TDOT PARTNER AGENCY

ZERO-EMISSION READINESS QUESTIONNAIRE

Contents

Acronyms

Acronym	Description
AC	Alternating Current
ADOT	Arizona Department of Transportation
APTA	American Public Transportation Association
BEB	Battery Electric Bus
BEV	Battery Electric Vehicle
CARTA	Chattanooga Area Regional Transportation Authority
DC	Direct Current
ESS	Energy Storage System
FCEB	Fuel Cell Electric Bus
FTA	Federal Transit Administration
HV	High Voltage
HVAC	Heating, ventilation, and air conditioning
ICE	Internal Combustion Engine
KAT	Knoxville Area Transit
LV	Low Voltage
MATA	Memphis Area Transit Authority
MDOT	Michigan Department of Transportation
MTA	Nashville Metropolitan Transit Authority (WeGO)
MV	Medium Voltage
NCDOT	North Carolina Department of Transportation
NFPA	National Fire Protection Association
NTD	National Transit Database
OEM	Original equipment manufacturer
PPE	Personal Protective Equipment
PPP	Public Private Partnership
SOC	State of Charge
TCRP	Transportation Cooperative Research Program
TDOT	Tennessee Department of Transportation
UCHRA	Upper Cumberland Human Resource Agency
ZEB	Zero emission bus
ZEV	Zero emission vehicle

Definitions

Term	Description
Apprenticeship	Apprenticeship is a system for training a new generation of workforce with on-the-job training and often some accompanying study. Apprenticeships are especially increasing in number in the maintenance field
Charge Management	Utilizing software to take advantage of off-peak utility charging fees, while ensuring fleet availability due to operational requirements.
Charging Cabinet	Cabinet containing equipment to charge battery electric vehicles. Charging vehicles is safe with simple training. However, only a trained professional should enter or work within the cabinet.
Greenhouse Gases (GHG)	A greenhouse gas is a gas that absorbs and emits radiant energy, causing the greenhouse effect. The primary greenhouse gases in Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide, and ozone.
Internal Combustion Engine (ICE)	Vehicle powered by conventional, oil-derived resources such as gasoline or diesel fuels.
Off-Peak Charging	Charging at lower utility tariff times of the day, during the overnight hours.
On-Route Charging	On-Route charging is when equipment is installed at a fixed location, usually along a fixed route bus line, where a bus can charge during a layover.
Pantograph Chargers	Pantographs chargers are sets of scissor-like contact arms that draw their power for vehicle operation from stationary masts. The commercial vehicle industry adopted this idea from rail technology, in which pantographs have long been used to supply continuous power to electrically powered locomotives from overhead lines
State of Charge	The amount of battery life remaining in the vehicle.
Zero Emission Vehicle	A vehicle that provides zero emissions at the tailpipe

Figures

Tables

Overview

This readiness questionnaire is intended for any Tennessee Department of Transportation (TDOT) partner agency considering the purchase of battery electric or fuel cell electric vehicles. The document is organized into six parts:

1. Overview
2. Introduction to Zero-Emission Vehicles
3. Overview of Zero-Emission Bus/Vehicle Transition
4. Zero-Emission Vehicles in Tennessee
5. Key Lessons Learned
6. Readiness Questionnaire

The questionnaire follows the format of the Federal Transit Administration (FTA) requirements for a Zero-Emission Transition Plan, which is required as part of the Low or No Emissions Program (U.S. Code 5339(c)). Even if an agency is not planning to apply for those grant funds, these questions should be used to guide zero-emission vehicle (ZEV) deployment.

Introduction to Zero-Emission Vehicles

What is a Zero-Emission Vehicle (ZEV)?

A zero-emission vehicle (ZEV) is a transit vehicle that generates zero tailpipe emission. Today, vehicles that are ZEVs and are commonly in use in the transit market utilize battery-electric propulsion and, to a lesser extent, hydrogen fuel cell systems. Smaller transit vehicles utilizing hydrogen are not currently available without a retrofit, so most of this section is focused on battery electric vehicles.

Early or first-generation ZEVs were conventional buses with the driveline removed, and batteries and an electric drive motor added. This design made the buses heavy, and consequently led to a decrease in passenger carrying ability. Because the battery packs were bulky and could weigh two to three tons, batteries were placed on the roof. New vehicles now have purpose-built battery packs that the original equipment manufacturers (OEMs) have designed to fit into their structures and provide more passenger space. Integral design buses (body-incorporating chassis) are lighter and have become prevalent.

Battery Electric Vehicle Technology

The primary difference between battery electric vehicles (BEV) and conventional or internal combustion engine (ICE) vehicles is their fueling and propulsion systems. A battery electric bus's (BEB) propulsion system consists of an on-board battery bank, charging ports, and electric traction motors. Today's market available BEB come with on-board battery banks with capacities of 300 to 700+ kilowatt hours (kWh) of energy storage and can achieve up to 200 miles on a single charge. Battery technology is continually advancing; Proterra recently announced a 738-kWh battery to be produced in 2023 that is projected to support an estimated vehicle range of 300 miles. The cutaway market is not as mature as the bus market, but new vehicles are being introduced to the market frequently.

Although BEV technology is promising, it does have some drawbacks. Batteries are heavy and less energy dense than other forms of transit fuel. Adding battery capacity to increase range above 200 miles often comes at a cost of reducing passenger capacity to meet gross vehicle weight rating restrictions. Hills, driver behavior, and heating ventilation and cooling system (HVAC) load all take their tolls on battery capacity and can drastically reduce vehicle range.

Figure 1: Charging Cabinet with Plug-in Dispenser

Three methods are currently on the market for providing power to charge BEVs: pantograph, plug-in, and inductive charging. Each technology is available at a variety of power levels, starting at 60 kilowatts (kW) and extending up to 660 kW, depending on operational needs. The two methods for maintaining state of charge (SOC) for daily operations are depot and on-route charging, each with benefits and drawbacks. For depot charging, a large array of chargers is installed and arranged at each vehicle parking location. Chargers, such as the one shown in Figure 1, are typically rated at 150 kW, and are arranged in a charger-to-dispenser ratio that limits the amount of power required from the local utility, such as one charger per two buses. Overnight depot charging ensures that vehicles have a full SOC for morning pullout. However, depot charging requires significant amounts of power to be brought on site and would require upgrades to an agency's existing utility service, including transformers and switchgears. Redesigning or constructing a bus depot to support charging involves additional effort and efficient utilization of space. Battery electric buses can be introduced in phases, with pilot projects followed by larger scale deployments. Sites can be prepared for electrification in alignment with regular procurement cycles that convert the fleet to BEVs.

On-route charging typically involves installing charging stations at existing bus layover sites. Buses may charge during existing operator breaks to maintain SOC on long routes. On-route chargers typically range in power from 250 to 600 kW to maximize the amount of power delivered to vehicle batteries in short timespans. Opportunity charging systems require significant planning to ensure that vehicles do not run out of power while in service. Opportunity charging is a good option for existing bus rapid transit routes and for layover locations where transit agencies own land and have the option to make a long-term infrastructure investment. While opportunity charging is a solution for increasing the daily range of a battery electric bus, due to the cost to operate is not recommended as a full-fleet charging strategy. However, a transition plan would be able to look at all options and recommend the best solution for an individual agency operating requirement.

Vehicles

Table 1 summarizes currently available vehicle models and their base purchase prices. Vehicle manufacturers are experiencing delivery schedule impacts due to ongoing supply chain challenges. These delays particularly impact vehicles that are subject to the FTA's Buy America requirements because these vehicles may only use materials and parts from U.S. manufacturers. Some OEMs purchased substantial inventory at the start of the COVID-19 pandemic, but even they are experiencing impacts from U.S. supply chain issues.

Table 1: BEB Vehicle Options

Length	Manufacturer(s)	Battery Capacity	Propulsion Type	Base Price[1]
40 feet	BYD[2]	348 kWh	BEB	$730,000
	ENC	518 kWh	BEB	TBD[4]

	Gillig	490 kWh	BEB	$757,732
	Proterra	450 kWh	BEB	$821,944
	New Flyer	525 kWh	BEB	$824,400
	Nova	TBD	BEB	TBD[4]
35 feet	BYD[2]	435 kWh	BEB	$750,000
	Gillig	490 kWh	BEB	$753,521
	Proterra	450 kWh	BEB	$816,914
	New Flyer	440 kWh	BEB	$774,400
30 feet	Greenpower	260 kWh	BEB	TBD[5]
	BYD[2]	295 kWh	BEB	$630,000.00
Paratransit	Greenpower EV Star	118 kWh	BEB	$200,000
	Lightning ZEV4	120 kWh	BEB	$230,000
	Lightning ZEV3	80-120 kWh	BEB	$175,000
	Motiv E-450	127 kWh	BEB	$250,000
	SEA Ford Transit EV	88 kWh	BEB	$160,000

[1] Base Price from Florida State Contract via Pinellas Suncoast Transit Authority (PSTA) December 2021, unless otherwise noted
[2] BYD North America. Ltd. vehicles are not currently eligible for purchase with federal funds
[3] California State Contract April 2019
[4] Nova Bus and ENC recently passed Altoona durability testing; competitive pricing is difficult to find
[5] Greenpower Motor Company is currently re-evaluating Buy America Vehicles.

Key: BEB = battery electric bus; BYD = BYD Auto Co. Ltd.; kW = kilowatts; kWh = kilowatt hours; New Flyer = New Flyer of America; TBD = to be determined

Interviews with Arizona Department of Transportation (ADOT), Michigan Department of Transportation (MDOT), and North Carolina Department of Transportation (NCDOT) highlighted their recent procurements were significantly delayed due to supply chain issues, and significant price increases. Manufacturers were initially providing proposed schedules between 12 and 18 months for delivery of new buses, however OEMs took longer than expected to supply resellers with their chassis. Over the first half of 2022, supply chain issues, especially with microchips, have had an impact on the OEM and delivery schedules. The OEMs are working on solutions, and all of them are in various stages of reengineering and testing product development to address supply issues. When an agency begins a broader procurement process for a larger order of ZEVs, they should discuss with OEMs how the current state of the supply chain may impact the schedule.

Zero-Emissions Fueling and Charging

This section provides an overview of the technology associated with fueling and charging zero-emissions vehicles. Battery electric vehicle (BEV) charging, equipment, and utility information is discussed in this section.

BEV Charging Overview

BEVs use onboard batteries, referred to as energy storage systems (ESS), to store and distribute energy to power an electric motor and other onboard systems. The capacity of an ESS is expressed in kilowatt-hours (kWh) and is sized based on the duty cycle, operating environment, and availability of electrical supply for the BEV. Table 2 lists terms used to describe BEV power and energy consumption and their corresponding equivalent for internal combustion engine vehicles.

Table 2: Terms for BEV Units and Equivalent Terms

Term	Unit	Meaning	Example	ICE Equivalent
Kilowatt	kW	Power	A 100-kW motor is equivalent to a 75-horsepower engine	Horsepower
Kilowatt-hour	kWh	Energy	A 400 kWh ESS should be able to supply 400kW for an hour and 200 kW for 30 minutes	One gallon of fuel is equivalent to approximately 35 kWh for gasoline and 40 kWh for diesel
Kilowatt-hour per mile	kWh/mi	Energy consumed per mile	An average city transit bus might use 2.1 kWh/mi. In spring, with the air conditioning on, the bus might use 2.9 kWh/mi	Miles per gallon (mpg)

Source: WSP, Altoona Bus Research and Testing Center

Current BEV charging strategies include charging at the division, also often referred to as depot charging (overnight or midday), opportunity charging (typically during layovers between service assignments), or a combination of both. A division charging strategy consists of buses with high-capacity battery packs that are charged for four to eight hours with lower power DC chargers—usually rated at less than 250 kilowatts (kW)—while being stored overnight. An opportunity charging strategy typically consists of buses with low-capacity battery packs that are charged with higher power chargers – usually rated over 100 kW – during bus layovers (typically 5-20 minutes). The battery can be considered like packing luggage for travels. If a person has 5 minutes to pack, they will throw everything into their luggage, sit on the lid to zip up the bag, and potentially damage and wear out the straps which can shorten the bag's useful life. If a person has more time to pack, they are more deliberate and careful in packing in their belongings. Similarly, a battery will charge faster at a higher power rate, but the higher power rate generates extra heat and quickens the battery capacity's degradation. With a lower charging rate, the longer charging time can extend the lifetime of the BEV batteries.

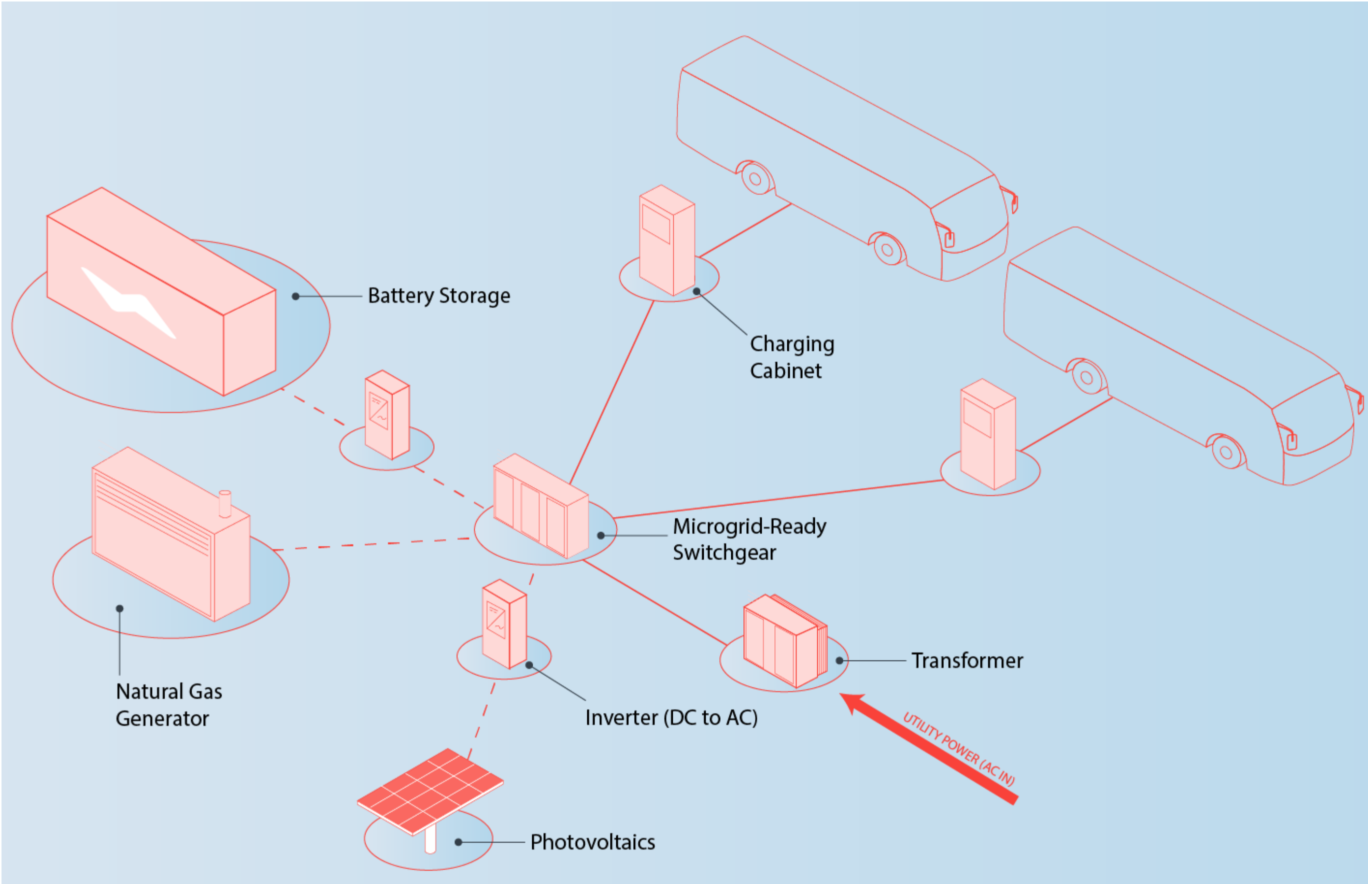

Figure 2: Typical BEV Charging System Components

Source: WSP

BEV chargers come in several dispenser types (conductive, which includes plug-in and pantograph chargers, and ground-based inductive) and orientations to the vehicles (overhead or ground-mounted). The most common dispensers in the US market are plug-in and pantograph chargers.

Charging System Components

To charge a BEV (or a fleet of BEVs), the following infrastructure and equipment must be in place in the operating depot:

- Switchgear(s) – Allows for the isolation of power from the grid
- Transformer(s) – Steps down electricity from the grid to a safe and suitable limit
- Charging cabinet(s) and dispenser(s) – Dispenses power and, in most cases, converts grid-supplied power from Alternating Current (AC) to Direct Current (DC) to charge vehicles
- Distribution network to connect BEVs, which in some systems may entail a distribution panel to allow multiple dispensers to be operated by a single charger

The charging cabinet (or charging station with AC systems) is provided by a charging equipment manufacturer and has manual and/or automated controls (or smart charging). The charging cabinet takes generic AC power and distributes charger-specific power to the bus through one or more dispensers that are connected to the buses. While batteries need to be charged with DC power, electricity is distributed as AC power due to the limitations on the distance over which DC power can be distributed. A device, the rectifier, then converts the incoming AC power to DC power.

Other components can also be considered to provide additional resiliency to transit agencies that depend on battery-electric vehicles to provide services, such as battery energy storage systems, photovoltaic equipment such as solar panels, and backup generators.

Regardless of the specific charging technology, most BEV charging systems will require an enhancement to utility-provided electrical service to the site, on-site electrical distribution, charging equipment, and a charge management system that monitors vehicle charge levels and the time of day at which vehicles are charged.

Charging Dispensers

The dispenser is the equipment that physically connects the charging cabinet to the bus. The type of dispenser varies by charging system type, manufacturer, and agency preference. Figure 3 illustrates the types of dispensers available and how each connects to the vehicle. The three types of charging methods are plug-in, pantograph, and inductive charging. For smaller vehicles currently the only option is a plug-in charger.

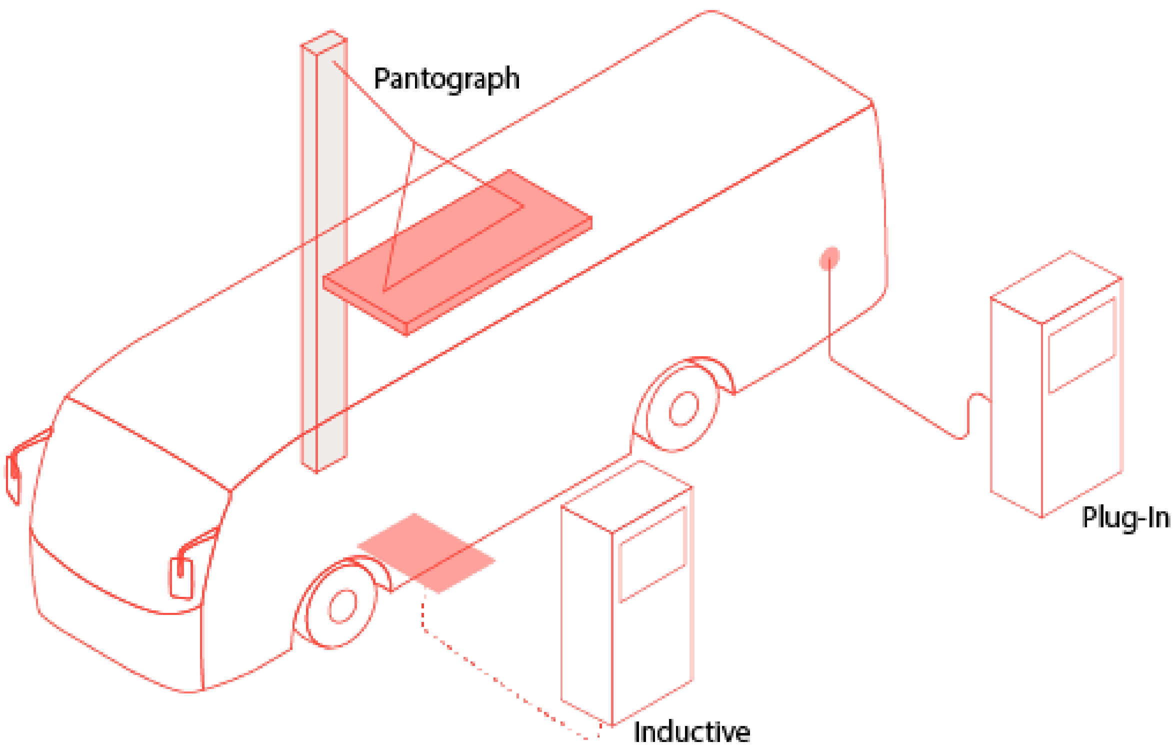

Figure 3: Dispenser Types

Source: WSP

Infrastructure Upgrades for Depot Charging

Due to the high-power demand for charging BEVs and the small amount of spare capacity left in existing circuits, expanded or new electrical service is typically required to serve BEVs that are added to the fleet. Table 3 shows examples of the types of service offered by the utility provider.

Table 3: Utility Service Types

Type of Service	Voltage (V)	Common Examples
Primary Voltage Service	Above 1,000 V	2,400 V; 4,160 V; 13.8 kV; 115 kV
Secondary Voltage	Below 600 V	480 V; 208 V
Medium Voltage (MV)	Typically, 480 3-phase	13.8 kV to 480 V 3-phase

Source: WSP

Depending upon the load to be served, a local utility provides two types of service –primary voltage, which is above 1000 Volts (such as 2,400 V, 4,160 V or 13.8 kV, or 115 kV), or secondary voltage, which is below 600 Volts (208 or 480 Volts). Primary service tariffs are typically much less expensive than secondary voltage service rates but require the facility owner to own and maintain more of the interconnection equipment to utility power like the medium-voltage switchgear. Depending on the transit agency, fleet size, number of routes, and length of bus routes, the type of utility service will vary.

Secondary service is more common and usually the existing service level in most transit facilities due to the low loads. Smaller fleets with a few vehicles like a 20-vehicle paratransit system can continue to stay on secondary service. The point of interconnection and utility metering is after the utility-owned and maintained secondary voltage transformers utilized by the agency.

Given the large loads required for BEV charging for large fleets (for example 150 40-foot buses), primary service will be brought to the site at 13.8 kV (referred to as medium voltage, or MV). The utility metering for primary voltage service is located at the customer owned MV switchgear or switchboard.

The best way to determine the facility's new service type is to analyze the fleet's new load, coordinate with the serving utility on service eligibility, and estimate the cost differences between the two different service levels. Sometimes, the serving utility has restrictions on the level of service provided to a facility based on their new load demand.

If the agency's load to be served needs high reliability, utility companies usually meet these customer requirements by providing two or three service feeders from different utility substations. This way, if one of the feeders is out of service for any reason (such as a ground fault), the second or third feeder can carry the entire load. To allow any component on the site to be fed by any of the service feeders, the main breakers are arranged in what is referred to as a main-tie-main configuration. This type of redundancy arrangement on the HV/MV side is called primary-selective service.

For proposed facilities with a fleet of 100 or more large (30-foot) BEVs, the local utility may opt to bring the redundant primary service feeders at primary voltages. If the facility has primary voltage service, the facility will need to own and maintain interconnection equipment, like primary switches/switchgears and medium voltage (MV) step-down transformers. This setup is commonly referred to as an onsite substation. After the substation, the electrical infrastructure will be like secondary service electrical connections. To provide redundancy, a double-ended substation, with two service feeders and two sets of transformers, would be used. All this equipment requires a large fenced or wall-enclosed area (in the range of 30 by 60 feet) on the customer's site.

While the initial capital expense of constructing an electrical substation and providing and installing the equipment is borne by the local utility, if used solely to provide power to a single customer's property, the cost of the substation will be passed on to the customer either through a one-time charge or amortized on monthly electrical bills.

Charging Strategies and Considerations

Charge management is the hardware or software system that monitors and controls the installed vehicle charging stations and cabinets on a site. With a charge management system, an on-site service manager can:

- View the status of the various individual charger stations and cabinets (e.g., open, in-use, offline)
- View the State of Charge (SOC), the available battery capacity, of a specific BEV that is connected to a specific charger on site
- Control prioritization of connected chargers (i.e., where one charger can power two or more dispensers at a time, the system is able to control which dispenser gets power and how much power it receives)
- Monitor the total amount of power used by the site for charging, adjust charging rates and time of charging to keep maximum daily use under a desired maximum power usage

The importance of charge management systems cannot be overstated. The charge management system on a site should be compatible with multiple charging equipment manufacturers. The ability to remotely monitor and control the charge management system at various sites from a central location can provide for optimal monitoring of the depot charging process, including centralized charging oversight and assessment of the status of the electrical infrastructure at each facility.

Dedicated vs. Shared Charging

Dedicated charging (1:1) refers to a charging system configuration where a single charger is connected to a single dispenser and can only charge a single BEV at any given time. Shared charging (1:2, 1:3, etc.) refers to a charging system configuration where a single charger is connected to multiple dispensers.

The main differentiating factors between these methods are shown in Tables 4 and 5.

Table 4: Dedicated Charging Advantages and Disadvantages

Advantages of Dedicated Chargers	Disadvantages of Dedicated Chargers
Any BEV parked and connected to a dispenser will receive the maximum amount of power that the BEV can accept and is available from the charger until the vehicle is fully charged, regardless of the number of vehicles being charged on the site. A BEV plugging into any dispenser will not alter or impede the charging rate of another vehicle currently plugged into another dispenser within the system. The plan for charging BEVs is straightforward. Any track can be used for any purpose and a vehicle can pull into any charging position. Pre-specified charging positions are not required. Numerous BEV OEMs and third-party charger manufacturers produce 1:1 charger.	More space is required to accommodate a complete set of charging cabinets, in addition to higher costs for a 1:1 charging cabinet set. Larger or more transformers and switchgears are required to support more chargers means higher infrastructure costs and more space than shared charging. Potential to incur higher electricity costs due to potentially higher peak demand usage.

Table 5: Shared Charging Advantages and Disadvantages

Advantages of Shared Chargers	Disadvantages Shared Chargers
The required electrical service is smaller than for a dedicated 1:1 charging system. Smaller or fewer transformers and switchgears means lower infrastructure cost, and a smaller space requirement. Reduced rates of charge to a battery may extend BEV battery life.	Any BEV that pulls in and begins charging is not guaranteed to receive the full or any amount of power from a charger, as the power may be being directed to another vehicle. Shared charging is not commercially available from every OEM for every dispenser type. Most OEMs can accommodate shared plug-in charging, but only a few can accommodate shared pantograph charging. Dispenser locations must be carefully considered and coordinated to establish which parking positions are expected to be filled in what order and at what time so that all BEVs assigned to the facility can receive a full charge in the requisite amount of time.

Public-private Partnership for Charging Infrastructure

One method of implementing, operating, and maintaining charging infrastructure is to implement a public-private partnership (sometimes called a PPP, P3, Energy as a Service, or Charging as a Service) model. This would allow an agency to contract with a firm that would be responsible for the implementation, operation, and maintenance of the charging infrastructure. Transit agencies of all sizes are considering this model, for several reasons. This method allows a transit agency to focus on its core business and what it knows—operating and maintaining vehicles—and it saves the time and effort needed to prepare staff for the transition to zero-emission vehicles. This third-party operator would focus on the aspects of the work that are new, such as working with high-voltage infrastructure, cabinets, and switchgears. This option would provide the necessary operations and maintenance portion of the charging infrastructure, without requiring the creation of a whole new department and job category.

Figure 4: Bus with Pantograph Charger

Charge Management

Zero-emission vehicles provide a robust source of data that can be used in real time to inform dispatching and service decisions, and for analysis to inform future vehicle procurements, service adjustments, and facility investments. Charge management software can assist many aspects of zero-emission transit operations. This software works with day-to-day operations, allowing dispatch or the control center to monitor SOC in real time and works daily to optimize the time vehicles charge to reduce peak demand, which would reduce costs to a transit agency.

Table 6 outlines some of the available options for charge management solutions. All the vehicle OEMs have a charge management program that is specific to their brand and will only provide vehicle information, not charger information. Proterra is the one OEM that claims the ability to provide a full solution that works with all vehicles and charging infrastructure.

Table 6: Charge Management Solutions

Company Name	Highlights
ABB	ABB is one of the largest charging infrastructure and charge management solutions on the market. It can be found all over the United States and globally.
Ampcontrol	Ampcontrol is a newer solution that has a product where the program manages charge between fleet vehicles and public revenue-generating charging opportunities. This allows one set of chargers to be used for more than one use (public open charging and fleet). The program will be a charging program that ensures the fleet is charged and ready for service when it is needed. It works with transit fleets in Europe.
Amply Power	Amply Power provides charge management solutions, as well as charging as a service solution. It is owned by BP and utilized by Solano County Transit in California.
ChargePoint/ViriCiti	ChargePoint is another large player in the charge market and has purchased ViriCiti. ViriCiti is a vehicle agnostic charge management platform, which is used by some transit agencies. It plans to work more with fleets to provide better software solutions. Chicago Transit Authority uses ViriCiti.
Init	Init is a popular solution for many technical solutions in the transit field. GoRaleigh uses this service to manage their battery electric vehicles.
Proterra	In addition to providing buses, Proterra also has a business line focusing on charging infrastructure and charge management solutions. The charging solutions are OEM agnostic.
The Mobility House	The Mobility House has been in operation for 11 years. The company focuses on its own technology platform, ChargePilot, but can also provide charging as a service or turnkey solutions using ABB equipment. King County Metro uses the ChargePilot solution.

Workforce

On the surface, no major change is required for job duties and descriptions in operations during a transition from ICE vehicles to ZEVs. Technicians continue to maintain responsibility for providing preventative maintenance per a predesigned checklist and to troubleshoot vehicle issues while remaining observant of safety protocols per their training. Operators still operate the buses on the same routes (some route adjustments may have to be made to accommodate the shorter range of BEVs) with the same bus stops and customer service protocols.

However, while the job descriptions are not impacted, the required skills of these tasks are subject to change with the transition to ZEVs. The operating procedures that process the vehicle at the end of the day will have to be modified to accommodate responsibility for charging the vehicle. Typically, end of service inspections are performed at the fueling station as the vehicle is pulled up to the fuel pumps. In contrast, ZEVs may be pulled up directly to their parking station where they will charge overnight. This will require agencies to restructure their end of service maintenance and inspection protocols.

The ZEV transition will also have impacts on the necessary skills for employees in the maintenance, facilities, procurement, scheduling, and dispatch departments. New trainings, personal protective equipment (PPE), and support will be required to help employees prepare for the new incoming technologies. Training programs can be created in collaboration with OEMs for maintenance programs since OEMs have the strongest understanding for these recent technologies. Maintenance and facilities positions will have the largest set of new skills to learn, including proper high voltage procedures, and familiarization with high voltage PPE. For each employee role in an agency, Table 8 summarizes the training required to ensure they have the necessary skills and knowledge after transition to ZEVs.

Table 7: Employee Roles and ZEV Training Requirements

Employee Role	Training Requirements
Training Instructors	They will be the direct connection to the recent technology and employees with prior skillsets suited to ICE vehicles. Trainers working with maintenance and operators will need to receive the full scope of the associated training. Their knowledge should be direct from the OEMs with as much hands-on education as possible and annual refresher training.
Technicians	They will have to be trained in the new systems that come with ZEVs. PPE procedures around high-voltage electricity will be an unfamiliar risk for technicians, and so will require training regarding this safety concern. More systems will be software oriented as opposed to mechanically oriented, so significant training will be needed surrounding these systems.
Dispatchers/Operations Control	Troubleshooting training will be necessary so that dispatch can support operators while in the yard, during service, or in an emergency.
Operators	One of the staff groups most heavily impacted by the ZEV transition are operators. Operation techniques have significant impacts on the battery's performance and affect the overall range of the vehicle. ZEV transitions are an opportunity to focus on careful driving techniques and should be addressed in training. Operators will also need to know how to safely operate and evaluate a ZEV in an emergency. OEMs often provide operator training programs to show best practices related to the specific vehicle and model.
Cleaners/Utility Staff	Basic BEV operations and safety training will be required to ensure everyone's safety. If they have a CDL, then all training appropriate for an operator will also be required of them.
Facility Technicians	To support charging system maintenance, asset records, system drawings, maintenance manuals, preventative maintenance and inspection, and task descriptions for the new equipment should be available for the facility technicians. Training for interacting with charging system vendors will be necessary since most components of the charging system will be under warranty and identification of issues for formal reporting will be required for warranty claims.
Safety	Knowledge of potential hazards will be important for the safety department. Proper PPE procedures and evacuation strategies should be reviewed. Coordination with first responders will be necessary to ensure proper training is in place for events such as battery fires or other propulsion incidents.
Schedulers/Planners	Due to the decrease in range with ZEVs compared to ICE alternatives, service planners will have to understand the more limited vehicle capabilities when

	determining schedules. Delivery dates of ZEVs will need to be well known to plan for and ensure smooth deployment with appropriate service schedules. Planners will need to be aware of any new standard operating procedures put in place for ZEVs that should be factored into service scheduling.

Overview of the National Zero-Emission Vehicle Market

ZEVs are a vital element in transitioning to a more sustainable transportation system, despite barriers to large-scale implementation such as high investment costs and limited driving range. In January 2023, CALSTART reported that in 2021, the zero-emission transit bus market grew by 66% in the United States, for a total of 5,480 buses either on the road, awarded, or on order. California leads the charge, but considerable growth can be found in all corners of the country, including New York, Florida, and Texas. The growth is partly due to legislative requirements or an agency's interest in cleaner, quieter, energy-agnostic technologies and partly to an increase in local, state, and federal funding. Despite this growth, this share of the nationwide bus fleet is still marginal nationwide when compared to the number of diesel vehicles still in operation.

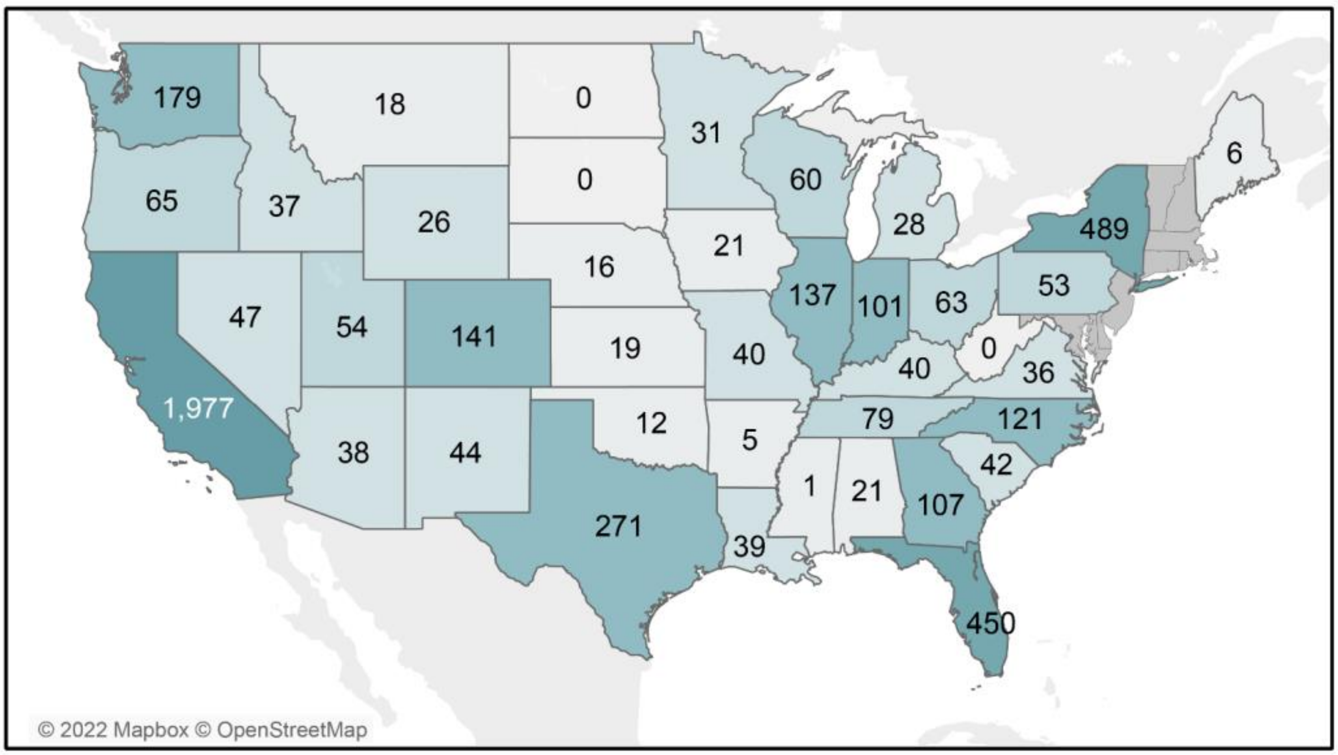

Figure 5: Full-Sized Transit ZEBs Funded, Ordered, or Delivered within the United States (September 2022 from CALSTART Zeroing in on ZEBs)

CALSTART's *Zeroing in on ZEBs* report is an excellent resource for understanding where the U.S. public transit market currently stands regarding the transition to ZEVs for any agency thinking about making the transition. The report link and other helpful resources can be found at the end of this document.

Table 8: FTA Region 4 State by State Full Size ZEB

	BEBs	FCEB[1]	Totals
Alabama	20	1	21
Florida	450	0	450
Georgia	107	0	107
Kentucky	40	0	40
Mississippi	1	0	1
North Carolina	121	0	121
South Carolina	42	0	42
Tennessee	79	0	79
[1] Fuel Cell Electric Bus			

Source (Table A--4 CalStart Report)

Tennessee Zero-Emission Vehicle Overview

While battery electric buses are increasingly being deployed in service, there are agencies such as Chattanooga and WeGo in Nashville that have been earlier adopters with the technology with mixed results. Table 8 below displays select summary characteristics from the 2021 Annual Agency Profiles, followed by details about each agency's electrification efforts.

Table 9: Select NTD Data from Tennessee Transit Agencies

	CARTA	WeGo	KAT	UCHRA	MATA
Service Area Square Miles	289 sq. mi.	504 sq. mi.	104 sq. mi.	Not Available	291 sq. mi.
Service Area Population	179,690	694,144	190,223	Not Available	690,943
Annual Vehicle Revenue Miles	1.9 M	6.8 M	3 M	2.4 M	5.1 M
Annual Vehicle Revenue Hours	162,000	517,000	237,000	164,000	336,000
Revenue Vehicles	110	553	92	121	197
Service Vehicles	14	58	17	18	60
Facilities	10	8	2	2	16

Source: 2021 NTD Annual Agency Profiles

Chattanooga (CARTA)

Chattanooga Area Regional Transportation Authority (CARTA) was established in 1973 and serves the City of Chattanooga, Hamilton County, and the surrounding areas. CARTA operates 13 fixed routes, three (3) all-electric shuttle routes, an incline railway, and on-demand paratransit service (CARTA GO).

CARTA was an early adopter of electric buses, purchasing their first two (2) electric buses in 1992. The decision to purchase electric buses was born out of a downtown revitalization effort that sought to reduce air pollution, relieve traffic congestion, and minimize the amount of land dedicated to parking lots through a free downtown shuttle service funded by parking fees. CARTA had to address several challenges early on, including training staff on electric vehicles, working with the supplier to improve the bus design, and building a combined electric bus terminal and parking facility for more efficient battery charging. Since the initial investment in 1992, CARTA has expanded their electric vehicle fleet to include an all-electric shuttle fleet, as well as electric buses and most recently, electric van-sized vehicles. CARTA has also continued to advance its electric infrastructure, installing inductive charging stations in 2019 to power its electric bus fleet.

Nashville MTA (WeGo)

The Nashville Metropolitan Transit Authority (MTA), also known as WeGo, operates in Nashville and the surrounding areas. WeGo operates fixed route, rail, and demand response service. WeGo's fixed route service includes 26 local bus routes and eight (8) regional routes, with a mix of frequent, local, connector, express, and shuttle service. WeGo Star provides regional rail service between the City of Lebanon and downtown Nashville. WeGo's paratransit service, WeGo Access, provides door-door service within Davidson County for persons with disabilities who are unable to use fixed-route transit.

WeGo began investing in electric vehicles and infrastructure in 2014, when it constructed an electric bus charging station and purchased nine (9) electric buses from Proterra to support the free downtown Music City Circuit. This service was later discontinued, and WeGo's FY 2022-2026 Proposed Capital Investment Plan does not specify any plans to purchase more electric vehicles.

Knoxville (KAT)

Knoxville Area Transit (KAT) is the public transportation system for the City of Knoxville. KAT operates fixed route buses, trolleys, and paratransit service. KAT's fixed route buses service 23 routes (two routes are suspended as of this writing due to workforce shortages). KAT also provides free trolley service through three routes that operate in downtown and the University of Tennessee area. LIFT, KAT's paratransit service, provides door-to-door service to riders who are unable to use the fixed route system.

In 2020, KAT used Volkswagen Settlement Environmental Mitigation Trust (VW Settlement) funds to replace three (3) diesel buses with three (3) diesel-hybrid buses. KAT added all-electric buses to their fleet in 2021 with the purchase of 12 New Flyer Xcelsior® electric buses. To integrate the new electric buses into their fleet, KAT also partnered with The Mobility House as the project's charging and energy management provider. The charging infrastructure utilizes Heliox's 180 Flex product, which was installed in the US for the first time as part of this project. KAT plans to add six (6) more electric buses and seven (7) more dual-port chargers in 2023.

Upper Cumberland Human Resource Agency (UCHRA)

Upper Cumberland Human Resource Agency (UCHRA) provides fixed route and demand response transportation services in the 14-county Upper Cumberland area of Tennessee. UCHRA offers the following services: Connect Upper Cumberland, intercity bus service on I-40 and I-24 routes; Go Upper Cumberland, deviated fixed-route service that serves Algood, Cookeville, McMinnville, and Crossville; Pick Up Upper Cumberland, mobility-on-demand service within Cumberland and Putnam counties; Ride Upper Cumberland, door-to-door service within all 14 counties; and Shuttle UC, shuttle service available for private events, individual contracts, and after-hours transportation service.

In 2021, UCHRA was selected by the Tennessee Department of Transportation (TDOT) to receive an IMPROVE Transit Investment Grant for the purchase of two (2) electric vehicles and associated charging infrastructure. The first electric shuttle bus was delivered to UCHRA in December 2022. The vehicle purchase was part of an initiative with Tennessee Technological University and The US Department of Energy called "Upper Cumberland EV Testbed," which seeks to create proof-of-concept for electric vehicles in the Upper Cumberland region in Tennessee. In addition to the procurement of the electric shuttle bus, the project also established an electric charging station network in the rural Upper Cumberland region, which includes one (1) DC fast charging station and eight (8) public level-2 dual-port charging stations.

Memphis (MATA)

The Memphis Area Transit Authority (MATA) provides public transit within the Memphis area through fixed route buses, paratransit vehicles, on-demand service, and trolleys. MATA's fixed route service operates on 24 routes and the trolley service operates along three (3) routes. Additionally, MATA provides shared ride, curb-to-curb paratransit service through MATAplus as well as on-demand service through Ready! and Groove On-Demand, which are available in select service areas.

In 2018, MATA received $19.9 million in federal funds from the Congestion Mitigation and Air Quality program to purchase ten (10) electric buses and construct charging stations. The buses served a new bus route servicing the Memphis International Airport and southeast Memphis area. MATA received an additional $2.1 million in funds for three (3) electric buses from the Volkswagen Settlement Environmental Mitigation Trust. Most recently, MATA was awarded $22.3 million from the Low- and No-Emission program to buy electric buses and charging equipment as well as to provide workforce development training for operating and maintaining the buses.

Key Lessons Learned

Advances in electric vehicle technology and a decline in battery costs has resulted in many new electric vehicle deployments. While this means that processes and best practices can now be analyzed and improved upon, it also requires flexibility and quick adaptation on the part of the transit agencies. Understanding the experiences of transit agencies that have already implemented ZEVs will improve the transition experience for any TDOT partner agency considering this change. Several recommendations were created based on the experience of other agencies, as described below.

Figure 6: RideOn Bus with Plug-in Charger

Planning

Begin with the End in Mind: Take the time to understand the whole-systems approach—where you want to end up, how to get there, and how to future-proof strategies to take advantage of technology improvements. Understanding your end goal is critical to developing the roadmap to achieve it.

Start the Conversation with Utilities Early: Utility companies across the country are at various levels of readiness to work with transit agencies transitioning to ZEVs. It can take up to two years to get a new power service to a depot, and utility companies are often hesitant to start work until a substantial amount of electric vehicle depot infrastructure design work is complete. It is necessary to establish solid, collaborative partnerships with utilities from an early stage and open a dialogue about goals and interests from the outset. Some agencies have successfully partnered with utility companies or state DOTs to share the costs of connecting their charging infrastructure, often called a "Make Ready Program." The state of Tennessee has a “Make Ready Program” as part of the TN Electric Vehicle Plan.

Additionally, agencies should collaborate with both public officials and local utilities to develop a transportation rate for electricity and to use rate modeling in the planning process of launching an electric bus service.

Transition Plan: A detailed transition/master plan sets up a baseline, sets the stage for future decisions, and encourages adjustments to the plan. A transition plan also documents the current fleet and facilities’ operational status, including critical components like local power and utility supply. In the transition planning process, it is equally important to revisit the transition plan and its underlying assumptions regularly and to update the plan based on current zero-emission technology, keeping in mind identified best practices and lessons learned.

It is not necessary to be a large transit agency to complete a transition successfully. Antelope Valley Transit in California was the first agency to switch to 100% ZEVs. They operate forty-seven buses and twenty-five demand response vehicles. Other small agencies that have conducted an electrification transition plan include Solano Transportation Authority for the one hundred vehicles they operate in service and Placer County for their forty-five vehicles.

Implementation

Run a Pilot: The battery electric heavy-duty vehicle market, including buses and cutaways, has matured to the point that there are fewer concerns about the buses and more options available for cutaways. However, pilot programs are still an excellent opportunity to answer questions about converting a facility to accommodate ZEVs. Pilot programs can allow agencies to ensure that their workforces are adequately trained to safely and efficiently operate and maintain the new vehicles; to understand the new relationship with utility providers; and to learn how the different types of propulsion systems in ZEVs will affect maintenance schedules, new charge management practices, and new processes for scheduling and assigning vehicles to service. Other benefits of a pilot program to the workforce include the ability to test out successful responses in emergency situations and to understand the impacts that the new vehicle modalities will have on the dispatch team.

Pilots allow all these changes to be implemented, monitored, and evaluated so that the build-out for the additional training, standard operating procedures, and rollout plans for the full ZEV program is as successful as possible.

Use the "Yes, if" approach: Change is hard in any industry, and it is a natural response to say “No” when considering the barriers to entry. When dealing with a significant transition like fleet electrification, it is more helpful to think in terms of *yes, I can do that if*—if I have enough funding, planning, people, etc. The change to ZEVs is significant, but this reframing of perspective combined with a master plan will help agencies identify the resources necessary to complete this transition.

Be Flexible and Open-Minded: The transition to ZEVs is quickly evolving, and while it is essential to develop a plan, it is also crucial to understand that the baseline assumptions may become outdated by the end of the planning process. Planning for a ZEV transition should be iterative, with each stage building on the knowledge and lessons learned from the previous one. Agencies should develop plans that allow for change and flexibility as added information, resources, and procedures are developed.

Have a Good Relationship with Original Equipment Manufacturers (OEM): Transit agencies recognize that the relationships with their OEMs are long term, and therefore it is in their best interest to ensure they have direct contacts to address manufacturing issues, IT, and system malfunctions and to provide available parts for replacement. This also allows the agencies’ mechanics to become more skilled with the recent technology. One valuable lesson learned for choosing an OEM is ensuring that the contract includes provisions to guarantee protection if the vehicles delivered do not perform as promised. Before going to bid, agencies should have OEMs run a sample of existing diesel bus routes to ensure that the bid includes the needs of each individual route. The purchase contract can include training hours to be provided directly by the OEM. Some agencies have extended that to include a year or two of having an OEM representative onsite to assist with training and warranty claims.

Integration

There is no "one size fits all" approach to ZEVs: While some agencies have successfully transitioned their fleets to ZEVs, it is still hard to apply one ZEV format across a single agency, let alone multiple agencies and transit programs with various facilities, utilities, fleets, etc.

Factors that can affect an agency's ZEV transition include:

- topography
- local temperature
- average route speeds
- operator driving styles
- facility age and state of good repair

While best practices and lessons learned from other agencies are incredibly valuable tools, it will never be possible to apply one agency's approach wholesale to another.

This change will impact everyone at your agency: Nearly every employee at an agency will be impacted by the transition to ZEVs, including operators, cleaners, facility maintenance, supervisors, dispatch, schedulers, etc., so everyone should be included in the planning. Operators, maintenance workers, and other front-line workforce are crucial as they are the "eyes and ears" of the transition. They will have to operate and maintain the new ZEV fleet every day, during and after the pilot and full conversion. Finding ways to include staff at all levels in planning for the transition can provide valuable feedback and will help develop better trust and understanding as the project moves forward.

Good training impacts success: Establishing hands-on training and safety protocols for all maintenance and operators early in the transition will increase the program's overall success. For operators, this includes retraining to take advantage of regenerative braking and establishing a minimum state of charge for the ZEVs, so operators will always be able to return to the yard. The range can vary as much as 20%, depending on the driving style.

Some examples to consider for maintenance include:

- New PPE procedures
- New tool requirements
- High Voltage training
- Electrical principles refresher training
- Reviewing parts room and ensuring proper spare parts are on hand
- Understanding reading electrical schematic drawings.

Workforce development strategies must be customized and scaled as appropriate for each agency. Workforce development includes not only training for maintenance technicians, but also operations staff, planning staff and facility staff. Additionally, some policies and procedures may need to be adjusted to accommodate the requirements and needs of a zero-emission vehicle. This could include vehicle assignments and how vehicles are processed at the end of the evening.

RANGE CAN VARY AS MUCH AS 20% DUE TO DRIVING STYLE. USE THE ZEV TRANSITION TO TRAIN DRIVERS ON HOW TO TAKE ADVANTAGE OF REGENERATIVE BRAKING AND ESTABLISH A MINIMUM STATE OF CHARGE FOR THE ZEVS, SO OPERATORS WILL ALWAYS BE ABLE TO RETURN TO THE YARD.

Agency Readiness Questionnaire

1.Fleet

FTA Zero-Emission Transition Plan Minimum Requirement:

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

Figure 7: BYD Buses

Self-Assessment Questions

1.Do we understand the range of my current and future service blocks and if they would be compatible with zero-emission buses?

Battery electric and fuel cell electric vehicles have different ranges than diesel-powered vehicles, as well as each other. Agencies may find it helpful to re-route or adjust vehicle work schedules (run cuts) to some of their current lines due to these constraints, but with adjustments, a seamless transition can be made. Some agencies can make schedule adjustments based on their understanding of the average daily miles a vehicle operates. However, it should be noted that operator behavior, topography, temperature, and the number of stops will impact overall battery performance, so some agencies may opt to begin with a route modeling exercise. A model allows a more in-depth analysis of an agency's service by showing which service blocks can be completed by a zero-emission vehicle. This allows the agency to develop solutions in advance for routes that, according to the model, will not pass.

2.Have we engaged the appropriate stakeholders, both internal and external?

Procuring battery electric or fuel cell electric vehicles requires coordination with internal stakeholders and OEMs. For example, training employees requires an agency to schedule staff to attend OEM bus familiarization and safety orientation. It is vital to include internal stakeholders as part of the plan since they will be the people that are most directly impacted by the project. It can also be beneficial to reach out more broadly. For example, suppose the agency is operating as part of a city or county system—does it have sister agencies also running alternative-fueled vehicles that it can learn from or partner with for its ZEV project? In addition, general community outreach can be undertaken to communicate the project benefits and schedule.

At a minimum, the following stakeholder groups should be engaged:

1) Agency Workforce
2) Local Elected Leadership
3) Groups with a sustainability and clean energy interest
4) Local Utility
5) First responders

3. Have we considered the possibility of running a mixed propulsion system fleet?

Depending on the agency's resources, a mixed fleet can be the best option while adjusting to see what recent technology best suits them. Some states, like California and Maryland, have mandates to switch to 100% ZEVs, but that is not the case in Tennessee. TDOT partner agencies could consider converting as much of the service that makes sense given the current ZEV technology while continuing to operate the rest of the service with gas or diesel.

4. Is hydrogen a consideration? Have we considered the opportunities and challenges related to site clearance and the agency's ability to have hydrogen available reliably?

Hydrogen fuel cell electric vehicles use a quick refueling process like gasoline, diesel fuel and CNG. In addition, hydrogen fuel cell electric vehicles have extended ranges compared to battery electric vehicles and therefore can operate for more extended periods without frequent refueling.

Challenges of this fuel type include obtaining hydrogen fuel and understanding the relative environmental impact. Hydrogen fuel is obtained by trucking in compressed fuel or onsite production, both of which can be very costly. Currently hydrogen is not available in the state of Tennessee, however as part of the Infrastructure Investment and Jobs Act, the U.S. Department of Energy is providing $8 billion in funding for regional hydrogen hubs. A recently formed coalition of major utility companies and the Tennessee Valley Authority plans to pursue this funding for financial support to establish a Southeast Hydrogen Hub. The coalition hopes to focus on developing scalable projects at key locations in the Southeast to support their shared carbon-reduction goals, especially in the transportation sector. The technology should be assessed for the full lifecycle of carbon emissions compared to BEBs and legacy vehicles, because emissions vary depending on the source of the hydrogen fuel.

5. Are we aware of how weather conditions affect battery electric and/or fuel cell electric vehicles?

Extreme cold and extreme heat can affect battery range due to extra utilization of the vehicles HVAC system. While Tennessee does not experience the extreme cold temperatures that can be found further north in the United States, drivers and maintenance staff should be aware of these effects on the buses. Hot temperatures will require additional air conditioning, drawing down the battery in a way that could have impacts on service during heat waves. Each agency's route profiles are different, and ambient temperature is one of many factors that can impact battery range.

6. Have we completed a preliminary risk assessment? Do we understand any new or modified procedures that will need to be created to support these new propulsion systems?

Introducing any new type of vehicle and fuel are reasons to update an agency's current risk assessment procedures. In addition to assessing how ZEVs might perform (step 1), an agency should consider policies and procedures, procurement impacts, and emergency response plans (weather, security & fire). A risk assessment is specific to an agency's existing conditions and plans for development.

2.Policy & Regulations

FTA Zero-Emission Transition Plan Minimum Requirement:

Consider policy and legislation impacting relevant technologies.

Figure 8: Optimal EV/Proterra Shuttle Bus

Self-Assessment Questions

1.Does the state of Tennessee, or my local county or city, have any specific emission mandates or governed air quality goals in the coming years? If so, have we considered how converting to low- or no-emission buses could support that goal or program?

Agencies in some parts of the country have specific legislative mandates that they must consider as they transition their fleets. At the time of the creation of this document, the state of Tennessee does not have any specific goals or requirements. However, it is good practice when considering the transition to understand if there are any local, county, or state goals that this transition could support.

2.Do we plan to join the FTA Sustainable Transit for a Healthy Planet Challenge? Is this project part of our overall plan to address climate change?

On June 15, 2021, the FTA launched this project to encourage transit agencies to take bold action to reduce greenhouse gas (GHG) emissions from public transportation to support the US government's GHG reduction goal. The challenge calls for transit agencies to develop climate, sustainability, electrification, or zero-emission transition plans that include strategies with measurable goals to achieve GHG emission targets. Transitioning an agency's vehicles to a cleaner propulsion system can be included as part of the Healthy Planet Challenge.

3.Do we know if the local municipality, county, or state have any sustainability initiatives that the transition to clean vehicles would support?

Tennessee has a handful of green vehicle laws aimed at protecting the environment. These include vehicle emissions testing for most alternative fuel vehicles (excluding electric cars), liquefied gas and compressed natural gas taxes, and licensing and driving restrictions for low- and medium-speed electric vehicles. More Tennessee state regulations and electric vehicle incentives can be found here: Tennessee Green Vehicle Laws and Alternative Fuel Regulations | DMV.ORG

One example is Knoxville's goal of reducing community emissions 80% by the year 2050. This includes the transit services and the positive impacts that transit services can reflect on that goal in the community.

3.Funding

FTA Zero Emission Transition Plan Minimum Requirement:

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

Self-Assessment Questions

1.Are we aware of/have we applied for any state or federal grants?

Several states and cities offer their own incentives to electric vehicle buyers. They usually take the form of a tax credit or a cash rebate, with some areas also offering financial assistance. Provisions and exclusions are plentiful among electric vehicle incentive programs.
Tennessee Green Vehicle Laws and Alternative Fuel Regulations | DMV.ORG

2.Have we identified potential funding sources for the transition?

Transitions to zero-emission or lower-emission vehicles like those fueled by compressed natural gas require infrastructure investments. Those investments can cost millions of dollars, depending on the fleet size, facility, and charging needs. Some agencies have funding available to leverage the change; others must seek additional funding. Some have considered using a financing partner to help support the infrastructure investments. Staggering implementation and investments can also be a way to manage cash flow needs for the overall system upgrade. Tennessee agencies can apply for discretionary funding both through Federal Transit Administration 5339 (c) Low- and No-Emission Grants and TDOT IMRPOVE Transit Investment grants.

3. Have we reviewed our current fleet replacement schedule?

One strategy for vehicle replacement is looking at the current ICE vehicle replacement schedule and evaluating when vehicle replacements can be completed with zero emission vehicles. However, agencies need to keep in mind that with a zero-emission vehicle purchase, the requisite charging infrastructure needs to be installed and ready to be tested prior to vehicle delivery. This is why some agencies end up with a slower initial replacement schedule while they time their infrastructure upgrades to time with vehicle replacements.

Federal Funds 5307 and 5303 can be used for transition planning, as well as state-supported funding resources in the state of Tennessee.

Federal funds can also help offset the cost of infrastructure upgrades, design, construction, and vehicle and equipment purchases, as well as support workforce development activities, including training and apprenticeship programs.

4.Utilities

FTA Zero-Emission Transition Plan Minimum Requirement:

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

Figure 9: Plug-in Bus Depot Chargers

Self-Assessment Questions

1.Do we know if our utility provider can offer sufficient support for battery electric vehicle charging?

Early engagement with the local utility company can help an agency determine the feasibility of utilizing zero-emission technology and make transitioning easier. Additionally, modeling can help an agency understand how many charging positions are needed and when vehicles will need to be charged. This will allow the agency and the utility to engage in discussions about peak utilization needs.

Examples of questions to ask the utility include:

1) Service reliability (power outage frequency)
2) Capacity availability
3) Timeline and process for the agency to request additional power

America Public Transit Association (APTA)

In March 2023 APTA released a ***Checklist for Engaging on Fleet Electrification***. Designed to guide a transit agency on the coordination with their local utility. It is posted on the Zero Emission Bus section of the Research and Technical Resources. Membership is not required for access to this document.

APTA_Checklist_For_Engaging_Your_Electric_Company_On_Fleet_Electrification.pdf

2. Are we interested in opportunities for solar, on-route, and off-peak charging?

Solar, on-route, and off-peak charging can help offset the costs of energy, as well as reduce the risk of a vehicle losing charge while on the route and requiring road call assistance. It is advisable for agencies to discuss this with their utility providers since peak charging may vary. This is another item that can be further analyzed when an agency models its service needs. These strategies can be used to keep the battery at a serviceable level all day.

3. If we have already successfully deployed zero-emission or low-emission vehicles, have we considered the implications of how a scaled-up deployment would impact workforce/utility?

Depending on the utility, some agencies need to adjust to either workforce development programs, or utility needs, when upgrading a higher percentage of their fleet to zero emission. Some agencies running a few ZEVs have faced challenges when moving toward a 100% zero-emission fleet when they have not done thorough transition planning. Utility infrastructure upgrades can take time and be expensive to plan, making an early understanding of the requirements crucial.

Transit Cooperative Research Program (TCRP)

TCRP completed a report in 2015 called ***Practices in Utility Coordination for Transit Projects Synthesis 118.*** This report, while not zero-emission specific, speaks to Utility coordination in general for transit projects. It can be a great resource as the report below is being developed.

http://nap.nationalacademies.org/22172

TCRP has a report in progress called ***Examination of Transit Agency Coordination with Electric Utilities.*** This report focuses specifically on agencies converting to zero-emission vehicles. The report is expected to be available later in 2023.

http://apps.trb.org/cmsfeed/TRBNetProjectDi

4. Have we considered investing in charge management software?

Battery electric buses have a different type of "refueling" process than diesel and gasoline buses. The cost of power is based both on the total amount of electricity delivered as well as the amount of power delivered at a specific time (the peak load). Recharging a BEB correctly requires more diligence than recharging a typical bus. Charge management software allows an agency to understand the energy needs and consumption from the charging infrastructure. Charge management software has been a valuable investment for several agencies by improving both efficiency and awareness. The programs also assist an agency in programming charging times so that an agency takes advantage of the least expensive times of day to charge. Charge management software can be purchased either with charging infrastructure or as a separate standalone program. Regardless of how it is purchased, it is important to confirm compatibility with the charging equipment and the agency's existing IT infrastructure and vehicle telematics.

5. Do we know how much power this transition will require?

The first question a utility will ask is, "What is the maximum amount of power you will you need?" For BEB projects, agencies will need to know how many chargers they plan to build and the kW rating for the charger. (This can be mitigated with charging strategies, but utilities look at the highest possible demand). For FCEV, agencies should consider if they will be producing green hydrogen on site. If so, they will have a significant new power requirement to create, compress, and dispense hydrogen fuel.

5.Facilities

FTA Zero Emission Transition Plan Minimum Requirement:

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

Figure 10: King County Metro Pantograph Chargers at Bus Deport

Self-Assessment Questions

1.Do we understand the facility requirements, including charging infrastructure locations and additional electrical or hydrogen infrastructure requirements?

Even an agency running a pilot program of a few ZEVs should think about future requirements and installations so that they do not have to repeat work down the road.

Infrastructure required for ZEVs can take up valuable space at a transit facility. Some transit facilities have room to accommodate these requirements, and some do not. There are innovative space-saving designs that can help in some situations, but in other cases, facilities cannot be modified—for example, hydrogen clearance requirements can be a challenge to accommodate on a constrained site. Even an agency running a pilot program of a few ZEVs should think about future requirements during initial installations, so they do not have to repeat work down the road. Common phasing for BEBs includes:

- Installing all the required conduits up front
- Pulling cable as the fleet grows
- Adding charging dispensers as the fleet grows

Common phasing for FCEV includes:

- Installing required building and gas detection upgrades for FCEV
- Building small storage units for Hydrogen delivery (fossil fuel based Hydrogen) for pilot vehicles
- Adding additional Hydrogen storage as the fleet grows

Having the end in mind when planning in the short term can avoid issues like building a storage tank in a location that will be needed for a larger storage tank later, saving an agency additional work and expense down the road.

2. Have we considered coordinating with first responders in developing the facility modifications?

First responders can have two roles in an agency's transition to ZEVs. First, they can help ensure that the new facility upgrades (or new facility) have the required elements for safety related to the new vehicles. In most cases across the country, building codes and requirements have not caught up to the technology, but first responders and the agency's insurance adjuster can be helpful resources with design elements.

Examples of questions to ask in coordination:

1. What sort of defaults do we need to install in case of emergency, such as stopping the HVAC, or limiting additional power?
2. What elements are required for the safety of life and property? Protective barriers, fire protection equipment, and training?

Agencies with smaller equipment such as cutaways can utilize some of the existing first responder training material directed towards passenger vehicles. The National Fire Protection Association has resources available on its website (www.nfpa.org)

Second, additional coordination with first responders in response to any incident involving a ZEV is essential. When the vehicle first arrives, an agency should work with the local first responder jurisdictions to have a live walk-through of the vehicle. This also may mean that the agency's emergency response policies and procedures will be adjusted for emergency situations.

3. What are our current facility conditions? How can this effort align with our State of Good Repair goals? Do we have long-term plans to grow and is there nearby space to do so?

Before embarking on a capital infrastructure investment, an agency should have a clear understanding of its current assets and needs. Agencies can begin by reviewing their asset management plan.

Major capital investments like these are a good opportunity to align with other long-term plans. For example, if an agency is already looking to replace a facility's roof, doors, or HVAC system, it may be more cost-efficient to bundle this in with the BEB charging system. Alternatively, an agency might be able to remove a planned fuel system upgrade from the capital plan if a BEB transition plan is underway.

Agencies should also understand the current site circulation. Charging or Hydrogen infrastructure locations should be considered relative to how the buses move around the site. For BEBs, parking configurations that allow a vehicle to park in a row, rather than nose-to-tail, allow greater flexibility for operations. (Vehicles return at various levels of charge and charge up at their parking spot, requiring different amounts of time to be fully charged.)

Agencies should be aware of issues like flooding and other natural hazards when choosing the location for investments.

In some cases, agencies have plans to expand service and create a new facility. Those agencies choose a site and development program that aligns with the ZEV transition.

4. Do we understand any necessary inventory management needs and modifications?

Specific tools are required to safely maintain ZEVs, including insulated hand tools and specific personal protective equipment rated for arc flash. An agency will also need to consider what common parts must be maintained in the parts room inventory, as the requirements will change from gasoline or diesel vehicles.

For agencies that contract out maintenance, they will need to ensure that their current provider can accommodate electric vehicle maintenance or identify a new provider that can.

5. If hydrogen is being considered, are we aware of the space requirements necessary?

There are two types of hydrogen storage in each hydrogen storage system – liquid and gaseous. Both states of hydrogen have their own clearance requirements. There are various exposures group clearances that need to be considered for both types of storage. These exposures groups include but are not limited to:

- Parked vehicles
- Buildings of varying construction
- Wall openings (operable and inoperable windows, air intakes, etc.)
- People gathering spaces like offices, lunchrooms, etc.

Each exposures group has its own clearance requirement and varies depending on the amount of hydrogen stored. Clearance requirements for some of these spaces can be reduced with the use of fire barrier walls, but other clearances must be maintained, regardless of the presence of fire barrier walls or lack thereof. Some examples of clearance requirements for a liquid hydrogen tank include, but are not limited to:

- Lot Lines – 25 to 75 ft depending on total capacity
- Between other liquid hydrogen storage tanks – 5 ft
- Inlet to underground sewer – 5 ft
- Overhead utilities – 15 to 50 ft, depending on type of utility (trolley wire, bus charging system, building services, piping, etc.)

This is only a small subset of considered clearances defined in NFPA 2.

6. Who will be impacted by these investments?

Many federal grants require agencies to identify the communities that will be impacted by a new investment. Agencies should review who is served by the routes being deployed from a facility to be assured that the transition is being deployed fairly.

Agencies should also consider the location of their maintenance/dispatch facility. Traditional fossil fuel vehicles emit air pollution. The transition to BEB or FCEV can benefit neighbors and so provides an important consideration when policy decision makers prioritize funding.

6.Workforce

> *FTA Zero-Emission Transition Plan Minimum Requirement:*
>
> ***Examine the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers of the applicant to operate and maintain zero-emission vehicles and related infrastructure and avoid displacement of the existing workforce.***

Figure 11: BEB Technician Utilizing a Multimeter

Self-Assessment Questions

1.Do we have a plan for training staff on the recent technology and safety precautions?

Agencies may use internal or external resources for training their staff on the recent technologies. Some agencies have created zero-emission training curriculum on what some training plans and requirements must be completed for the workforce. These detailed plans include the type of course, material covered, and the amount of time dedicated to each specific training. The OEM can support vehicle-specific training, but it is geared toward maintenance, with a single module for operators. The rest of the staff will need training on how to manage and deploy the vehicles effectively, including changes in procedures for trouble shooting or emergency response.

The International Transportation Learning Center and the Transit Workforce Center are resources for zero-emission-specific training. Also, the America Public Transit Association's Zero Emission Fleet Committee can be an opportunity to connect with peers who are going through the same transition and may be able to share resources.

2. If we have previously successfully deployed zero-emission or low-emission vehicles, have we considered the impacts of scaling up services on the workforce and utility needs?

After the initial transition to electric vehicles, an agency may start to consider slowly adding more vehicles to its fleet. Adding more electric vehicles will place additional demands on utilities and the workforce. For example, if the initial deployment of ZEVs had only specific maintenance technicians working on the vehicle, then the agency needs to plan for how to prepare the entire workforce for this transition. It is common to find that some technicians are not comfortable with electrical principles or modern diagnostic tools. There are resources to help such technicians get up to speed, as well as prepare an entire workforce for the transition, and an agency can leverage the existing knowledge it has gained from the initial set of electric vehicles.

The FTA has emphasized workforce-related activities for any grant application requesting zero-emission vehicles or infrastructure. However, even if an agency is not going to apply for FTA funds, the FTA Workforce Development Tool is a terrific way for an agency to do a self-assessment.

More details can be found here or in the appendix of this document:

https://www.transit.dot.gov/funding/grants/zero-emission-fleet-transition-plan-element-6-workforce-evaluation-tool

3. Have we coordinated with first responders and developed a plan for training and awareness for local first responder agencies?

In the event of an emergency involving a ZEV, first responders must be aware of specific safety procedures when dealing with battery electric or fuel cell electric technology. Currently, there are some first responder training courses online for electric automobiles, but nothing is currently available for larger public transit vehicles. The agency may have to work directly with the OEMs, first responders, and a consultant to create course content.

This field is rapidly evolving, and while there are no resources for public transit first responder training today, some are in development.

4. Have we considered staffing options for aiding fleet management implementations?

Staffing to support a ZEV transition and operation may be in-house or outsourced/contracted for some support functions.

Some larger agencies have created new departments for the oversight and management of their zero-emission transition. This may not be necessary for smaller agencies, but consideration must still be given to how the additional work of coordinating vehicle purchasing, design projects, infrastructure construction, and activities related to other zero-emission implementation would impact current workloads. Agencies can use consultants to augment staffing levels temporarily. This may not be necessary for a pilot but thinking long term about how a program will scale up can help an agency progress smoothly through the transition.

5.Have we considered how multiple propulsion systems may increase and complicate operations, maintenance staff, and training?

Agencies nationwide operate transit systems with mixed propulsion fleets with success. However, each agency is different, so the impact of running a mixed propulsion fleet on operations, maintenance staff, and training should be considered as part of a zero-emission transition. For example:

1. Does the parts room have sufficient space to hold a separate set of parts?
2. Does the dispatch software give dispatch staff the tools to effectively manage the vehicles regardless of the propulsion system, such as monitoring the state of charge?

Transit Cooperative Research Program (TCRP)

TCRP has another study in progress called *Lithium-Ion Battery Transit Bus Fire Prevention and Risk Management.* When completed this study will provide information and guidance on fire protection and response related to zero emission vehicles.

http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5258

6.Have we identified any potential workforce development partners that can support its workforce development needs?

Workforce shortages existed in the skilled trades before COVID-19, and the pandemic only increased the challenges of finding skilled labor. Adding requirements for a transit agency's workforce for a zero-emission transition increases that skilled labor demand.

Workforce training programs, like apprenticeship programs, are a way to help reduce that skilled gap in the local workforce. Some transit agencies already have existing educational partnerships in place for diesel technician programs and the same philosophy can be applied to developing apprenticeship programs for zero-emission technicians.

If an agency already has a training program, co-op, or apprentice program in place, creating a new program for zero-emissions will be easier. If not, an agency can consider developing a workforce pipeline to support the zero-emission transition. Moreover, agencies may be able to leverage additional funding sources for workforce development, such as Department of Labor grants, workforce development grants, and local and state funding.

Figure 12: Vehicle Technicians at a zero-emission training class

3. Have we considered the impact of zero-emission fleet transition on operations, maintenance, and training?

When upgrading to a zero-emission fleet, it is standard to adjust training. The training is foundational and impacts all mechanics and service employees. Safety and familiarization training includes:

- High-voltage hazards
- Lockout and tag-out procedures
- Battery-specific hazards: electrocution, fires, and short-circuiting
- Emergency shut-off locations
- Maintenance and testing of safety-critical systems
- Hazards associated with operating and maintaining high-pressure hydrogen systems

Operations, maintenance, and facilities staff should be aware of the following:

- The different components and controls that affect performance—e.g., training drivers on the efficient operation of vehicles
- How to troubleshoot all-electric propulsion and auxiliary systems, onboard diagnostic systems, and safe high voltage/hydrogen practice
- Expected range and endurance limitations (including seasonal variations) and expected refueling/recharging times

Zero-emission technology may pose complications in the event of an emergency such as a weather event. This could be addressed through resiliency strategies or modified operating plans that account for the role of the recent technology.

Some agencies benefit most from a mixed zero-emission/diesel fleet because of their specific sites and resources. Zero-emission technology is still nascent, and transitions are not always linear; therefore, continuing familiarity with conventional vehicles may be helpful in maintaining reliability. Also, in a scenario where an agency has trouble running ZEVs, a diesel fleet could be used as a backup to keep routes moving.

7. Did we consider potential modifications to road call strategies, reporting, and documenting?

In the beginning stages of transitioning to electric vehicles, it is helpful to keep a clear log of road calls to document any recurring issues that may arise and have a plan in place to retrieve any buses experiencing maintenance problems on route.

Additionally, these vehicles have specific requirements for towing, so it is important to make sure that both agency staff and any contracted recovery staff are fully aware of them. Most bus OEMs have training courses to address this specific topic, however with smaller vehicles training is not always as robust. Agencies can ensure they receive the training they need, regardless of vehicle type by including the requirement in their procurement. There are also numerous resources for training outside of the OEM that can provide training support, some of those organizations are mentioned in the resource section at the end of this guide.

4. Have we considered how weather conditions could affect battery electric and/or fuel cell vehicles?

Extreme cold and extreme heat can affect battery range due to increased utilization of the HVAC system. Drivers and maintenance staff should be aware of these effects on the vehicles. Tennessee is in a part of the country where this should not be a frequent issue. However, it is still vital to understand how extremely hot and cold temperatures impact battery performance.

Because unfamiliar problems can arise with the recent technology, it is important to be able to troubleshoot and mitigate them. Such problems may include:

- Basic maintenance issues or common problems, i.e., battery life and charger issues
- Extreme weather conditions
- New vehicles entering the market
- Vehicle sharing and reconfiguration
- Technicians’ availability
- Parking placements

Additional Resources

International Transportation Learning Center/Transit Workforce Center

- www.transportcenter.org/

CALSTART

- *Zeroing in on ZEBs.* www.calstart.org/wp-content/uploads/2023/02/Zeroing-in-on-ZEBs-February-2023_Final.pdf

American Public Transit Association (APTA)

- *Checklist for Engaging on Fleet Electrification*
  - APTA_Checklist_For_Engaging_Your_Electric_Company_On_Fleet_Electrification.pdf

N-CATT Zero Emissions Archives (focus on smaller and rural agencies)

- https://n-catt.org/topic/zero-emission-vehicles/

West Coast Center for Excellence

- https://www.sunline.org/alternative-fuels/west-coast-center-of-excellence-in-zero-emission-technology

National Fire Protection Association

- www.nfpa.org

NYSERDA Clean Transportation Reports and Guides: Deploying Battery Electric Buses at Scale Toolkit

- Clean Transportation Reports and Guides - NYSERDA – search for 2022 report on Transit Agencies

Transit Cooperative Research Program Reports

Published:

- *Practices in Utility Coordination for Transit Projects Synthesis 118.*
  - https://www.trb.org/Publications/Blurbs/172412.aspx
- *Guidebook for Deploying Zero-Emission Transit Buses Report 219*
  - *www.trb.org/Main/Blurbs/180811.aspx*

In Progress:

- *Lithium-Ion Battery Transit Bus Fire Prevention and Risk Management*
  - https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5258
- *Examination of Transit Agency Coordination with Electric Utilities.*
  - https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=5371

Appendix

FTA Workforce Development Assessment Tool

https://www.transit.dot.gov/funding/grants/zero-emission-fleet-transition-plan-element-6-workforce-evaluation-tool

(Next page)

ZERO EMISSION FLEET TRANSITION PLAN

Element 6: WORKFORCE EVALUATION TOOL

All applicants proposing funding for zero-emission projects under FTA's Buses and Bus Facilities Competitive Grant Program and/or the Low or No Emission Competitive Grant Program are required to develop a Zero Emission Fleet Transition Plan. This plan has six discrete elements. The sixth element is an examination of the impact of transition to a zero-emission fleet on the current workforce.

This tool is designed to aid applicants in drafting Element 6 and identify skill gaps, training needs, and retraining needs of the existing workers of the applicant in order to operate and maintain zero emission vehicles and related infrastructure and avoid displacement of the existing workforce.

Additional guidance, reference materials and best practice resources to aid applicants in completing the areas of evaluation in this template are provided by the FTA funded Transit Workforce Center with a specific site for Zero Emission Buses (ZEB):

https://www.transportcenter.org/ZEB.

FTA encourages applicants to use this tool in collaboration with its workforce and workforce representatives.

THIS TEMPLATE IS FOR INTERNAL TRANSIT AGENCY USE AND SHOULD NOT BE ATTACHED TO AN APPLICATION.

ZERO EMISSION VEHICLE FLEET TRANSITION PLAN WORKFORCE EVALUATION TOOL

1. Identify the skills, training and credentials required to maintain and operate the proposed fleet and associated infrastructure. NOTE: This may be vehicle-specific, and some elements may not be able to be determined until the Transit Vehicle Manufacturer (TVM) is selected. Consultation with the utility provider may also be appropriate.

2. Describe how the skills of existing workers will be assessed. Identify the estimated number, and percentage, of workers who may be impacted by this transition as a result of new skills requirements. The assessment should include both transit technicians and bus and rail operators.

3. Assess and identify any current or anticipated gaps between necessary workforce skills identified above and the existing baseline skills/credential requirements of the current workforce.

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

5. Identify the process by which training programs and partners will be identified and selected. Consider whether previous training programs have been successful or not. Potential recipients may propose the development of a training program. Example training programs and partnership resources are listed on the ZEB website: https://www.transportcenter.org/ZEB.

6. Indicate the role training resources will play in supporting the recruitment, training and development of new workers, and what steps are being taken to ensure non-displacement of the existing workforce. Example resources are posted on the ZEB website: https://www.transportcenter.org/ZEB for definitions.

7. To demonstrate steps to avoid displacement, explain how current workers were engaged in the development of these transition strategies and how they will be consulted in finalizing any plans and training to meet the needs of this transition.

8. Identify how training needs will be paid for.