen fuel a day. An annual dispense rate of 456,250 kg/year was assumed.*

Source: Argonne National Laboratory

similar characteristics and vulnerabilities as a BEB in terms of vehicle weight and potential fire hazard. As detailed in the BEB's Depot Considerations, agencies should take extra steps to plan for the effect of an FCEB fleet on their fire protection systems, ventilation/HVAC systems, and their mechanical lifts.

Natural Gas (CNG, LNG, RNG) Infrastructure

Fueling Infrastructure

The infrastructure needed for CNG fueling varies based on the station's configuration. There are three main types of natural gas fueling stations:

- Time-fill
- Fast-fill
- LNG

Time-fill stations fuel vehicles directly from a compressor in a central location, which can take multiple hours. Fast-fill stations refill vehicles from a high-pressured storage tank at similar speeds of refueling a diesel or gasoline vehicle. While fast-fill stations offer faster refueling speeds, time-fill stations are more energy-efficient, can fuel multiple vehicles at once, and can more densely fill the tanks of CNG vehicles than the fast-fill method. A CNG refueling station can also be built with both fast-fill and time-fill components in the same station.

LNG stations are different from CNG stations, as the natural gas fuel is kept in a liquid state at very cold temperatures. LNG stations require similar infrastructure to a diesel or gasoline station such as storage tanks, pumps, and a dispenser.

Whether the feedstock for the natural gas fuel is fossilized or produced from RNG sources, the infrastructure needs for the fueling station remain the same. Agencies using RNG may want to invest into additional/high-grade gas dryers; however, natural gas from renewable sources tends to be wetter than natural gas from fossilized sources.

Agencies commonly use a buffeted fast-fill station configuration, as this allows for vehicles to be fueled quickly and sequentially.

Table 5. CNG/LNG/RNG Fueling Station Cost Assumptions

Station Aspect	Financial Assumption
Total Station Cost	
LNG	\$0.5102 x Dispensing Rate (GGE/yr.) + \$190,521
Time-Fill	\$2.9151 x Dispensing Rate (GGE/yr.) + \$6,245.9
Fast-Fill	\$226.41 x Dispensing Rate (GGE/yr.) ^0.67
Annual O&M	6.5 percent of Total Station Cost
Installation Cost	50 percent of Equipment Costs
Capital Costs for a Mid-Size Transit Fleet*	
LNG (Annual O&M Cost)	\$ 1,643,060 (\$85,011)
Time-Fill (Annual O&M Cost)	\$ 8,305,536 (\$519,111)
Fast-Fill (Annual O&M Cost)	\$ 4,778,980 (\$302,577)

* *Assumes a fifty 40' bus fleet with an on-board fueling capacity of 120 GGE for an LNG bus and 150 GGE for a CNG bus. The annual dispensing rate is assumed to be 2,190,000 for LNG and 2,737,500 for CNG.*

Source: Argonne National Laboratory

A buffeted fast-fill station configuration requires the following equipment:

- Gas dryer
- Compressor
- Priority-sequential panels
- Cascade storage tanks
- Hose/dispenser

The capital costs for a CNG fueling station are dependent on the configuration of the station as well as its size. The financial assumptions of constructing a CNG fueling station are shown in **Table 5**.

Safety

Facility safety equipment and ventilation should be upgraded to be in-line with the safety codes set for a CNG/LNG fueling station. Extra steps need to be taken with an LNG station due to the fuel's low temperatures. Insulated and protective gear such as gloves, masks, and clothing must be acquired for staff.

Propane

The infrastructure needed to fuel a propane fleet is like that needed to fuel a gasoline or diesel fleet. A propane fueling station is composed of four main elements:

- Storage tank
- Dispenser
- Pump and motor
- Fuel management system

While propane fuel needs to remain pressurized when fueling a vehicle, a compressor is not needed for vehicle fueling.

When transitioning to a propane fleet, an agency must understand the codes and safety laws surrounding the handling of propane fuel and take the proper steps to update the necessary safety systems and equipment. Additionally, agencies note their area's climate and severe weather, as additional infrastructure may be needed to insulate the fueling station from the outside elements.

Propane is a commonly used fuel throughout the United States and Virginia by numerous commercial suppliers and public fueling stations. On-site production of propane fuel is not common for agencies, as propane fuel is inexpensive and abundant, making delivered propane fuel the more cost-effective method. For this reason, in addition to the lack of infrastructure needed, constructing a propane fueling station requires less capital than other alternative fuels. The costs for constructing a propane fueling station are shown in **Table 6**.

Table 6. Propane Fueling Station Cost Assumptions

Station Aspect	Financial Assumption
Total Station Cost	0.24x annual GGE + $10,650.50
Annual O&M	5-8% of Total Station Cost
Costs for a Mid-Size Transit Fleet*	
Total Station Cost	$142,050.5
Annual O&M	$7,103 - $11,364

* *Assumes a fleet of fifty 40' buses using 30 GGE of propane fuel a day. An annual dispense rate of 547,500 GGE/year was assumed.*

Source: Argonne National Laboratory

Making the Choice

Each alternative fuel technology has its own opportunities and challenges when it comes to deploying the necessary infrastructure. The "correct" choice of alternative fuel technology is ultimately dependent on the priorities and values of the agency and the community(s) it serves. However, the quality of each technology lends themselves better to agencies with the following characteristics.

BEBs are best choice for agencies that:

- **Want a faster transition to zero-emissions:** BEBs is one of the two main zero-emissions bus technologies, along with hydrogen/FCEBs. Transitioning to BEBs will not require an additional transition to reach zero-emissions.
- **Have smaller fleets:** BEB infrastructure is implemented on a per-bus basis, making the technology more scalable and less costly for smaller agencies.
- **Have non-traditional fleets:** BEBs are the most mature zero-emissions technology, and BEB models exist for cutaways/BOCs, coach buses, and sprinter vans. Hydrogen, the other zero-emission technology, is still a juvenile technology; thus, there are very few, if any, models of FCEBs for cutaways/BOCs, coach buses, or any other type of transit vehicle that is not a 40′ transit bus.

FCEBs are best choice for agencies that:

- **Want a faster transition to zero-emissions:** FCEBs is one of the two main zero-emissions bus technologies, along with BEBs. Transitioning to BEBs will not require an additional/intermediate transition to reach zero-emissions.
- **Have larger fleets:** FCEB infrastructure requires significant capital infrastructure upfront but upgrading/expanding the infrastructure is less costly. Transitioning to FCEBs is more cost-effective for agencies with larger fleets, as they will have lower capital costs per vehicle.
- **Have limited facility space:** FCEB fueling infrastructure is centralized and operates similarly to a traditional fueling station. The centralized station can serve multiple vehicles in short amount of time, and expansion and upgrades to the fueling infrastructure do not require extensive amount of space. While the transition period between two fuel types could put strain on the available space at a

facility, the final fueling station should not spatially constrain an agency's depot.

- **Are transitioning from other gaseous fuels:** The vehicle maintenance and fueling for FCEBs are similar to those of CNG, propane, and other gaseous fuels. Agencies transitioning from a gaseous fuel and their staff must be familiar with the necessary FCEB infrastructure, as it will ease the transition.
- **Want greater zero-emissions reliability:** Of the two zero-emissions technologies, FCEBs offer greater range and reliability than BEBs. Agencies with long operational blocks and/or are situated in areas with severe weather, extreme ambient temperatures, or hilly topography will have less operational issues with FCEBs. Additionally, FCEB fueling infrastructure is not dependent on the electric grid; thus, agencies can continue operations in the event of a power outage.

CNG/RNG and propane are the best choice for transit agencies that:

- **Are new to alternative fuels:** CNG/RNG and propane share many of the same benefits; thus, they are grouped together. They are mature fuels that have been used by agencies across the country for decades. Agencies that are new to alternative fuels may have an easier time transitioning to CNG or propane due to their widespread usage, as sourcing and materials for fuel sourcing, vehicle procurement, maintenance, and best practices are readily available.
- **Have smaller budgets:** CNG and propane fueling infrastructure is significantly cheaper than the infrastructure needed for BEBs and FCEBs. A full transition to CNG or propane might would be easier for agencies with smaller budgets.
- **Have larger fleets:** CNG and propane infrastructure, like FCEB infrastructure, requires significant capital infrastructure upfront, but upgrading/expanding the infrastructure is less costly. Transitioning to CNG and propane is more cost-effective for agencies with larger fleets, as they will have lower capital costs per vehicle.
- **Have limited facility space:** CNG and propane fueling infrastructure, like FCEBs, is centralized and operates similarly to a traditional fueling station. The centralized station can serve multiple vehicles in short amount of time, and expansion and upgrades to the fueling infrastructure do not require extensive amount of space. While the transition period between two fuels could put strain on the available space at a facility, the final fueling station should not spatially constrain an agency's depot.
- **Want greater reliability:** The two zero-emissions technologies, BEBs and FCEBs, are still relatively new and are more subject to operational challenges from externalities. CNG and propane fuels are more much more operationally resilient and are good fits for agencies with large reliability and range concerns. Additionally, CNG and propane fueling infrastructure is not dependent on the electric grid; thus, agencies can continue operations in the event of a power outage.

Workforce Development Guidance

Adopting a new vehicle technology requires considerable investment and planning. The transition to low- and zero-emissions vehicles by agencies across Virginia and the United is being spurred by record levels of federal support. In addition to federal finances supporting the purchase of new transit vehicles, fueling infrastructure, and workforce development, federal agencies and partner organizations are developing guidance and providing support to agencies to tackle the considerable technical and managerial challenges associated with new vehicle technology.

Despite this support, many agencies do not have sufficient guidance on how they can make sure their workforces have the requisite skills and certifications to operate, maintain, and plan service for vehicles powered by batteries, natural gas, and hydrogen fuel cells. The challenge of adopting low- and zero-emissions vehicles is exacerbated by the pre-existing transit workforce shortage.[6] Agencies across the country of all sizes report a years-long difficulty recruiting and retaining transit operators and mechanics. These challenges are likely to grow as agencies seek to attract and retain employees with new and in-demand skills. As a result, agencies will need to plan such that their workforces can support the deployment of low- and zero-emissions fleets.

6 *American Public Transportation Association. "Transit Workforce Shortage." Washington DC, March 2023. https://www.apta.com/wp-content/uploads/APTA-Workforce-Shortage-Synthesis-Report-03.2023.pdf.*

Guiding Principles for Workforce Development

Operators and mechanics will need the most substantial formal retraining during the transition to low- and zero-emissions vehicles. That training can be provided in a variety of different venues, each with its own implications in terms of cost, timeframe, and the degree of relevance to the day-to-day work at the agency itself. This section outlines guidance and practical steps that agencies can take to prepare a resilient workforce for the zero-emissions transition:

- **Carefully manage labor relations**
- **Approach transitions as an opportunity for workforce development**
- **Have an administrative process for addressing skills gaps**

Carefully Manage Labor Relations

The low- and zero-emissions transition will challenge the relationships between agencies and their employees, in part because of the uncertainty associated with the changes. The uncertainty will dissipate with time as public transportation providers and Original Equipment Manufacturers (OEMs) gain more experience. However, to assuage concerns about the zero-emissions transition, agencies should engage with employees and labor organizations early and often as agencies plan for a zero-emissions fleet transition.

Despite the potential for challenges between agencies and employees, the low- and zero-emissions transition poses several attractive opportunities to protect the existing workforce from economic hardships caused by rapid technological changes while also appealing to a new generation of transit employees as the industry continues to face general labor shortages. Agencies and their employees both stand to gain from proactive cooperation to structure the future of transit together.

Employees will view technological changes and the effects they will have on job satisfaction both positively and negatively. Low- and zero-emissions vehicles offer a few clear benefits to mechanics, specifically among them that these vehicles are simply cleaner to work on. Fewer liquid lubricants and no soot means that the image of a mechanic with dirty coveralls and greasy fingernails will no longer apply—this will benefit existing employees as well as appeal to a new generation of younger employees who would otherwise avoid a transit career because of those working conditions. Younger employees may also find the electronic- and data-intensive aspects of zero-emissions transit operations intriguing.

Nevertheless, the existing workforce cannot simply be discarded. Their institutional knowledge of O&M and planning makes them essential to a smooth transition from one vehicle technology to another. Furthermore, the incremental cost of additional training is lower than acquiring a new employee and providing that training. However, retaining existing employees' experience will require investment in upskilling. This process may be difficult, as training resources may remain scarce for some time, and late-career employees, especially mechanics, may struggle at first to acquire new skills.

Agencies can take steps to make sure that necessary retraining does not also displace the existing workforce by assessing skill aptitude and streaming employees who require more time to acquire certain skills into appropriate roles while they work towards full retraining. For example, longtime diesel engine specialists who require more time to shift to battery-based vehicles may continue to work on mechanical or body systems until they qualify on higher voltages.

For many public transportation providers, anti-displacement provisions will involve cooperation between agencies and organized labor. Both groups stand to gain from employee continuity, and both groups will have to work together to guide the transition to low- and zero-emissions operations along a smooth trajectory to full implementation.

Approach Fleet Transitions as an Opportunity for Workforce Development

The transition to low- and zero-emissions vehicles is an opportunity to both invest in the current workforce and expand agencies' ability to attract their future employees. Due to the ongoing employee shortage and impending retirement cliff among many O&M staff, agencies must work towards this opportunity so that they have uninterrupted high-quality transit service in the communities they serve.

The existing transit workforce has an enormous wealth of experience with providing transit service that cannot simply be replaced. Though many agencies are in the process of adapting to make space for a new generation's workplace expectations, pre-existing knowledge of vehicle maintenance, field operations, dispatch, and planning is essential to making sure that the zero-emissions transition is seamless for passengers. Agencies and their employees should look at the transition as a moment of great investment in the current employees, which involve upskilling and increasing competence in the workforce. They should look for ways to support their existing employees through their evolution to zero-emissions operations through clear training requirements, providing sufficient training resources, and working together to ensure smooth labor agreement revisions.

Every transit employee will require some training to upskill into their roles for low- and zero-emissions transit operations. However, many veteran employees—especially mechanics—may view the changes as significant to overcome because of how long they have been working on conventional vehicles. Their experience with transit service provision is indispensable, but managing their transition will look different than for employees with more willingness or aptitude to shift their skills to zero-emissions systems. Agencies should employ three strategies to balance the roles of new and veteran employees and make sure that their existing employees can remain part of the transit workforce.

- **Fill low- and zero-emission positions by retraining existing staff as well as recruiting new hires.** Emphasizing internal advancement will prevent displacing existing employees and demonstrate the agency's goodwill towards its employees, boosting retention. In the process of assessing skills gaps, agencies and their employees should include an evaluation of how many future roles will go unfilled by existing employees and link those findings to subsequent strategies for recruitment and retention.
- **Ensure training requirements and opportunities are accessible well ahead of time.** Agencies and their employees should work together with appropriate state agencies to develop a centralized source for training information and announce updates routinely.
- **Plan to accommodate employees with different interests and skills.** Agencies should invest in their employees' professional development by having a plan for utilizing all interests and skill levels. This includes providing pathways for existing employees who do not show immediate aptitude or interest in new vehicle systems to continue to work productively on other, more familiar ones (e.g., brakes and suspension) as well as ways for these employees to transition into other agency roles such as supervisory positions.

Likewise, agencies should also view the transition to low- and zero-emissions vehicles as an opportunity to become a more attractive workplace to future employees. Agencies continue to face an employee shortage, a situation only made more competitive by an increased demand for high-voltage skills. To have adequate staffing, agencies should plan for higher wages and retention bonuses, which will be necessary to attract and keep higher-skilled employees, whether they be new recruits or upskilled existing employees.

The skills required to work on low- and zero-emissions vehicles, particularly ZEBs, are likely to become increasingly in-demand as the

transportation sector decarbonizes. Candidates who may not have considered a career in the transit industry before may be more interested now since the roles will have less interaction with dirty combustion engines and involve more data- and electronics-focused work. Agencies and their workforce leaders should pursue all available avenues for recruiting and retaining new employees, including apprenticeship programs, and engaging with their local community colleges to promote transit roles.

Have an Administrative Process for Addressing Skills Gaps

Applying the principles above will have little effect if the agency cannot account for existing resources and make plans. Agencies and their employees should collaborate to develop strong processes for inventorying existing roles and their skills, characterizing how those may change (in quantity and in substantive scope), and then acquiring appropriate training and recruitment resources to fill identified gaps.

Robust training administration will especially help with managing differences among different agency work units. On one hand, operations staff, including drivers, dispatch, and planners, will all be as equally unfamiliar with new technologies, methods, and skills as their peers during deployment. Entire cohorts of these work units will need to learn new ways of performing their work functions, so agencies may plan to upskill them as large groups.

Conversely, maintenance employees will have varying levels of familiarity and aptitude with new systems, such as high-voltage electricity. Agencies will need to plan more granularly for addressing maintenance skills gaps, considering individual employees' development pathways and whether recruiting new employees will be necessary to make up for shortfalls after existing capacity is considered. Agencies and employees across agency units should cooperatively develop processes for upskilling and productively addressing capacity shortages that make sense for their expected needs as the transition progresses.

Designing Training Processes and Programs

The Role of OEMs in Training

OEMs generally provide operator and mechanic training as part of vehicle procurement. Such training tends to reflect the most detailed and up-to-date information about the specific vehicles going into service. OEM-provided training can take two forms. OEM representatives can train agency mechanics directly, which provides employees with an opportunity to ask questions and receive guidance directly from the OEM personnel. However, agencies also need to find a way to train employees on an ongoing basis. For this reason, agencies can also adopt a "train-the-trainer" approach, whereby OEM representatives train agency staff to train employees, who will require training after the initial training sessions are completed.

Use-cases for OEM-provided training include:

- Upskilling operators and mechanics at the time of fleet transition
- Using a "train-the-trainer" approach to supplement an agency's in-house operator-training program

In-House Training

Agencies can also seek to provide training on low- and zero-emissions vehicles via their in-house training programs. These will be especially useful for upskilling their existing employees, as agency partners—including OEMs—may have already trained staff who can train others. Agencies can also offer apprenticeships and mentorships, which can provide a key role in bridging the gap between the skills learned in a mechanic technical school or other third-party training venue.

Labor representatives told the DRPT that apprenticeship programs and mentorship programs, including those run and funded by unions, are important for supplementing the skills and training that employees receive in classroom programs. However, some agencies do not have the staff time or expertise to upskill mechanics directly to work on new fleet technologies.

Use-cases for in-house training include:

- Regular operator training, supplemented with "train-the-trainer" support from OEMs
- Mechanic continuing education programs, e.g., for new mechanics with some experience but who are unfamiliar with low- and zero-emissions vehicles or the specific fleet technology in use
- Apprenticeships and mentorships for mechanics and operators to familiarize new employees with an agency's specific equipment and working practices

Outside Education Institutions

While agencies will be able to provide some training for low- and zero-emissions vehicles in-house with the support of OEMs, in many cases, the best course may be to partner with an outside educational institution, for a few reasons:

- Some agencies are unlikely to be large enough for it to make sense to keep a trainer on staff full-time
- Agency-provided training programs may be appropriate for current, veteran mechanics, but not new hires, who may need more comprehensive training

Community colleges are a key resource for agencies. The Virginia Community College System (VCCS) and the state's technical schools were established specifically to support the state's workforce by providing two-year degrees and diplomas in a variety of subjects as well as non-degree training and certifications. They provide resources for preparing candidates for roles within agencies as well as certifications such as the Virginia Inspectors Licenses examination (i.e., those meeting the requirements of 19 VAC 30-70-9). VCCS and community colleges already offer traditional automotive and electrical trades certificate programs, and so represent a significant resource to the state in developing a home-grown zero-emissions transit workforce.

Use-cases for training provided by outside educational institutions include:

- Mechanic training for employees new to the profession, where the extent of education exceeds the time and material resources available to the agency
- Training to upskill mechanics on new fleet technology, including both general and manufacturer-specific training, where agencies are not well positioned to provide the latest information directly

Vehicle Deployment Guidance

Prior to vehicle deployment, agencies should make sure sufficient planning and implementation has been completed. The path to transitioning transit fleets to low- or zero-emissions vehicles will look different for every agency—timelines, propulsion technologies, fleet mixes, and order of steps may vary, amongst other things. As a generalization, the graphic below illustrates the relationships between various elements of the transition process. This generalized timeline shown in **Figure 6** can be used to determine if the agency is ready for vehicle deployment.

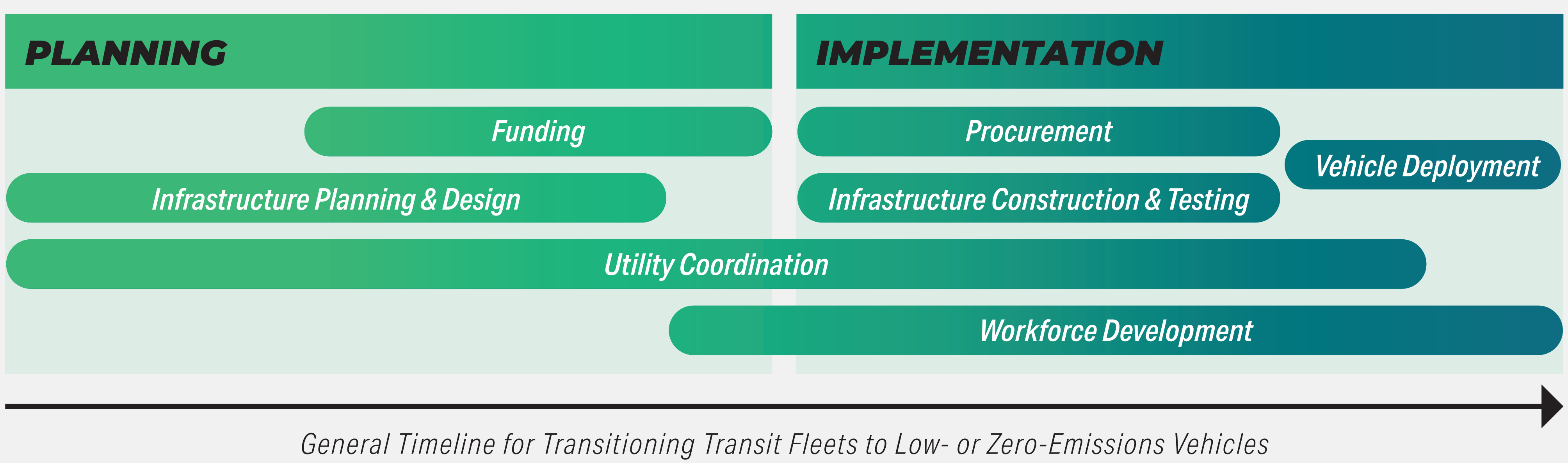
If the agency believes it is approaching or ready for vehicle deployment, this chapter can provide general guidance for how to approach vehicle deployment.

Goal Setting for Fleet Deployment

Setting goals prior to fleet deployment is critical to a productive deployment. Consider some of the following questions to guide the agency's fleet deployment goal setting:

- Why is the agency pursuing a low- or zero-emissions fleet?
- What is the size and scale of the deployment? Is it a pilot, partial fleet, or full fleet deployment?
- Will the deployment consist of replacement or expansion vehicles?
- Will deployed vehicles operate on all routes or selected routes?
- What kind of metrics will be used to measure the success of the deployment?

Figure 6. General Timeline for Transitioning Transit Fleets to Low- or Zero-Emissions Vehicles



SMART Goals

Goal setting can be a challenging task. Vague or ambiguous goals may be difficult to achieve. Following the SMART goals framework helps establish goals that have an actionable path to completion. SMART is an acronym that represents what goals should be characterized by:

S *Specific*
M *Measurable*
A *Achievable*
R *Realistic*
T *Time-Bound*

While SMART goals may take more time and thought to establish prior to deployment, they will guide the agency towards a more productive and successful deployment.

The SMART goals framework is widely known and can be researched further as needed. Examples of SMART goals in the context of vehicle deployment include:

- Train 25 percent of the maintenance workforce on the new technology/technologies being deployed
- Achieve a maximum of 30 percent of vehicle runs requiring a vehicle switch due to low battery
- Reduce fleet tailpipe emissions by 10 percent

Pilot Programs

Pilot programs have been widely used by agencies across the United States to test the performance of low- or zero-emissions buses in the context of their geography and unique operations prior to initial deployment. Pilot programs are typically done on an exceedingly small scale (two to 10 buses, depending on the existing fleet size and operational needs) to determine the feasibility of adopting new technologies for an agency's fleet. This allows agencies to experience the function and performance of new technologies firsthand prior to committing to transition a partial or full fleet to a low- or zero-emissions vehicle type. Similarly, pilot programs may allow agencies to compare the performance and compatibility of certain vehicle manufacturers with their O&M. It also should be noted that pilot programs not only allow agencies to test a vehicle, but in doing so, agencies are able to experience and test associated fueling technology, charge management systems, workforce trainings, and more. Pilot programs can be of great benefit to agencies unsure of if or how they should pursue transitioning to a low- or zero-emissions fleet.

Defining Success

Pilot programs may be exploratory or have specific goals associated with them. Therefore, it is critical to define what the agency would

Metro Transit Pilot Program

Metro Transit in Minneapolis/St. Paul, MN implemented a pilot program of eight 60-foot BEBs on its C-Line Bus Rapid Transit (BRT) corridor in June 2019. This program would influence the decision to purchase more BEBs, and in 2023 would be awarded an FTA LoNo grant for procurement of 12 BEBs and 15 BEB chargers.

consider to be a successful pilot by setting goals, as discussed in the prior section. A period of assessment and analysis following a pilot can help determine whether goals were achieved or summarize exploratory findings.

Decision Making and Flexibility

The next step following a pilot program or initial deployment is to analyze, assess, and summarize the performance of the deployment and any lessons learned to inform decision making. At this time, and based on the results of the initial deployment or pilot, it is important to re-evaluate and potentially update the agency's fleet transition plan and goals. Fleet propulsion technologies are constantly evolving and improving, so it is important to stay flexible as an agency and be willing to adapt to the changes in the industry. Below are some sample questions to consider when revisiting the agency's plans and goals following initial deployment:

- Did any or all the deployed vehicles meet the initial O&M goals set for the agency?
- Would the agency like to conduct an additional small-scale deployment for performance testing purposes due to uncertain/unfavorable results or further questions?
- Does the agency wish to transition its full fleet or maintain a mixed fleet of technologies for resiliency purposes?
- Are there any new funding opportunities available that the agency could pursue for fleet procurement, supporting infrastructure procurement, or capital projects?
- Are there new emissions guidelines for the agency's region or locality that need to be factored into the agency's goals for fleet transitions?
- Are there any new or changed directives from the agency's regional, locality, or agency leaders related to fleet electrification or composition?

Monitoring and Reporting

Monitoring, collecting, and reporting out data on deployment performance is a critical part of deployment, primarily for the following reasons:

- Data informs the agency's decision-making. In an ever-evolving industry of low- and zero-emissions transit vehicles, it is important that decisions related to propulsion technology and manufacturer are data-driven. In addition, the performance of low- and zero-emissions transit vehicles is highly dependent on various factors unique to every agency, such as terrain/topography, climate, route block lengths, operator performance, and land uses. As a result, the performance of various vehicles will be unique to the agency's agency and locality.
- Data serves as evidence for the agencies and locality's leaders. Many local agency and locality leaders do not have the opportunity to witness the performance and function of fleet vehicles firsthand. Collecting clear

and useful data on the performance of deployed vehicles will help inform leaders on the status of deployment and support the agency's recommendations to them.

- Data is useful for peer agencies to reference. The performance and application of low- and zero-emissions transit vehicles is ever-evolving. As a result, there is a constant need for knowledge sharing among peer agencies. Case studies of low- and zero-emissions vehicle deployments are heavily leveraged for guidance in planning, implementation, and decision-making. Tracking and documenting the performance of the agency's deployment may assist other agencies in their path to adoption.

The agency should consider collecting some or all the following types of data to ensure comprehensive monitoring and reporting (note that this list is not comprehensive):

- Range Performance of Vehicles
    - Keep this data route-specific
    - Document battery capacity over time (if deploying BEBs), as it may degrade
- Fueling or Charging Time
- Operator Performance/Efficiency
- Employee Feedback
    - Gather feedback from both operators and maintenance technicians
- Fuel or Electricity Costs
- Maintenance Costs (Cost per Mile)
- Baseline Data for all of the above
    - Make sure the agency has all of the above data for its current fleet propulsion type(s), for comparative purposes

Blacksburg Transit

When Blacksburg Transit first implemented BEBs in their fleet, they built their own data reporting and monitoring tool that pulls both manufacturer standard reporting and any additional information they knew would be important to their maintenance team.

Conclusion

This Guidebook was created because of action items proposed in the Virginia Transit Equity and Modernization Study. Emphasis is placed on the efforts to develop implementation resources for agencies to assist with their fleet transition planning. These resources are described in this Guidebook and cover the areas of funding and procurement guidance, utility coordination, infrastructure needs, workforce development for transit zero-emissions technology, and zero-emissions vehicle deployment. The purpose of the Guidebook is to provide tools that any Commonwealth agency can utilize to analyze their current operational needs and forecast needs for a long-term low- or zero-emissions transition.

The effort to plan, implement, and deploy low- or zero-emissions vehicles may be slightly different by agency. Overall, the transition planning process is the same no matter the size of the agency. However, larger agencies may involve more internal and external stakeholders. Larger agencies may have separate staff to oversee departments such as O&M whereas smaller agencies often have limited staff performing multiple roles. Some cost assumptions may also differ for BEB infrastructure. Large agencies may opt for pantograph or dropdown dispensers suspended from a gantry or spaceframe for convenience, where small agencies generally do not choose the higher-cost infrastructure. Additionally, smaller agencies may need more help due to the aforementioned staffing limitations. Smaller agencies may be more inclined to source help from external partners to conduct analyses, assist with decision making, guidance during the approval process, construction design and build, implementation, and deployment. Ultimately, all agencies should seek out information and the appropriate support needed to aid in their low- or zero-emissions transition.

An essential part of this process is providing agencies the information for where to start. The Transition Planning Checklist ("Checklist") below is the first step in the process. Agencies should review the Checklist in its entirety prior to initiating the transition planning process.

Fleet Transition Readiness Checklist

This Checklist was developed to aid agencies in pre-planning and determining when they would initiate a long-term low- or no-emissions transition plan. The Checklist provides a series of questions that prompts the agency on suggested activities such as data collection, goal setting, funds planning, stakeholder engagement, and workforce development. These activities are integral and should be performed prior to drafting a low- or zero-emissions transit vehicle transition plan. This is a guide for the agency planning process, which includes understanding the agency's service parameters, accessing and understanding fleet data, and exploring the steps needed to address future needs and priorities.

As stated in the Fleet Transition Template section of this Guidebook, the Checklist should be utilized during the Planning and Initiation stage. During the Planning and Initiation phase, the agency should make sure staff from relevant departments (e.g., planning, procurement, operations, IT, maintenance, and facilities) is involved to provide the necessary input into each portion of the Checklist. The Checklist will guide agencies through tasks using the following set of questions and topics:

- Has the agency collected or have access to relevant data and information to support the analyses needed for Low- or ZEB Transition Planning?
- Has the agency set fleet transition planning goals based on local priorities, constraints, and regulatory requirements?
- Has the agency initiated or completed a discussion with the appropriate utility provider or hydrogen supplier?
- Has the agency identified funding sources to support the procurement of Low- or ZEBs and fueling infrastructure?
- Has the agency begun working on the following activities pertaining to Workforce Development?
    - Research of needed skills
    - Assessment of staffing skills
    - Assessment of operator and technician training needs
    - Review of operational planning to identify effects of transitioning to low or ZEB technology.
    - Evaluate what is needed to obtain and retain employees.
- Has the agency contacted other agencies and/or reviewed published lessons learned from agencies that have deployed or are deploying Low- or ZEBs?

A short list of agencies for Urban, Small Urban, and Rural agencies are listed in **Table 7**.

The agency will have a good understanding of the transition plan components once they have completed the Checklist. The agency should then be equipped to move forward with the low- or zero-emissions transition planning tool.

Table 7. Urban, Small Urban, and Rural Agencies Who Have Published Lessons Learned from Transitioning to Low- or Zero-Emissions Buses

Urban
Blacksburg Transit
Driving Alexandria Safely Home (DASH) and the City of Alexandria
King County Metro (Washington State)
StarMetro (Tallahassee, Florida)

Small Urban/Rural
AppalCART (Boone, North Carolina)
Green Mountain Power GMP (South Burlington, Vermont)
Duluth Transit Authority (Minnesota)
Biddeford Saco Old Orchard Beach (BSOOB) Transit (Maine)
Link Transit (Washington State)
Mountain Line Transit Authority (Morgantown, West Virginia)
Port Arthur Transit (Texas)
Spokane Transit Authority (Washington State)

Appendix

Fleet transitions have ramifications for every function of an agency. This toolkit is intended to help agencies think through the workforce implications of their chosen fleet technology. However, once the agency understands the steps required to equip a workforce to roll out a new fleet, they may find it appropriate to revise the choice of vendor, technology type, or pace of transition. This tool is meant to be part of an iterative process of fleet transition planning where workforce and other considerations inform one another.

Assessing Training Needs and Workforce Planning

The questions in this section of the toolkit will help agencies identify the skills that will be required to roll out a new fleet and determine which capabilities their current workforce may lack.

Table 8. Assessing Training Needs and Workforce Planning

Key Questions	Considerations	FTA Planning Tool Question
ASSESSING SKILLS NEEDED FOR NEW FLEET		*1*
✦ What type of **safety-related skills and training** will be required for each category of employees? ✦ What skills are needed to **maintain the proposed fleet**? ✦ What skills will be needed to **maintain the proposed fueling equipment**? ✦ What skills will be needed to **operate the proposed fleet**? ✦ What skills will be needed to **plan, monitor, and support operations** for the proposed fleet?	✦ OEMs may be able to provide the learning objectives from their training materials. ✦ Agencies may need to consider cross-training with local public safety officials like fire and emergency medical services. ✦ Agencies should consider both the skills needed by operations personnel as well as those needed by employees in support roles such as dispatch, planning, and management.	
ASSESS SKILLS OF EXISTING EMPLOYEES		*2*
✦ How does the agency currently **track skills and certifications** on employees? Are there any gaps in the agency's data? ✦ What **skills and certifications do current employees have** related to the maintenance, operation, and planning of transit vehicles?	✦ The agency may want to build a spreadsheet of employees and the skills they possess. ✦ It may be useful to survey employees to learn about skills and certifications they have earned outside of the agency. ✦ Depending on the agency's collective bargaining agreement (CBA), surveying employees about their skills may involve coordination with the agency employees' bargaining unit. ✦ Anonymous surveys may elicit more accurate responses and could be used to estimate the amount of training the agency will need to provide.	
ASSESS GAPS BETWEEN SKILLS OF CURRENT WORKFORCE AND THOSE THAT WILL BE NEEDED		*3*
✦ Based on the agency's assessment of the skills needed to deploy their new fleet and the skills that their current workforce possesses, **what skills will their employees need to acquire**? ✦ What **types of trainings will be needed** to provide those skills? ✦ What **credentials** exist that certify the completion of relevant training courses?	✦ As agencies are assessing skill gaps, they should consider the needs of their fleet over the full lifetime of the vehicles. For example, agencies with BEBs will need to monitor battery degradation over time.	

Assessing Training Options

Now that the agency knows what skills they need to acquire, they need to figure out what training resources are available to help them fill the gap.

Table 9. Assessing Training Options

Key Questions	Considerations	FTA Planning Tool Question
INVENTORY EXISTING TRAINING PROGRAMS		***4, 5***
✦ What **types of training** does the agency currently provide in-house? ✦ Are there **staff at the agency who conduct trainings regularly**, and could their roles be expanded to cover trainings required of the new fleet? ✦ Could **existing in-house training programs be modified** to help employees gain proficiency on operating and maintaining the proposed new fleet? ✦ What **external trainings** does the agency rely on?	✦ Since on-the-job training is such an important component of transit workforce development, agencies should include in their assessment: apprenticeships, mentorships, and less formal processes by which mechanics and operators learn the skills they need to do their jobs.	
ASSESS VIABILITY OF TRAINING OPTIONS		***4, 5***
✦ Does the **OEM of the proposed fleet offer the trainings** the agency's workforce requires? ✦ Does the **OEM have capacity** to deliver on the timeframe the agency's needs? ✦ Is there a **community college** in the agency's area that offers transit training courses? ✦ Are there **vocational schools** or other institutions that offer transit training?	✦ OEM-provided training is subject to the availability of trainers; agencies should be sure that details concerning OEM-provided training, particularly concerning timing, are incorporated into purchase agreements. ✦ In some circumstances, agencies have sent working to receive OEM trainings in other jurisdictions to overcome training capacity issues.	

Achieving Equitable Allocation of Training Resources

Agencies need to make sure they have a workforce that can effectively operate, maintain, and plan for low- and zero-emissions vehicles. However, the transition to buses powered by alternative fuel sources will have impacts beyond the provision of transit service. When considering the workforce component of the fleet transition, agencies must also consider the impacts on employee morale, the relationship with unions, and the distribution of opportunities for training and employment.

Table 10. Ensuring Equitable Allocation of Training Resources

Key Questions	Considerations	FTA Planning Tool Question
ENGAGING EMPLOYEES AND UNIONS		*7*
✦ How will the agency **engage employees and their unions** regarding the impact of the new fleet deployment? ✦ **How will employees be advised** of new training requirements and opportunities?	✦ Changes to the skills required of the agency positions may require revisions to CBAs or other interaction with unions. ✦ To make sure that employees can take advantage of new opportunities, agencies should provide clarity around new training requirements and ample time to complete them.	
ANTI-DISPLACEMENT MEASURES		*6*
✦ **How will the agency support employees** who want to be trained? (Consider both administrative and financial support.) ✦ How will the agency respond to **employees who are not interested in training** on how to maintain and operate low- and zero-emissions buses?	✦ While all mechanics will likely need some training (e.g., concerning safety), there may be opportunities for employees who are less interested in completing a comprehensive training course to continue working; for example, working on systems like brakes and suspension.	
RECRUITING AND HIRING WITH EQUITY IN MIND		*6*
✦ How can the agency **expand its recruiting and hiring efforts** to reach a broader range of potential employees?	✦ Agencies should seek to expand their recruiting and hiring efforts to make sure all potential employees, particularly those from disadvantaged backgrounds, can participate. ✦ The transition to low- and zero-emissions vehicles will provide new opportunities for the transit industry's employees; it also has the potential to attract new employees who may previously have not considered a career in transit.	

Glossary

AC — Alternating current, known commonly as AC current, is one of the two main currents of electricity. AC current obtains its name as the electrical flow periodically changes/alternates direction, AC current can transmit electrical power at higher magnitudes than DC current and is commonly used to transmit electricity across power lines and power household appliances.

Battery Electric Bus — Often abbreviated as BEB. Battery electric buses operate through an electric motor powered from electric stored in an on-board battery. Battery electric vehicles can obtain their power from the grid through either plug-in, pantograph, or induction charging. Battery electric buses produce no tailpipe emissions and are thus classified as zero emission vehicles.

CNG — Compressed Natural Gas, abbreviated as CNG, is an alternative fuel for transportation which is primarily composed of methane. CNG fuel is a gaseous fuel which is stored and used in at high pressures. CNG fuel is considered a low-emission fuel as it produces less greenhouse gas (GHG) emissions than diesel and gasoline fuels.

DC — Direct current, known commonly as DC current, is one of the two main currents of electricity. The electrical flow for DC current travels in one direction, and DC current is commonly used for the charging of electronic devices and batteries.

DC Fast Charging — DC Fast Charging, also referred to as Level 3 charging, is the fastest mode of recharging EVs. DC Fast Charging uses DC current and can charge a rate between 50-600kW, capable of recharging an EV in a matter of minutes.

Depot Charging — Depot charging is the process of charging a BEB at a hub or depot when the bus is out of service, typically overnight. Depot charging charges the BEBs slowly over the course of a couple hours, but depot charging is the most economically effective option as BEBs are charged more efficiently and the electrical use is during periods of lower demand.

Diesel-Fuel Bus — Diesel-fuel buses are buses which use diesel fuel as the source of their power. Diesel buses are the most used type of bus in the United States. Diesel-fuel buses are not considered either low or no emission vehicles.

Fast Charging — Fast charging, also known as opportunity charging or on-route charging, is the process of using high-powered chargers to quickly recharge a BEB while it is in service to extend a BEB's effective range. Using either pantographs or induction chargers, BEBs are charged during a brief break in service (10 – 20 minutes) to extend the range of the bus, and then sent back into service. Fast charging can happen multiple times throughout a BEB's operational block. Fast charging has the ability to get the most utility out of each BEB, but is often more costly as electricity is sired during peak demand periods and the BEBs' batteries are charged less efficiently.

FTA Bus and Facilities Program — The Buses and Bus Facilities Competitive Program (5339b) is a competitive grant program which provides federal funding to purchase buses and equipment and construct bus-related infrastructure. The program is administered by the FTA.

FTA LoNo — The Federal Transit Administration 5339c – Low or No Emission grant program is a competitive grant program administered by the Federal Transit Administration (FTA). FTA LoNo provides state and local governmental authorities federal funding to purchase or lease zero-emission or low-emission transit buses and their associated infrastructure and facilities.

Hybrid Electric Bus — Hybrid electric buses are powered by both an electric motor and an internal combustion engine. Hybrid electric buses typically use power from the electrical motor and then switch to the ICE when demand for power exceeds the battery's capacity. Hybrid electric buses are considered low emission buses as they produce less GHG emissions than diesel vehicles.

Hydrogen Fuel Cell Electric Bus — Hydrogen fuel cell electric buses, abbreviated as FCEBs, are buses which operate through an electric motor powered from a hydrogen fuel cell. FCEBs' store compressed hydrogen gas onboard and the fuel cell uses the store hydrogen and oxygen from the air to power the electric motor. FCEBs produce no tailpipe emissions, besides water vapor, and are thus classified as zero emission vehicles.

Internal Combustion Engine (ICE) vehicle — Internal combustion engine vehicles, abbreviated as ICE, are the most common vehicles worldwide and are power through an engine using the combustion/burning of gasoline, diesel fuel, oil, or other fossil fuels. ICE vehicles produce greenhouse gas emissions and other gaseous pollutants through the vehicles' operation.

kW — A kilowatt (kW) is a unit of measurement which measures the rate of power output or consumed by an electrical device.

Level 1 Charging — Level 1 charging is the term for charging an EV using 120-volt AC current, the power level of electricity found in US households. Level 1 charging defines the slowest form of recharging EVs as the power output is typically 1kW and takes 40-50 hours to fully recharge a battery electric vehicle (BEV).

Level 2 Charging — Level 2 charging is the process of charging EVs through higher rates of AC current, typically 240-volt. Level 2 can charge a BEV at rate of 4-16.8 kW, taking 4-10 hours to fully recharge a BEV.

LNG — Liquid natural gas, abbreviated at LNG, is alternative fuel for transportation composed of natural gas, mainly methane. LNG fuel is distinct as it stored and transported in a liquid form, at lower pressure and at very low temperatures. LNG fuel is considered a low-emission fuel as it produces less greenhouse gas (GHG) emissions than diesel and gasoline fuels.

Low Emission vehicle — Low emission vehicles, abbreviated as LEVs, are vehicles which produces less tailpipe emissions than a standard vehicle of its class. The exact classification of a LEV depends on the agency or organization.

MERIT Grant — Making Efficient and Responsible Investments in Transit grants, known commonly as MERIT, are a group of competitive, state-aid grants administered by Virginia's Department of

Rail and Public Transportation (DRPT) to transit agencies. There are five types of grants awarded under the MERIT program: operating assistance, capital assistance, technical assistance, demonstration project assistance, and public transportation workforce development program.

NEVI Program — The National Electric Vehicle Infrastructure Program (NEVI) is a funding initiative administered by the DOE through the Alternative Fuel Infrastructure Grant Program. The program aims to accelerate the adoption of EVs by supporting the development of EV charging infrastructure across the United States.

Procurement — Procurement is the process of acquiring a necessary good or service to fulfill a need of a business, organization, or governmental entity.

RNG — Renewable natural gas, abbreviated as RNG, is natural gas fuel in which the feedstock of the natural gas is sourced from renewable sources. The most common sources of RNG are captured methane from landfills, livestock operations, and wastewater treatment plants. RNG fuel can be used in either CNG or LNG form.

SMART SCALE grant — The System Management and Allocation of Resources for Transportation: Safety, Congestion, Accessibility, Land Use, Economic Development, and Environment grant program, abbreviated to SMART SCALE, is a state grant program administered through the Commonwealth Transportation Board (CTB). SMART SCALE uses a prioritization process based on certain key factor to score each project submitted for funding. The project's SMART SCALE score determines the amount of funding, if at all, the CTB allocated to the project.

Zero Emission vehicle — Zero emission vehicles, often abbreviated as ZEVs, are vehicles which produce no tailpipe emissions. As of 2024, there are two models of zero emission vehicle technology: battery electric vehicles and hydrogen fuel cell electric vehicles.