Duplin County Public Transit

DUPLIN COUNTY
NORTH CAROLINA

ZERO EMISSIONS FLEET TRANSITION PLAN

June 16, 2025

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

A	ampere(s)
AC	air conditioning/alternating current
ACT	Advanced Clean Trucks (program)
ADA	Americans with Disabilities Act
amb.	ambulatory
ARPA	American Rescue Plan Act
avg.	average
BEV	battery electric vehicle
cap.	capacity
CCS	Combined Charging System
CDL	commercial driver's license
CMAQ	Congestion Mitigation and Air Quality
CPR	cardiopulmonary resuscitation
DC	direct current
DCFC	direct current fast charger/charging
DCPT	Duplin County Public Transit
DEQ	Department of Environmental Quality
DOE	Department of Energy
EO	executive order
est.	estimated
EV	electric vehicle
EVITP	Electric Vehicle Infrastructure Training Program
FEMP	Federal Energy Management Program
FTA	Federal Transit Administration
GVWR	gross vehicle weight rating
hr	hour(s)
HVAC	heating, ventilating, and air conditioning
ICE	internal combustion engine

ICEV	internal combustion engine vehicle
ID	identification
IEA	International Energy Agency
IIJA	Infrastructure Investment and Jobs Act
IMD	Integrated Mobility Division
IRS	Internal Revenue Service
kVA	kilovolt-ampere(s)
kW	kilowatt(s)
kWh	kilowatt-hours
lb	pound(s)
LOTO	lock-out tag-out
LTV	light transit vehicle
LV	low voltage
MACS	Mobile Air Conditioning Society
max.	maximum
mi	mile(s)
MOU	memorandum of understanding
MV	megavolt(s)
NCDOT	North Carolina Department of Transportation
NEVI	National Electric Vehicle Infrastructure
NFPA	National Fire Protection Association
No.	number
O&M	Operations and Maintenance
OEM	original equipment manufacturer
OSHA	Occupational Safety and Health Administration
pass.	passenger
PHEV	plug-in hybrid electric vehicle
PPE	personal protective equipment
Qty.	Quantity

req.	requirement
RFP	request for proposal
RTAP	National Rural Transit Assistance Program
SAE	Society of Automotive Engineers
SoC	state of charge
SUV	sport-utility vehicle
SWBD	switchboard
TOU	time-of-use
U.S.	United States
VAC	volts of alternating current
VDC	volts of direct current
veh.	vehicle
vs.	versus
YOY	year-over-year
yrs.	years
WC	wheelchair
XFMR	transformer
ZEV	zero-emission vehicle

EXECUTIVE SUMMARY

Duplin County Public Transit (DCPT) provides rural transportation for the public and Human Services of Duplin County with a fleet of 16 vehicles. DCPT, with the support and coordination of the North Carolina Department of Transportation (NCDOT) and its Integrated Mobility Division (IMD), commissioned a Technology Feasibility Study and accompanying Zero Emission Fleet Transition Plan to evaluate opportunities for electrification. The Technology Feasibility Study identifies electrification challenges unique to DCPT and informed the proposed transition strategy outlined in the Zero Emission Fleet Transition Plan. The following Zero Emission Fleet Transition Plan can serve as a two-phase roadmap for DCPT to bring battery electric vehicles (BEV) into the transit fleet.

Internal support, local support, and grant support will be essential to realize the vision of transitioning the fleet to zero-emission vehicles (ZEVs). A transition toward BEVs could result in additional capital costs to build new infrastructure and purchase more expensive but cleaner vehicles. This plan may serve as a guide for DCPT's potential transition to a cleaner transit fleet.

PURPOSE OF PLAN

This Zero Emission Fleet Transition Plan can support DCPT and NCDOT's key missions while meeting Federal Transit Administration (FTA) compliance requirements for grant funding opportunities for zero-emission buses and infrastructure.

DCPT Mission

DCPT's mission is to provide safe, dependable, and affordable quality transportation to the citizens of Duplin County. As a rural transportation provider, DCPT connects communities without transportation access to critical destinations that provide medical care, higher education, employment, and food services. This Zero Emission Fleet Transition Plan is intended to further DCPT's mission while identifying opportunities to utilize sustainable ZEVs that support transit operations without disruption. DCPT aims to deploy ZEVs when feasible to contribute to improved environmental and human health throughout Duplin County.

NCDOT Mission

In 2020, North Carolina's governor signed the Multi-State Medium and Heavy-Duty ZEV Memorandum of Understanding, committing to electrifying buses in the state. In response, NCDOT is supporting transit agencies throughout North Carolina with the coordination of numerous Zero Emission Fleet Transition Plans.

NCDOT's mission is to connect people, products, and places safely and efficiently with customer focus, accountability, and environmental sensitivity to enhance the economy and vitality of North Carolina. The IMD's mission is to provide leadership for safe, affordable, and innovative multimodal transportation throughout North Carolina. NCDOT provided support for the following plan in line with its mission and dedication to improve the air quality index, reduce noise pollution, and support more sustainable communities across the state.

FTA Compliance

The FTA requires a Zero Emission Transition Plan from each transit agency that applies to the FTA Low or No Emission Grant Program and the FTA Bus and Bus Facilities Grant Program for zero-emission projects. The Zero Emission Transition Plan must include at a minimum the following six elements:

- ✓ **Policy & Legislative Impacts:** Consideration of policy and legislation impacting relevant technologies
- ✓ **Fleet Transition Plan:** Demonstration of a long-term fleet management plan with a strategy for how the applicant intends to use the current request for resources and future acquisitions
- ✓ **Facility & Infrastructure Plan:** Evaluation of existing and future facilities and their relationship to the technology transition
- ✓ **Utility & Fuel Partnerships:** Description of the partnership of the applicant with the utility or alternative fuel provider
- ✓ **Funding Plan:** Address the availability of current and future resources to meet costs for the transition and implementation
- ✓ **Workforce Transition Plan:** Examination of the impact of the transition on the applicant's current workforce by identifying skill gaps, training needs, and retraining needs of the existing workers. This focuses on supporting the applicant's short-term and long-term needs to operate and maintain zero-emission vehicles while avoiding displacement of the existing workforce.

This Fleet Transition Plan includes the six elements outlined above to prepare DCPT for zero-emission grant opportunities and the impacts of a future transition.

TECHNOLOGY FEASIBILITY STUDY SYNOPSIS

As part of DCPT's Fleet Transition Plan, a technology Feasibility Study was conducted to determine if BEVs could operate on DCPT service. This process was guided by fleet data, input from key stakeholders including operators and maintenance, and a market analysis of commercially available BEVs. The study evaluated the feasibility of a full transition through a series of memoranda that covered the following topics:

- Existing Conditions
- Stakeholder Engagement
- Technology Review: Maturity and Reliability
- Energy Modeling Review
- Facility Review
- Capital Requirements
- Workforce Development

The Technology Feasibility Study revealed that DCPT's service poses a variety of challenges that make a 100 percent zero-emission fleet infeasible today. Vehicles experience variable routes and high average mileage requirements due to the on-demand service DCPT provides for its rural, 800 square mile service area. In addition, the average DCPT vehicle may travel between 220-330 miles during its typical service, depending on ride requests received for the day.

Vehicles' average daily mileage and hours of use were entered into a model to determine whether available BEV equivalents could support current service. The modeling results determined that DCPT's service currently exceeds the capabilities of available BEV transit vans and cutaways offered through the NCDOT State procurement list and the broader market. To identify other electrification paths forward, DCPT considered the following alternative strategies:

- **En Route Charging via County Chargers:** Midday charging via county-owned charging sites would not be an effective solution as DCPT's routes are highly variable and would require a widespread network of charging sites throughout the 800 square mile service area. In addition, the installation of county-owned charging stations would require a significant investment in charging infrastructure.
- **En Route Charging via Public DCFC Stations:** Limited public charging access is a common challenge in rural communities throughout the United States (U.S.), like those of Duplin County. A geospatial analysis of publicly available direct current fast chargers (DCFCs) in Duplin County revealed that only two sites offer DCFC. The project team reviewed DCFC sites because Level 2 chargers would not provide fast enough midday charging for vehicles that must quickly return to service. The identified sites are in Wallace and Warsaw, within proximity to DCPT's depot where the need for public charging access would be low. As a result, this feasibility study found charging via public DCFC to be an insufficient alternative due to limited sites and coverage.
- **Vehicle Redundancy:** Fleets may use a spare vehicle to cover the remainder of a shift if a vehicle is nearing the end of its range mid-shift. This would require a driver to make a deadhead return trip to the depot, swap the current vehicle for a fully charged and redundant vehicle, and resume service with another deadhead trip out to the next pickup. Without en route charging, energy modeling results indicated that every DCPT bus and transit van would require at least one redundant vehicle to complete an average day's service. This approach would be extremely cost prohibitive as well as disruptive to operations due to the increased fleet size and deadhead trips it would require.

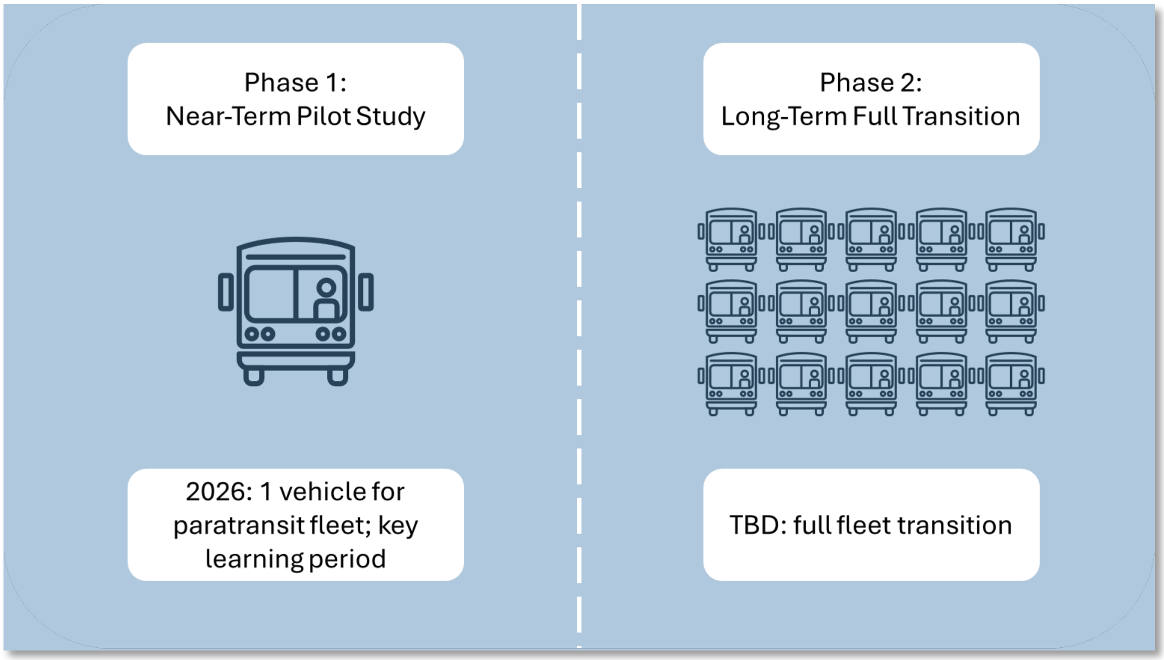
The feasibility study outcomes indicate that DCPT cannot fully transition at the time of this plan due to a combination of high mileage days and current electric transit van and shuttle bus range limitations. Despite the challenges identified, existing facility and operations conditions could support a full fleet transition in the future. DCPT's new depot facility offers enough space for the full buildout of charging infrastructure and bus parking canopies that can shield and prolong the life of charging equipment. In addition, DCPT is considering expanding its transit services with micro-mobility, which may be operated by BEVs due to shorter routes and more predictable service areas.

DCPT determined that while it cannot launch a full transition yet, it is considering alternatives that are suited for current limitations. DCPT considered various courses of action for their future fleet transition and developed the following phased fleet transition strategy.

FLEET TRANSITION STRATEGY

NCDOT and DCPT worked collaboratively to form a near-term and long-term strategy that DCPT may adopt to integrate zero-emission vehicles into the fleet when appropriate. DCPT's transition strategy is summarized in the following two phases and in **Figure 1**.

Figure 1. Graphic representation of DCPT's Two-Phase Fleet Transition Plan

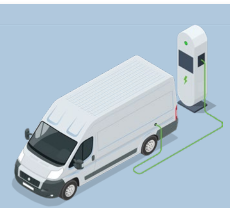


Phase One: Near-Term Pilot Study

The first phase of DCPT's transition would consist of a pilot study with one expansion vehicle for DCPT's paratransit fleet. While waiting for BEV range to improve, DCPT could operate the pilot vehicle within its battery capacity limits.

The transition could begin in 2026 with the initial procurement and deployment of one Ford E-Transit from the NDCOT State procurement list that would be supported by one 19.2-kilowatt (kW) Level 2 charger. Applicable funding opportunities are discussed in greater detail in the ***Financial Analysis & Funding Plan*** section. In 2025, DCPT can apply for zero emission transit grant opportunities offered through the FTA and/or identify local funding sources that can cover local match requirements for its procurement.

DCPT's pilot study could be an opportunity to test BEV performance on current transit services. This could allow DCPT operators, maintenance, and dispatchers to identify the opportunities and limitations of BEVs within their service. This phase may be a key period of learning for DCPT as it gathers real-time data on BEV performance, hones best practices for operations and maintenance, and prepares for a full transition.



Pilot Program Cost

As detailed in the financial analysis, the estimated start-up cost of DCPT's pilot study is $125,355. This cost estimate represents the pilot study's anticipated capital costs including the procurement of one expansion BEV for fiscal year 2026 and the purchase and construction of the associated charging infrastructure.

This phase could also include monitoring the market for commercially available BEV equivalents that may be capable of covering DCPT service. According to the energy modeling analysis, BEVs on the NDCOT procurement list cannot currently support DCPT's range requirements. This Fleet Transition Roadmap recommends that DCPT waits for advancements in BEVs to launch the remainder of its transition. By waiting, DCPT can make sure that when it invests in BEV technology, the vehicles and charging equipment will benefit operations, rather than disrupt them.

Since BEV technology is still developing, especially in smaller transit applications, BEV performance can dramatically improve within a short span of time. Rather than identify a set year to initiate Phase Two, this plan recommends that DCPT utilize market monitoring to pinpoint when it can confidently continue its transition. This plan lists out the market indicators DCPT can monitor to determine when a viable BEV equivalent has become available for both transit vans and shuttle buses. These indicators are included in the ***Technology Projection Evaluation*** section. Once DCPT has identified BEVs that can support its services, it may proceed to Phase Two, the long-term strategy.

Phase Two: Long-Term Full Transition

Phase Two, the long-term strategy, may begin when a BEV on the market meets the range and performance requirements of service. DCPT may launch the full transition of its fleet, starting with the next upcoming replacement cycle. The transition schedule could follow the existing fleet replacement cycle, replacing the 16 internal combustion engine vehicles with battery electric equivalents upon their retirement. A phased transition could allow DCPT to gradually build working knowledge of BEVs and prepare for a fully electrified fleet.

It is recommended that all conduit and electrical service upgrades required to support the full transition be installed at one time, once DCPT decides to proceed with Phase Two. This approach can be more cost effective and minimize construction disruptions to the fleet parking area. Chargers could be procured at a 1:1 ratio of Level 2 charging ports to BEVs. Charging procurement and installation may be phased in accordance with the vehicle transition schedule.

AGENCY OVERVIEW

Duplin County Public Transit (DCPT) is a rural transportation system that provides subsidized transit services to the public and Human Service Agencies of Duplin County. Transportation services are available for employment, education, congregate nutrition sites, medical facilities, and shopping. Duplin County provides general transportation services via demand-response service for which riders must submit their transportation requests 48 business hours in advance of their requested pick-up date. DCPT's demand-response service operates between approximately 5 a.m. to 5 p.m., with fleet vehicles running between 6 to 10 hours a day. The greatest trip generators include the towns of Kenansville, Wallace, and Warsaw.

DCPT also offers transport for Medicaid recipients as requested by the recipient's Medicaid provider, enabling riders to meet their transportation needs they would otherwise struggle to satisfy on their own. In addition, DCPT provides trips to out-of-county medical facilities on a scheduled basis and transport for Smithfield employees and students at James Sprunt Community College in Kenansville.

The current DCPT fleet includes 16 internal combustion engine (ICE) vehicles—5 raised roof transit vans, 10 light transit vehicle (LTV) cutaway buses, and 1 Dodge minivan. In response to steadily increasing ridership, DCPT ordered two fleet expansion vehicles in 2023 and, while waiting for these replacements, bought and placed two used cutaway buses into service (vehicles 1043 and 1044). The entire fleet is gasoline powered. Vehicle ages range from 2 to 15 years, and passenger capacities range from 3 to 13 ambulatory passengers with 1 to 2 wheelchair spaces available. All vehicles are Americans with Disabilities Act (ADA) compliant, with space for 1 to 2 wheelchairs, and are equipped with either wheelchair lifts or ramps. With passenger capacities of under 16, all fleet vehicles do not require a commercial driver's license (CDL) for operation. **Table 1** summarizes the existing fleet.

Table 1. Inventory of Existing Fleet Vehicles

ID No.	Model Year	Existing Vehicle Make / Model	Vehicle Type	Fuel Type	Service Type	Amb. Pass. Cap.	WC Cap.
836	2017	Ford Transit	20' Raised Roof Transit Van	Gasoline	Demand-Response	8	2
837	2017	Ford Transit	20' Raised Roof Transit Van	Gasoline	Demand-Response	8	2
841	2017	Ford Transit	20' Raised Roof Transit Van	Gasoline	Demand-Response	8	2
858	2018	Ford Transit	20' Raised Roof Transit Van	Gasoline	Demand-Response	8	2
859	2018	Ford Transit	20' Raised Roof Transit Van	Gasoline	Demand-Response	8	2
861	2018	Ford E-350	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
910	2019	Ford E-350	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
911	2019	Ford E-350	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
912	2019	Ford E-350	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
895	2019	Chevrolet Express	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
896	2019	Chevrolet Express	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
897	2019	Chevrolet Express	Cutaway 20' LTV	Gasoline	Demand-Response	8	2
1044	2008	Chevrolet Express	Cutaway 20' LTV	Gasoline	Demand-Response	13	2
967	2022	Ford E-350	Cutaway 22' LTV	Gasoline	Demand-Response	13	2
1043	2015	Ford E-350	Cutaway 22' LTV	Gasoline	Demand-Response	10	2
914	2019	Dodge Grand Caravan	Minivan	Gasoline	Demand-Response	3	1

STAKEHOLDER ENGAGEMENT

The project team held a series of stakeholder interviews centered on identifying potential impacts and opportunities for a future transition. These discussions gathered information relevant to a future fleet transition, including:

- Key stakeholders' existing programs, policies, and appetites for electrification
- Existing sustainable transportation efforts
- Capital improvement plans
- Potential funding and resource opportunities.

As the region continues to explore the transition to zero emissions, it is critical that DCPT and its key stakeholders continue to coordinate regarding infrastructure, power needs, and training.

DUPLIN COUNTY

To kick off the fleet transition feasibility study, the project team discussed fleet electrification opportunities with a Duplin County representative. The county does not currently have a zero-emission fleet procurement policy nor do any county fleet locations have electric vehicle (EV) charging stations on site. Since DCPT is a county-based transit provider, Duplin County would be an active participant in planning for a DCPT fleet transition.

Duplin County is interested in the outcomes of DCPT's feasibility study and future electrification. They noted DCPT's electrification could serve as an example for the Duplin County Schools' bus fleet that is located across the road from the DCPT fleet. The county noted an interest in existing opportunities to electrify school buses through the Environmental Protection Agency's Clean School Bus Program and noted that in the future, due to their proximity, DCPT and Duplin County Schools could share knowledge and resources regarding battery electric vehicles (BEVs) and charging.

Duplin County Maintenance Staff

The fleet is maintained by the Duplin County Garage, the county's maintenance department that provides in-house service, repairs, and maintenance to all county-owned vehicles, machinery, and equipment. The project team met with the garage foreman to identify maintenance challenges to and opportunities for electrification in the future.

Since BEVs are not operated within any of the county's fleets, technicians are unfamiliar with BEV technology and do not hold BEV-specific certifications like high-voltage training. While technician training does pose a challenge to future fleet electrification, County technicians were noted as resourceful and willing to learn via trainings and educational offerings through dealerships, a frequently used resource. The Workforce Development Plan section emphasizes updating existing training programs to include BEV-specific skills, alongside close collaboration with the workforce during the implementation of new protocols, addressing these challenges head-on.

The project team and garage representatives discussed funding opportunities offered through grant program set-asides dedicated to training the maintenance workforce for BEV maintenance. With funding support, the Duplin County Garage would be interested in implementing BEV training amongst current staff.

DUPLIN COUNTY PUBLIC TRANSIT

At the beginning of the fleet transition feasibility study, the project team met with the director of DCPT to identify opportunities and challenges for electrification as well as any significant future changes and relevant policies. Though no relevant agency-level policies are in place, DCPT is interested in integrating BEV technology within its fleet. DCPT expressed an interest in first piloting BEVs on its service within the limitations of current BEV ranges and utilizing the lessons learned amongst operators and maintenance personnel from a pilot for a full-fleet transition.

DCPT identified long shifts, high mileage routes, and schedules that vary day to day as significant challenges to transitioning the fleet. The agency noted that, of their 14 active vehicles, about 12 would operate simultaneously each day for between 7 to 11 hours. The large size of the county and rural context was also identified as a significant challenge to electrifying vehicles.

DCPT's future growth offers numerous opportunities to integrate BEVs into their service. In the future, DCPT would like to grow their service and explore micro-transit within a smaller, high-demand service area of Duplin County. This was identified as an optimal service line that BEVs could first serve while simultaneously demonstrating county support for sustainable mobility amongst the public.

Duplin County Public Transit Operators

The project team met with a representative for DCPT operators to first outline an operator's average day. The discussion also identified any challenges to and opportunities for electrifying the fleet. For operators, the primary challenge of transitioning to a BEV fleet is DCPT's high mileage and variable on-demand service routes. Operators take their lunch breaks wherever they may be on their route mid-shift, which could be up to 45 minutes from the depot, leaving minimal opportunity for midday depot charging. Changes in vehicle technology were also perceived as a concern for operators as they are unfamiliar with BEVs and would require training on how to operate them.

Though BEV technology is new to DCPT, it is anticipated that operators would be able to adapt to operational changes like charging and driving. Without incurring any labor issues, operators can simply replace the fueling responsibilities at the end of their shift with plugging in vehicles upon parking. DCPT is prepared to work with dealers and adapt their typical procedure of examining manuals and equipment to identify any operational changes between internal combustion engines and BEVs.

POLICY & LEGISLATION IMPACTS

Policy and legislation at the local, state, and federal level can significantly impact the trajectory of a transition. These impacts may drive the advancement of BEV technology, provide support for transit agencies' transition, or set targets for electrification. The following federal and state policies are relevant to DCPT's potential fleet transition.

FEDERAL GOVERNMENT

The passage of the Infrastructure Investment and Jobs Act (IIJA) authorized a historic level of funding for clean transportation and infrastructure efforts, including fleet electrification. As a result, the Federal Transit Administration (FTA) and other federal funding agencies have encouraged transit agencies nationwide to transition their fleets to low or no emission vehicle options, with funding priority given to zero-emission vehicles (ZEVs). Transit agencies must develop a Zero Emission Fleet Transition Plan in order to apply for funding for ZEVs and related infrastructure under the FTA's Low or No Emission Grant Program and Grants for Buses and Bus Facilities Program.[1]

STATE OF NORTH CAROLINA

There are numerous policies established by the state of North Carolina that encourage the transition of ICE vehicles to BEVs or may impact DCPT's potential fleet transition.

- **Executive Order Number 80**
  With the signing of Executive Order (EO) Number (No.) 80, North Carolina's Commitment to Address Greenhouse Gas Emissions and Transition to a Clean Energy Economy, in 2018, Governor Cooper set a statewide target of reducing greenhouse gas emissions by 40 percent from 2005 levels by 2050. In addition, EO No. 80 laid out a goal of reaching at least 80,000 registered ZEVs in North Carolina by 2025 and launched the development of North Carolina's ZEV Plan.

- **2019 Statewide ZEV Plan**
  In 2019, the North Carolina Department of Environmental Quality (DEQ) and North Carolina Department of Transportation (NCDOT) were tasked with the development of a statewide ZEV Plan. The plan identifies 20 recommendations for the state and relevant stakeholders to support ZEV adoption, including public education efforts, expanding the charging network, improving ZEV affordability, and establishing policies that promote ZEV adoption. Since the plan was published, the state has made significant progress on many of its ZEV initiatives including the signing of the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding.

[1] As of May 2025, these programs are still offering funding. However, the futures of these programs are uncertain given the recent change in administration and the new administration's differing priorities regarding electrification.

- **Multi-State Medium- and Heavy-Duty ZEV MOU**
  In 2020, Governor Cooper signed the Multi-State Medium and Heavy-Duty Zero-Emission ZEV Memorandum of Understanding (MOU), committing to electrifying buses in the state. The memorandum outlines a statewide goal that 100 percent of all new truck and bus sales be zero-emission vehicles by 2050, with an interim target of 30 percent by 2030. In response to the available IIJA funding and the MOU, NCDOT is facilitating technology feasibility studies and corresponding Zero Emission Fleet Transition Plans for transit agencies, including Duplin County Public Transportation.

- **Executive Order No. 246**
  In 2022, Governor Cooper signed EO No. 246, North Carolina's Transformation to a Clean, Equitable Economy. The EO sets goals for a 50% reduction in greenhouse gas emissions from 2005 levels by 2030 and net-zero emissions by 2050. A key component of the EO involves increasing the number of registered zero emission vehicles to at least 1.25 million by 2030 and ensuring that 50% of new vehicle sales are zero emission by the same year.

- **Executive Order No. 271**
  In 2022, Governor Cooper signed EO No. 271, Growing North Carolina's Zero-Emission Vehicle Market. The EO was intended to direct the DEQ to work with stakeholders to propose to the Environmental Management Commission an Advanced Clean Trucks (ACT) program. ACT was developed with the intent to increase the number of zero-emission trucks and buses available for purchase in the state. This program would require manufacturers to sell an increasing percentage of ZEVs over time while providing flexibility through credits, trading, and other features, as segments of the market grow at different speeds. As of October 2023, with the release of the North Carolina state budget, the ACT was struck down due to concerns over the program's proposed restrictions on vehicle manufacturers.

TECHNOLOGY REVIEW

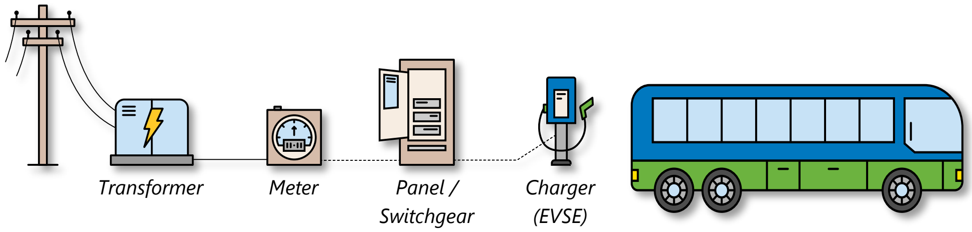
The transit industry is witnessing a significant shift towards sustainable vehicle technologies in efforts to reduce greenhouse gas emissions, improve quality of life, and meet zero emission targets at local, regional, and state levels. BEVs have gained significant industry prominence for several reasons, including their growing market presence and compatibility with the existing electric grid. This technology review outlines the BEV technology relevant to DCPT, focusing on the capabilities of battery electric cutaway vehicles, charging infrastructure, and anticipated technological advancements.

CHARGING TECHNOLOGY

Components of Charging

When planning to integrate zero-emission vehicles into an existing fleet, understanding charger components and prioritizing infrastructure needs are critical action items. Charging infrastructure for BEVs includes electrical delivery through the communications wiring, transformer, meter, and switchgear, as well as the charger (e.g., the cabinet used to supply power). A simplified diagram showing the components of charging infrastructure is shown in **Figure 2** below. Today's charging technologies can support current demand and be scaled to meet the growing needs of new vehicles and fuel markets.

Figure 2. Charging Infrastructure Equipment Layout



Levels of Charging

There are three levels of BEV charging: Level 1, Level 2, and Direct Current Fast Charging (DCFC). Since Level 1 charging typically requires multiple days of charging to reach a full charge, Level 2 and DCFC options are most suitable for DCPT's daily charging needs. The following provides a synopsis of the charging levels that can be considered for DCPT's fleet:

- **Level 2 Alternating Current Charging:** Provides an average power output of 3.5 to 19.2 kilowatts (kW) and is suitable for overnight charging, offering approximately 20 miles of range per hour plugged in regardless of vehicle type. Four examples of Level 2 alternating current (AC) chargers are provided in **Table 2** below.
- **Direct Current Fast Chargers:** Utilize three-phase AC power to provide fast charging at power levels up to 450 kW. Even at lower power levels, direct current fast chargers (DCFCs)

can supply over 100 miles of range per hour plugged in. This fast charge rate can enable rapid midday and/or en route recharging for BEVs that lack the range needed to complete daily service. It is important to note that, with their higher energy output, DCFCs have higher installation and procurement costs relative to Level 2 chargers. **Table 2** shows six examples of DCFCs on the market today.

Table 2. Sample of Market-Available Plug-In Chargers

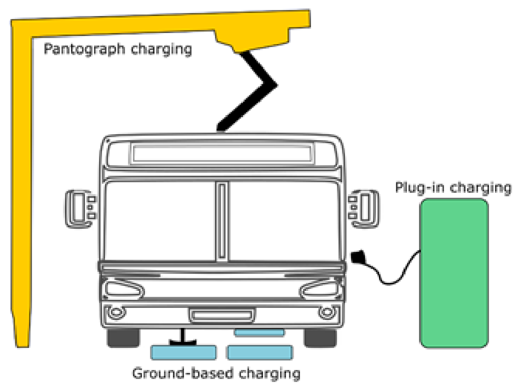
OEM	Model	Power Output	No. of Dispensers
Level 2			
Blink	IQ 200	19.2 kW	1
ChargePoint	CP F50	12 kW	1
Enphase	ClipperCreek HCS-60	11.5 kW	Up to 2
EvoCharge	Max (80A)	19.2 kW	1
DCFC			
ChargePoint	Express 250	62.5 kW	Up to 2
ABB	Terra124	120 kW	2
BTC Power	L3R-100	100 kW	2
BYD	DC Charger	150 kW	1
FreeWire	Boost Charger 150	150 kW	Up to 4
Siemens	Flex 180	180 kW	Up to 3

**kW= kilowatt (power)*

Methods of Charging

There are three methods to charge a BEV: a plug-in dispenser, a pantograph dispenser, and an inductive charging pad (i.e., wireless). **Figure 3** summarizes and depicts these three methods.

Figure 3. Overview of charging methods for BEVs[2]



For DCPT, plug-in dispensers are most suitable for battery electric cutaways and transit vans. These chargers can deliver a Level 2 charge or fast charging. Plug-in chargers use a Combined Charging System (CCS) connector. The cord connects the charging cabinet to the vehicle, and the rate of charge depends on the power output of the charging cabinet. All BEVs are equipped to charge using plug-in dispensers, which typically have the lowest capital and installation costs. However, the cords can pose maintenance and operational challenges if they are vandalized, run over by vehicles, or simply break from repeat and regular use.

Plug-in depot charging is used for both small and large-scale deployments as the infrastructure is less expensive than inductive or pantograph charging, and the equipment integrates more seamlessly into existing infrastructure. Society of Automotive Engineers (SAE) standards relevant to plug-in chargers are J-1772 and general power ratings for plug-in chargers are as follows:

- **Level 1:** 1.4 kW to 1.9 kW
- **Level 2:** 2.5 kW to 19.2 kW
- **DCFC:** Up to 350 kW

Plug-in chargers can provide single, sequential, or simultaneous charging. Single charging refers to charging one vehicle at a time via one dispenser, at full power. Simultaneous charging works by allowing two EVs to share a charger's power between its two dispensers. Sequential charging allows multiple vehicles to plug into a charger and charge one after the other, at full power.

[2] https://encyclopedia.pub/entry/16095

ELECTRIC VEHICLE MARKET

Battery Electric Vehicles

The majority of DCPT's vehicle types have commercially available battery electric equivalents that were developed relatively recently. As battery technology advances, original equipment manufacturers (OEMs) are introducing a range of BEVs with varying battery capacities, enabling fleets to maintain service levels while pursuing electrification goals. Battery packs come in different versions with varying chemistries and charging capabilities. Some vehicles have a smaller battery and are designed for high-power charging, while others have a larger battery but relatively lower charging power.

The market for battery electric cutaways is rapidly growing, with newer applications and options to consider for both passenger vans and cutaway shuttles. Electrification of a cutaway vehicle is often achieved through 'repowering,' where the vehicle operates on an OEM chassis, but the powertrain and other internal components are a product of a brand-independent manufacturer. Maintaining the warranty and certifications is a primary consideration when repowering a vehicle.

The latest NCDOT vehicle procurement list currently offers two BEVs—a transit van and a cutaway shuttle bus—which meet the passenger capacity and vehicle type criteria of DCPT's existing fleet. These models have various seating configuration options that offer one to two wheelchair spaces. **Table 3** provides vehicle specifications as listed by each vehicle OEM, displaying the two feasible replacement options that most closely match the vehicle type and passenger capacities of the existing DCPT fleet. BEVs with capacities of 15 passengers or less were selected to maintain DCPT's existing operations, including workforce requirements. As DCPT operates vehicles with capacities below 16 passengers, according to NCDOT policy, drivers are not required to have a CDL.

Table 3. NCDOT Procurement-Eligible BEVs (2024)

Electric Vehicle Make / Model	Vehicle Type	Pass. Cap.	Battery Capabilities			
			Max. Cap. (kWh)	Max. Range (miles)	Max. AC Rate (kW)	Max. DC Rate (kW)
MobilityTRANS Ford E-Transit	Passenger Van	7-12	68	126	11.3	115
Phoenix Motorcars Zeus 400	Cutaway Shuttle	12-14	105	115	13	50

Currently, BEVs have a limited operational range compared to conventional ICE cutaway buses, and the distance they can travel per charge is impacted by elevation, route profile, ambient temperature, and driver habits. While en route charging infrastructure can extend the operational range of BEVs, it is not always enough to provide BEVs with the same operational range as ICE cutaway buses.

Plug-In Hybrid Electric Vehicles

According to the Multi-State Medium- and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding adopted by the state of North Carolina, plug-in hybrid electric vehicles (PHEVs) are considered zero-emission vehicles and, as a result, can contribute to the state's zero-emission purchase goals for 2030 and 2050. Although battery-electric minivans are not commercially available, there are hybrid alternatives. As technology continues to advance, it is anticipated that more PHEV and hybrid electric vans will be on the market and suitable BEV models will eventually become available. At the time of this report, the latest NCDOT vehicle procurement list does not offer hybrid minivans. **Table 4** details the single PHEV minivan on the market that may serve as an example of the low emission technology available for minivans. Currently, the minivan in DCPT's existing fleet could feasibly be replaced by this vehicle. The PHEV's all electric 32-mile range can cover about half of the existing minivan's average daily mileage, while the remaining miles could be powered by gasoline.

Table 4. Market-Available PHEV (2024)

Electric Vehicle Make / Model	Pass. Cap.	Maximum Battery Capacity (kWh)	Estimated Electric Range (mi)	Estimated Total Range (mi)
Chrysler Pacifica Hybrid	7	16	32	520

POTENTIAL IMPACTS

DCPT's transition would require adjustments to operations and an investment in the equipment and training necessary to operate BEVs. The following are high-level impacts DCPT may consider as it evaluates the challenges and opportunities of utilizing BEVs.

Infrastructure Investments

As a different "fuel" source, battery electric charging would require an investment in electrical supply infrastructure and charging equipment. BEV charging at the depot would increase energy consumption on site and necessitate infrastructure upgrades. To prepare for this, DCPT could work closely with Duke Energy to determine the electrical infrastructure upgrades necessary to support the added energy demands of charging. Additionally, DCPT would have to plan for the added capital expenditure of charging equipment.

Vehicle Maintenance

Maintenance for BEVs differs from ICE vehicles and would require knowledge of BEV technology amongst maintenance staff. The time and money spent on maintenance is less for BEVs than ICE vehicles. While BEVs do not require oil changes, regular engine maintenance, or brake pad replacement due to regenerative breaking, they do need specialized maintenance. For example, trained technicians must periodically check battery coolant levels, power inverters, and charger modules, as well as flush corrosive materials like road salt from a vehicle's underbody to keep BEVs in good working order.

Charging vs. Fueling

Charging differs from fueling routines as it requires more vehicle downtime than refueling ICE vehicles. If DCPT were to utilize Level 2 plug-in charging to power the fleet, operators must adjust their existing end of shift and refueling routines. At the end of a vehicle's shift, rather than refueling at the county fueling station, operators would simply park for the night at DCPT's garage and plug the vehicle into a charger for overnight charging. Operators must also closely monitor their vehicle's state of charge en route to be certain they can cover their shift without interruption.

Charging best practices, like keeping a battery well-conditioned and charged, would be important to implement in DCPT's routine operations. DCPT could socialize these amongst operators to optimize charging and extend the life of DCPT's BEV fleet. Level 2 chargers offer charging management software that allows fleet managers to remotely manage charging, view vehicle charging data, and set charging schedules. This software, along with a vehicle's battery management software, can support DCPT in implementing charging best practices.

Managing charging costs would differ from fueling costs. Whereas gas and diesel fuel costs are typically tracked on fuel cards, charging costs and consumption can be managed via charging managing software. When public chargers are used, EV charge cards would allow DCPT to make and track payments just like conventional fuel cards.

Service Adjustments

Fleet managers and dispatchers must work closely with one another to arrange shifts so a BEV can meet range requirements without any unplanned interruptions. The fleet manager and dispatcher must consider if a BEV can reliably cover an entire shift on one charge or, if not, plan for a mid-shift charge with enough down time to allow for sufficient recharging. As an alternative, a BEV can return to the garage when its battery is running low and be replaced with a fully charged vehicle or ICE vehicle that may complete its shift. Consequently, a BEV fleet would likely require adjustments to DCPT's existing scheduling due to current charging and range limitations.

ENERGY MODELING

The project team conducted energy modeling to evaluate the feasibility of transitioning DCPT's existing fleet to BEVS and to identify the level of infrastructure upgrades needed. The energy model identified the power needed to charge a BEV fleet (using existing models on the market) operating on DCPT's typical service. By identifying a BEV fleet's anticipated energy demand, DCPT can determine if the BEV models offered on NCDOT's state procurement list can feasibly perform DCPT's service. The following Energy Modeling section outlines the methods and assumptions used in the model, summarizes its results, and discusses the feasibility of a full transition at DCPT based on findings.

The results demonstrate transition opportunities and challenges given current operational requirements and capabilities of today's BEV technology. Even if BEV battery capacity improvements match historic improvements over the next 5 years, DCPT's needs are unlikely to be met. In response, the project team identified alternative strategies to be considered and key takeaways that informed the final transition strategy.

FULL FLEET TRANSITION SCENARIO

This analysis first defines a primary analysis scenario used to model the anticipated energy demands of a full BEV fleet. The current fleet includes 16 ICE vehicles—5 raised-roof transit vans, 10 LTV cutaway buses, and 1 minivan. The modeling analyzes a scenario in which DCPT operates a full BEV fleet that leaves the facility in the morning, spends an average of 8 hours on the road, and then returns in the evening, to charge overnight.

Methods & Assumptions

A spreadsheet-based modeling tool was used to determine the level of demand each example BEV would place on its battery based on the inputs and assumptions outlined here. The analysis is based on assumptions derived from current operating data and the vehicle characteristics of assumed BEV equivalents. Many elements were considered in the modeling process, including:

1. **Fleet size:** The fleet size modeled was based on transitioning 100 percent of the fleet, or 16 ICE vehicles.
2. **Daily miles:** This input is used to calculate the amount of energy required to move a BEV over a shift. The values were based on odometer readings provided by DCPT. DCPT's vehicles travel up to 220 miles per day on average and up to 350 miles on a high-usage day.
3. **Daily hours:** This analysis reflects the total time in a service day that each vehicle's engine is turned on, including both motive and idle time. This input is used to calculate the energy used for non-motive purposes, such as running the heating, ventilating, and air conditioning (HVAC) system. Based on Duplin County's input, it was assumed that each vehicle is in use for 8 hours per day.

4. **Shift length:** The shift length assumes the length of time each vehicle is away from its assigned facility. This input was used to calculate the time available to charge overnight.
5. **Modeled vehicles:** BEV equivalents were selected from the available BEVs on the NCDOT state procurement contract. There is one option per transit van and one option per cutaway van that meets DCPT's vehicle type and passenger capacity requirements. Refer to the next subsection of this plan and **Table 5** for more details on the BEVs used.
6. **Minimum state of charge:** It is recommended that transit agencies include a state of charge (SoC) buffer when electrifying specific routes to accurately reflect battery performance over the BEV's service life. OEMs also discourage users from charging their batteries daily to 100 percent. A 30 percent buffer was used to account for battery degradation and reduced range in colder temperatures.

Existing operations data is summarized in **Table 5**. This includes daily mileage (derived from monthly odometer readings between December 2022 and November 2023), daily hours, and shift lengths.

Table 5. Existing DCPT Fleet Operating Data

Existing Vehicle Make / Model	Vehicle Type	Veh. Qty.	Amb. Pass. Cap.	WC Cap.	Daily Operations				
					Avg. Miles (mi)	Max. Miles (mi)	Avg. Time (hr)	Max. Time (hr)	Shift Length (hr)
Ford Transit	20' Raised Roof	5	8	2	217.5	327.9	7.8	11.3	10
Ford E-350	20' LTV Cutaway	4	8	2	218.7	333.7	7.9	11.5	10
Chevrolet Express	20' LTV Cutaway	4	8	2	218.7	333.7	7.9	11.5	10
Ford E-350	22' LTV Cutaway	2	13	2	220.5	294.2	8	10.3	10
Dodge Grand Caravan	Minivan	1	3	1	62.1	104.6	2.1	4	10

Total daily energy consumption was computed using both average and 'worst-case' (the most miles and operating hours per day) service days for each DCPT vehicle type. This allows overall site energy and fleet size impacts to be more accurately predicted. If the daily energy consumption of a vehicle exceeds the usable battery capacity threshold for its vehicle type, the model recommends purchasing additional vehicles of that type to enable midday vehicle swaps or installing high-power fast chargers to support midday recharging.

Battery Electric Vehicle Equivalents

Three example BEVs, referred to as BEV equivalents, were identified for energy modeling. The identified transit van and cutaway shuttle BEVs are Buy America-compliant, have capacity for up to two wheelchairs, and are already offered through NCDOT's state procurement list. The state has one electric shuttle bus and one transit van on its procurement list that meet DCPT's size and passenger capacity preferences.

Due to the lack of commercially available battery electric minivans, NCDOT does not currently offer minivans on its procurement list. In place of a minivan, a similarly sized battery electric sport-utility vehicle (SUV) was modeled to forecast the energy demand of a battery electric minivan if it were to operate on DCPT's service once a minivan becomes available. The BEV equivalents modeled for each of the 16 vehicles in DCPT's fleet are outlined below, and the battery characteristics of each vehicle are provided in **Table 6**.

- The **MobilityTRANS Ford E-Transit** was used to represent the fleet's five passenger vans as it is currently the only battery electric transit van available for DCPT to procure through NCDOT. This BEV can hold up to seven passengers and two wheelchairs. The battery capacity of a Ford E-Transit is advertised as 68 kilowatt-hours (kWh), equating to a driving range of up to 155 miles. However, this does not account for the impact of running the vehicles' HVAC systems, which will pull power from the same battery responsible for providing motive power.
- The **Phoenix Motorcars Zeus 400** was used to represent the fleet's 10 cutaway shuttle buses. This BEV is comprised of a Ford E-450 Super Duty chassis and a Starcraft Allstar body. It offers a configuration accommodating 12 ambulatory and 2 wheelchair passengers.
- The **Kia EV9 Standard** SUV was used to model the fleet's one Dodge Grand Caravan and its anticipated energy demands. Since a battery electric minivan is not commercially available, this analysis assumes the three-row, seven-passenger Kia EV9 for the current minivan's BEV equivalent. This selection was made because SUVs consume a comparable level of energy, are similar in size, and offer the same seating capacities to minivans. This allows DCPT to estimate and prepare for the energy requirements of a future battery electric minivan in its fleet prior to the technology becoming available.

Table 6. BEV Equivalents & Energy Modeling Parameters

EXISTING ICE VEHICLE FLEET				EXAMPLE ELECTRIC VEHICLE FLEET						
Existing Vehicle Make / Model	**Vehicle Type**	**Veh. Qty.**	**Amb. Pass. Cap.**	**Electric Vehicle Make / Model**	**Vehicle Type**	**Amb. Pass. Cap.**	**Battery Capabilities**			
							Max. Cap. (kWh)	Max. Range (mi)	Max. AC Rate (kW)	Max. DC Rate (kW)
Ford Transit	20' Raised Roof	5	8	MobilityTRANS Ford E-Transit	Transit Vans	7	68	126	11.3	115
Ford E-350	20' LTV Cutaway	4	8	Phoenix Motorcars Zeus 400	Shuttle Bus	12	105	115	13.0	50
Chevrolet Express	20' LTV Cutaway	4	8	Phoenix Motorcars Zeus 400	Shuttle Bus	12	105	115	13.0	50
Ford E-350	22' LTV Cutaway	2	13	Phoenix Motorcars Zeus 400	Shuttle Bus	12	105	115	13.0	50
Dodge Grand Caravan	Minivan	1	3	Kia EV9 Standard	SUV	7	76	230	11.0	210

Energy Modeling Results

Given the operating data provided by DCPT summarized in **Table 5** and the charging characteristics of the electric vehicle replacements summarized in **Table 6**, **Table 7** summarizes the battery usage for each vehicle in DCPT's fleet if it were replaced with its identified BEV equivalent on both average-usage day and maximum-usage days. This modeling analysis was used to estimate the percentage of each BEV's battery capacity that would be consumed if it were to complete an average or above average (i.e., maximum) day of service. This analysis pinpoints whether the fleet's existing service requirements exceed the battery capacity capabilities of the identified BEV models.

Table 7. Example BEV Fleet Battery Usage

Existing Vehicle Make / Model	Electric Vehicle Make / Model	Veh. Qty.	Max. Cap. (kWh)	Daily Battery Usage			
				Avg. Use (kWh)	Avg. % Use	Max. Use (kWh)	Max. % Use
Ford Transit	MobilityTRANS Ford E-Transit	5	68	169.6	253.2%	252.9	377.5%
Ford E-350	Phoenix Motorcars Zeus 400	4	105	265.7	253%	403.0	383.8%
Chevrolet Express	Phoenix Motorcars Zeus 400	4	105	265.7	253%	403.0	383.8%
Ford E-350	Phoenix Motorcars Zeus 400	2	105	268.1	255.4%	355.9	339.0%
Dodge Grand Caravan	Kia EV9 Standard	1	76	24.7	32.5%	42.5	56.0%

The average daily battery usage outlined in **Table 7** reflects a scenario in which DCPT's fleet departs the facility in the morning, spends an average of 8 hours on the road, then returns to the facility in the evening to charge overnight. The modeling results show DCPT's current operations exceed the transit van and cutaway shuttle equivalents' battery capacities. These BEVs would use about 250 percent of their respective battery capacities on an average-use day. On a worst-case day with longer shifts and higher mileage counts, these percentages are even greater.

Ultimately, DCPT would need a BEV with nearly three times the battery capacity of current models to complete a typical service day. Transitioning DCPT's fleet with today's technology is impractical and is likely to significantly impact operations, given the projected energy requirements that exceed the battery capacity of every modeled vehicle (except for the minivan).

ALTERNATIVE CONSIDERATIONS

Due to the challenges highlighted in the energy modeling, DCPT considered alternatives to a full fleet transition powered by overnight depot charging.

Midday Recharging

Since current BEV equivalents do not have the range required to complete DCPT's existing service, midday charging solutions were identified. These alternatives include midday depot fast charging and en-route public fast charging. Construction of DCPT-owned, mid-route charging stations was not considered due to the challenges associated with variable routes, infrastructure costs, and a lack of transfer sites. Through the energy modeling, the midday charging alternatives were found to be inadequate due to the existing BEV equivalents' slow recharge times and Duplin County's limited public fast charging options.

Based on the energy modeling results, DCPT's BEVs may need two recharging sessions throughout the day to complete their typical service. This would impact DCPT operations by requiring approximately two 40-minute periods of downtime mid-route. While it is apparent that Duplin County's public charging network cannot currently support midday charging, it is worth noting that funding from the National Electric Vehicle Infrastructure (NEVI) program is currently driving the development of a DCFC station along Interstate 40 in Duplin County.

Once a BEV is approaching the limits of its range while en route, the driver may return to the depot for a rapid charge. From an operational perspective, however, it was determined that DCPT's vehicles are unable to return to the depot for a midday fast charge due to the significant deadheading and downtime it would require, thus ruling out this option. In addition, the identified BEV equivalents do not offer high enough charging capacities (i.e., speeds) for quick midday charging turnarounds. Due to these limitations, midday vehicle swaps were explored and modeled as an alternative.

Midday Vehicle Swaps

A midday vehicle swap consists of a driver returning to the depot with their BEV once the battery is close to depletion, plugging the BEV in for charging, then resuming service with a spare BEV that is fully charged. This enables drivers to complete their route with a spare vehicle when their current vehicle's range and battery capacity cannot cover the necessary mileage. According to the energy modeling results for this scenario, the entire dispatched DCPT fleet (aside from the minivan) would need to return to the depot for at least one vehicle swap per day to complete typical service levels. This would require DCPT to nearly double its fleet size with redundant vehicles to allow for vehicle swaps. If DCPT were to use vehicle swaps, it would incur significant vehicle-related costs and create operational inefficiencies through swap-related deadheading.

KEY TAKEAWAYS

Given DCPT's current operations, its large service territory, and the lack of public DCFC stations in the area, it is not yet feasible to transition the existing fleet with the BEVs currently available on NCDOT's state procurement list while still meeting daily service requirements. Based on the energy modeling results, fleet transition alternatives such as midday charging via public DCFCs and vehicle swaps are not feasible due to operational impacts and significant costs, respectively. In addition, though BEV technology is improving rapidly, near-term advancements are unlikely to benefit DCPT's fleet given the hundreds of miles its vehicles travel each day.

Depending on how quickly BEV performance advances, DCPT may not be able to procure suitable BEV equivalents for another 5 years. As DCPT is looking to finding opportunities to integrate BEV technology into its fleet, it could consider alternative approaches to an immediate fleet transition such as testing BEV performance on select routes.

TECHNOLOGY PROJECTION

Though a full fleet transition is not currently feasible, DCPT can monitor the developing BEV market to identify future vehicles that are well-suited for its service. As discussed in the ***Technology Review*** section, DCPT can expect significant improvements in performance and offerings in the coming years as BEV technology advances. Continued investment in the BEV industry is likely to result in increased ranges, faster charging speeds, and more widespread public charging availability. These factors could shape DCPT's fleet transition in different ways:

- **Vehicle range improvements:** DCPT's existing vehicles travel more than 200 miles per day. Future BEV driving range improvements may enable DCPT to transition its fleet to BEVs while minimizing changes to operating procedure. Battery technology is expected to mature and improve significantly over the next decade, yielding higher ranges by allowing manufacturers to optimize battery capacity and vehicle efficiency.
- **Public charging availability:** Given the distance between DCPT's existing depot and the location of its vehicles throughout the day, returning to the depot for a midday recharge is not feasible. The expansion of public DCFC stations in rural areas would allow DCPT vehicles servicing those areas to top off mid-service.
- **Vehicle charging speeds:** DCPT's fleet has up to 16 hours overnight to charge once the BEVs return to the depot; therefore, improved charging speeds would not benefit DCPT in this case. DCPT would only benefit from industry-wide improvements in charging speeds in conjunction with its ability to charge at publicly available DCFCs.

MARKET INDICATORS

Vehicle range and battery capacity are good market indicators for DCPT to track as it considers a full fleet transition in the future. While current BEV equivalents' ranges are insufficient, recent progress has already demonstrated promising technological advancements in certain BEV markets. Vehicle types across the industry have continued to see improvements in range and battery capacity, including:

- **Global light-duty market:** A BloombergNEF analysis of light-duty vehicles observed a 10 percent year-over-year (YOY) increase in BEV driving ranges from 2018 to 2022. [3]
- **Global shuttle bus market:** In 2023, the International Energy Agency (IEA) published a study showing how average battery capacities have increased across most bus categories in recent years. The study demonstrated a 45 percent increase in shuttle bus models' average battery capacities between 2019 and 2022. [4]

[3] Battery Bloat Could Backfire on Electric Vehicle Manufacturers (Bloomberg)
[4] Trends in Electric Heavy-Duty Vehicles - Global EV Outlook 2023 (International Energy Agency)

- **Ford E-Transit:** Ford recently announced a 26 percent improvement in driving range on its 2024 model compared to the 2023 model.[5]

CONCEPTUAL MODELING EXERCISE

As a conceptual exercise, **Table 8** models future BEV range on DCPT's selected replacements if range improved 10 percent annually in alignment with historic trends for light-duty vehicles. This projection may be conservative given the greater improvements observed in larger transit vehicles' advertised battery capacities over the last 5 years. To provide a more aggressive range improvement forecast, **Table 9** shows estimated BEV ranges if they were to increase by 20 percent annually.

Table 8. Projected YOY Growth in BEV Range (10 Percent)

Electric Vehicle Make / Model	2024 BEV Range (miles)	Projected Range by Year (miles)					
		2025	2026	2027	2028	2029	2030
MobilityTRANS Ford E-Transit	126	139	152	168	184	203	223
Phoenix Motorcars Zeus 400	115	127	139	153	168	185	204

Table 9. Projected YOY Growth in BEV Range (20 Percent)

Electric Vehicle Make / Model	2024 BEV Range (miles)	Projected Range by Year (miles)					
		2025	2026	2027	2028	2029	2030
MobilityTRANS Ford E-Transit	126	151	181	218	261	314	376
Phoenix Motorcars Zeus 400	115	138	166	199	238	286	343

Table 10 highlights the BEV range required on an average-usage day, including a 30 percent SoC buffer reflecting the minimum SoC best practices discussed in the ***Energy Modeling*** section. If BEV ranges improve by just *10 percent* annually, the modeled BEVs would not have the range needed to meet DCPT's service requirements by 2030. If BEV ranges increase at *20 percent* annually, the BEVs would begin to have the range needed to satisfy existing service levels in 2029.

[5] 2024 Ford E-Transit Adds Range, Faster Charging Speeds (caranddriver.com)

Table 10. BEV Range Required with SoC Buffer

Electric Vehicle Make / Model	**Average Day Use** (miles)	**30% SoC Buffer** (miles)	**Range Req. for Avg. Day** (miles)
MobilityTRANS Ford E-Transit	217	65	**282**
Phoenix Motorcars Zeus 400	218	65	**283**

The conceptual exercise outlined here reflects the challenge in meeting DCPT's operating service requirements with viable electric alternatives between now and 2030. Range improvements could accelerate as viable alternatives to lithium-ion batteries begin to mature and prices decline. The installation of public DCFC stations in select parts of Duplin County may also aid in the transition.

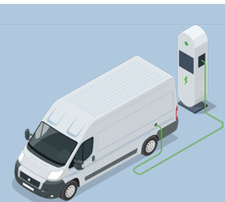
FLEET TRANSITION PLAN

The proposed fleet transition plan represents DCPT's preferred course of action for their fleet transition. NCDOT and DCPT worked collaboratively to determine a near-term and long-term strategy that DCPT may adopt to phase zero-emission vehicles into the fleet when appropriate.

PHASE ONE: NEAR-TERM PILOT STUDY

According to the energy modeling analysis, BEVs on the NDCOT procurement list cannot currently support DCPT's range requirements. As DCPT awaits viable BEVs, they could launch a pilot program with one expansion vehicle for DCPT's paratransit fleet. The pilot study can begin in 2026 with the initial procurement and deployment of one Ford E-Transit from the NDCOT state procurement list. DCPT would procure one 19 kW Level 2 charger to support the pilot vehicle in advance of the BEV's arrival.

Phase One would be a key period of learning for DCPT as it gathers real-time data on BEV performance, hones best practices for operations and maintenance, and prepares for a full fleet transition. This proposed pilot study would be an opportunity to test BEV performance on current transit services, allowing DCPT operators, maintenance, and dispatchers to identify opportunities and limitations.



Pilot Program Cost

As detailed in the financial analysis, the estimated start-up cost of DCPT's pilot study is $125,355. This cost estimate represents the pilot study's anticipated capital costs including the procurement of one expansion BEV for fiscal year 2026 and the purchase and construction of the associated charging infrastructure.

To prepare for the pilot vehicle, in 2025, DCPT can apply for zero emission transit grant opportunities offered through the FTA and identify local funding sources that can cover local match requirements for its procurement. Applicable funding opportunities to consider are discussed in the ***Funding Opportunities*** section.

Market Monitoring

Rather than identify a set year to initiate Phase Two, this plan recommends that DCPT utilize market monitoring to pinpoint when it can confidently proceed with its full fleet transition. Since BEV technology, especially in smaller transit applications, is still developing, BEV performance can dramatically improve within a short span of time. This plan lists out the market indicators DCPT can monitor to determine when a viable BEV equivalent has become available for both transit vans and shuttle buses. These indicators are included in the ***Technology Projection Evaluation*** section and summarized in **Table 10**. Once the market offers appropriate BEV equivalents, DCPT could proceed to Phase Two.

PHASE TWO: LONG-TERM FULL TRANSITION

Phase Two, the long-term strategy, could begin when a BEV meets the range and performance requirements of DCPT's service. After this is determined, DCPT could launch the full transition of its fleet, starting with the next upcoming replacement cycle. The transition schedule would follow DCPT's existing fleet replacement cycle, replacing the 16 internal combustion engine vehicles with battery electric equivalents upon their retirement. A phased transition would allow DCPT to gradually build working knowledge of BEVs and prepare for a fully electrified fleet.

Once DCPT decides to proceed with Phase Two, it could install all conduit and electrical service upgrades required to support the full fleet transition in advance of the first Phase Two vehicles arriving onsite. Installing all supporting electrical infrastructure (sans chargers) for full buildout at one time could be cost effective and minimize construction disruptions to DCPT's parking area. This is further discussed in the ***Sizing Infrastructure for Full Build-Out***. It is anticipated that chargers would be procured at a 1:1 ratio of Level 2 charging ports to BEVs. Ideally, charger procurement and installation will be phased in accordance with the vehicle transition schedule.

FACILITIES & INFRASTRUCTURE PLAN

The following section provides a review of DCPT's existing garage and maintenance facilities as well as facility recommendations for a pilot study and full transition.

EXISTING DCPT FACILITIES

Existing Garage Facility

DCPT's administrative offices, garage, and cleaning facilities are located at 144 Duplin Commons, a new DCPT-dedicated facility constructed in 2023 and made operational in 2024. The new facility, funded by the American Rescue Plan Act (ARPA), consolidates the previously separated DCPT offices and fleet parking at a new site.

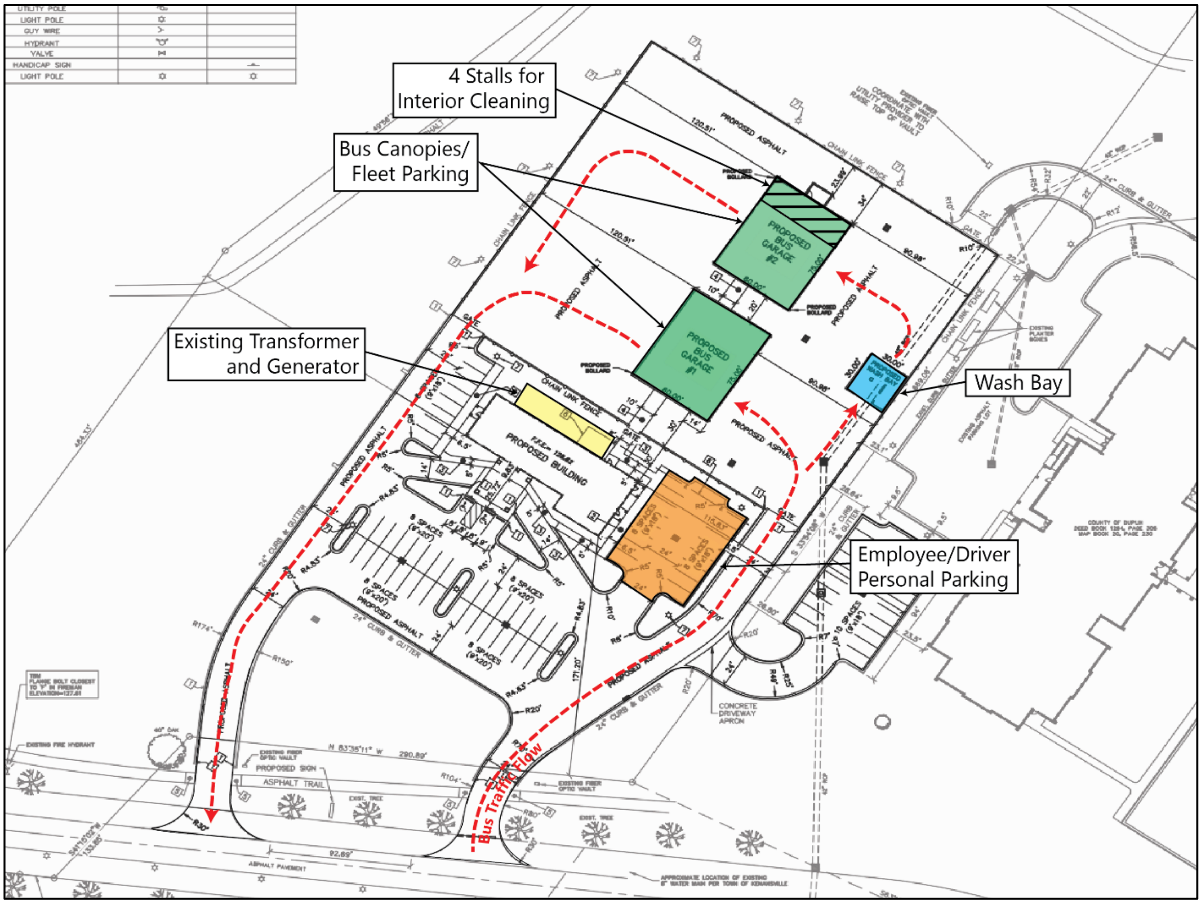
On site, two drive-through canopies accommodate parking for all fleet vehicles (**Figure 4**). Each canopy covers 10 parking stalls for a total of 20 parking stalls dedicated to transit vehicle parking and cleaning. Sixteen are currently used for vehicle parking while four of the stalls are reserved for interior cleaning and are equipped with air hoses. DCPT vehicles move through these lanes when being cleaned so they are currently not used for parking.

Figure 4. DCPT Covered Fleet Parking

For exterior cleaning, the site also includes a wash bay to the east of the parking canopies. Vehicles currently refuel at a Duplin County fuel pump off site and across the street from the depot. Maintenance occurs off site at the Duplin County Maintenance Garage.

After refueling at the county fuel pump at the end of a shift, all buses return to the site, entering through the right-hand driveway from Duplin Commons Drive. Vehicles then go through the wash bay and, on some occasions, may be cleaned at the interior cleaning lanes before returning to the parking area under the canopies for the night. When buses depart for service, they exit using the left-hand driveway to Duplin Commons Drive. The general flow of buses through the site is shown in **Figure 5**.

Figure 5. DCPT Offices & Garage Facility[6]



Key characteristics of the electrical infrastructure at the garage facility, including transformers and panelboards or switchgear, are summarized below and shown in **Figure 6**. Currently, the electrical infrastructure supporting DCPT's facilities is consolidated along the DCPT offices.

Utility Transformers

Ownership: Duke Energy

Average lifespan: 20-30 yrs.

Configurations: Pole- or pad-mounted

Low-Voltage Transformers

Ownership: Duke Energy

Average lifespan: 20-30 yrs.

Configuration: Pad-mounted

Panelboards or Switchgear

Ownership: DCPT/County

Average lifespan: 20-30 yrs.

Configurations: Panelboards are typically under a certain size, while the switchgear is used for a larger site configuration. Subpanels may be necessary to support charging in different phases and/or located in different areas of a facility

Future Charging Equipment

Ownership: DCPT

Average lifespan: ~10 yrs.

Configuration: Recommended to be pedestal-mounted

Equipment Specifications: The EvoCharge Max 80 A (19.2 kW) is used as an example of a Level 2 charger that DCPT may procure, as it is appropriate for their BEVs based on the energy modeling

[6] This drawing is the final design for the now constructed DCPT facilities. Please note that the parking lot, bus garages, and main building now exist.

Figure 6. Existing Electrical & Mechanical Infrastructure

Existing Maintenance Facility

DCPT fleet vehicle maintenance occurs at the Duplin County Maintenance Garage located in Rose Hill, roughly 7 miles from the DCPT Garage (**Figure 7**). The maintenance garage features four general purpose repair bays that are used as needed: one 20,000 pound (lb) lift, two 18,000 lb lifts, and one four-post lift. Most DCPT bus service is done in the four-post lift bay (**Figure 8**). Vehicles waiting for service are parked in a gravel lot in front of the maintenance garage. As county fleets do not yet have any BEVs, the Duplin County Maintenance Garage is not yet designed to maintain BEVs.

Figure 7. Duplin County Maintenance Garage

Figure 8. Four-post lift bay (left) and vehicle parking in the front of the garage (right)

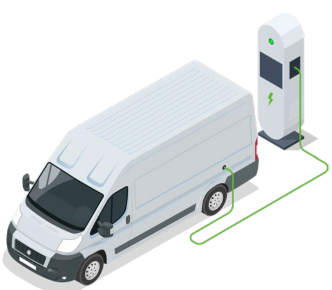
CHARGING INFRASTRUCTURE RECOMMENDATIONS

The following section presents the recommended facility upgrades for a pilot study and fleet transition at DCPT. Recommendations are provided by phase and include a conceptual site diagram of proposed charging infrastructure based on utility and site plans.

Given that a full fleet transition is not yet feasible, DCPT identified two electrification strategies that allow the fleet to phase its electrification in line with BEV technology advancements. DCPT could first consider the infrastructure investments needed to support the pilot study, which may include a single expansion vehicle (e.g., a Ford E-Transit). Once market indicators clearly point to feasible BEV equivalents, DCPT can make additional infrastructure investments that support electrification beyond the pilot study.

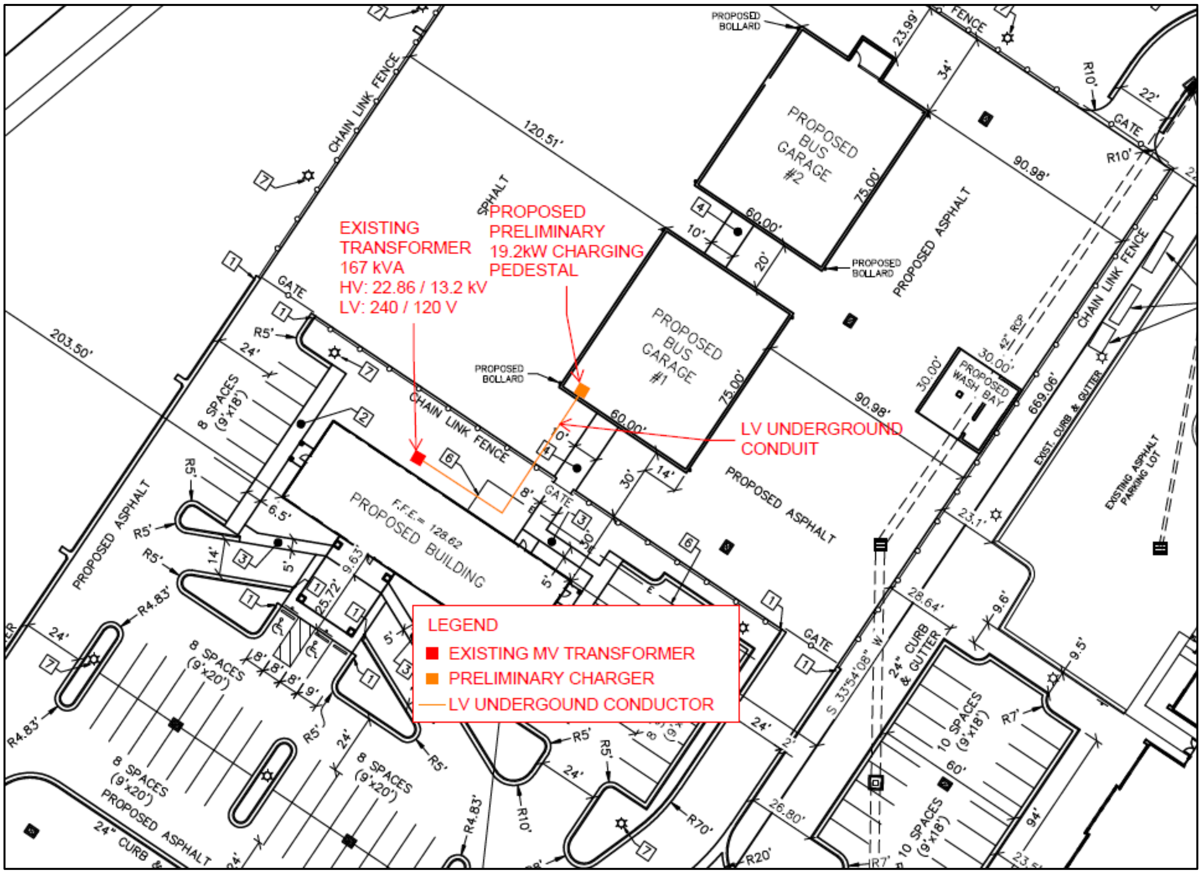
Phase One Pilot Study

DCPT could begin its proposed pilot study in 2026 by procuring one Ford E-Transit from the NCDOT procurement list and operating it on a service within the battery's range. In preparation, they can begin the procurement of the supporting charger and the installation of electrical infrastructure in 2025. While it is typically recommended to size infrastructure for the full fleet at the beginning of fleet electrification, this approach was not selected due to the uncertain start year of Phase Two. DCPT also wishes to avoid widespread trenching across the facility's newly paved parking area.



The pilot program would see one 19.2-kW pedestal-mounted Level 2 charger installed in the first canopy to support the operation of one expansion BEV (the Ford E-Transit). The pedestal should be installed near one of the existing columns of the canopy, as shown in **Figure 9**, the conceptual charging layout for Phase One. The existing 167-kilovolt-amperes (kVA) transformer on site likely has the necessary capacity to support this charger, so no service upgrades may be required. This can be confirmed with Duke Energy prior to installation. Underground conduit could run between the existing transformer on site and the charger. To prepare the Duplin County Maintenance Garage for the pilot study, it is recommended that the garage procure a mobile charger so vehicles have enough charge to return to the depot seven miles away.

Figure 9. Conceptual Phase One Charging Layout for Pilot Program[7]



As documented in the Capital Requirements Memorandum, the startup cost for the proposed pilot program is estimated at $125,355. This estimate represents anticipated capital costs, including the procurement of one expansion BEV for fiscal year 2026 and its supporting Level 2 charger. The charger is estimated to cost $20,855 for both purchase and construction. While start-up costs are greater than those of ICE vehicles, savings in routine maintenance and fueling may outweigh the discussed capital costs over the lifecycle of the new BEV.

[7] This drawing is the final design for the now constructed DCPT facilities. Please note that the parking lot, bus garages, and main building now exist.

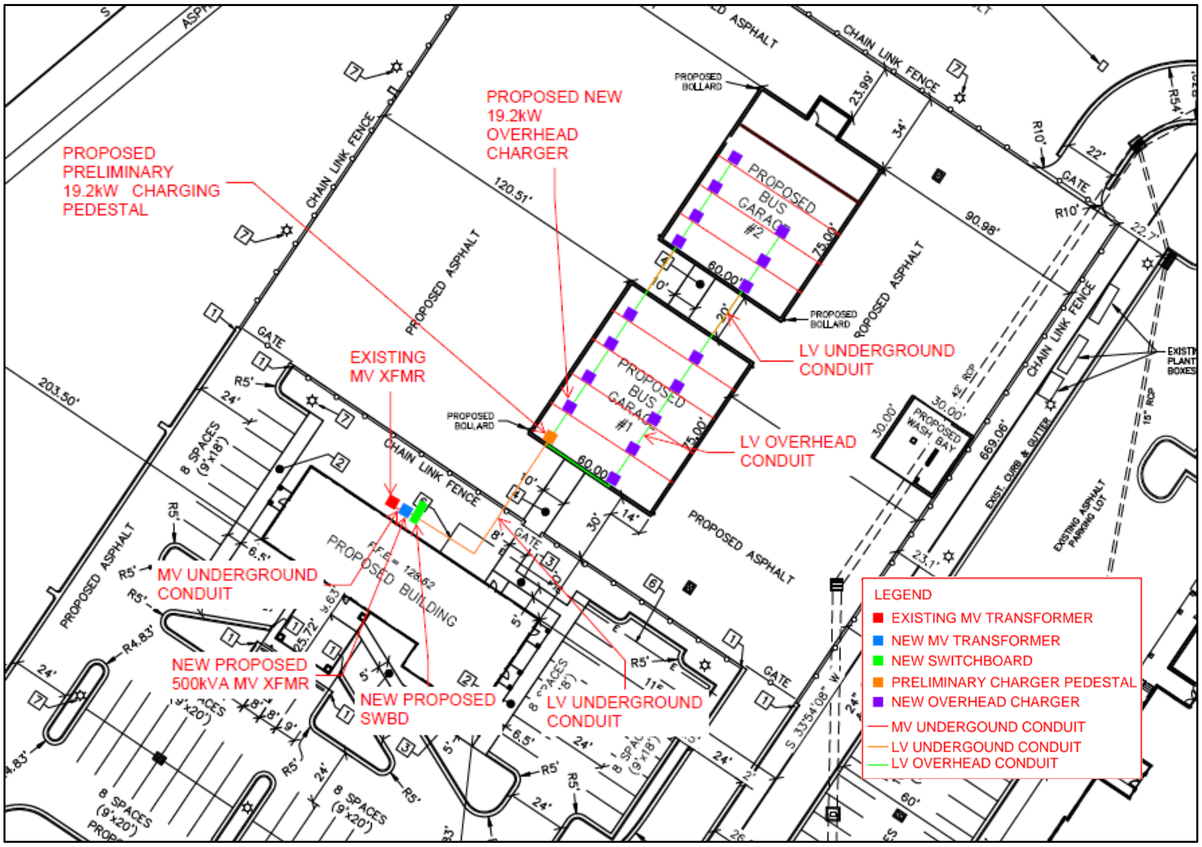
Phase Two Full Transition

Once it is determined that appropriate BEV equivalents are available on the procurement list, DCPT may initiate its full fleet transition. This fleet transition can follow the existing vehicle replacement cycle, gradually replacing DCPT's 16 ICE vehicles with BEVs as they are due for retirement.

The full fleet transition could utilize 16 overhead Level 2 chargers installed in the canopy ceiling, with 8 being installed in the first bus garage and 7 being installed in the second. Overhead chargers with pull down cables are recommended to avoid obstructing the current flow of the drive-through parking stalls under the canopy. To confirm the canopies can support the additional weight of overhead chargers, DCPT may conduct a structural analysis for each canopy. If DCPT were to use pedestal mounted chargers instead, the current pull-through parking configuration and lot vehicle flow must be adjusted.

Due to the uncertainty of the start year, energy requirements, and future infrastructure types and costs for Phase Two, this Fleet Transition Plan does not document the infrastructure costs or recommend specific power levels of charging equipment for Phase Two. Instead, the project team provided a charging layout (**Figure 10**) that indicates optimal placement for conduit and charging equipment for the full transition.

Figure 10. Conceptual Phase Two Charging Layout for Full Transition[8]



As DCPT awaits viable BEV equivalents, the power requirements of Phase Two are uncertain. These should be reevaluated once market indicators clearly demonstrate appropriate replacements. Based on a future power needs assessment, a new transformer would need to be added adjacent to the existing 167-kVA transformer to support Phase Two chargers. Overhead conduit could be run within the bus canopies, while a small amount of additional underground conduit would be run to connect them.

Sizing Infrastructure for Full Build-Out

Chargers could be procured in line with BEV procurements. DCPT may consider futureproofing by investing in full build-out at the start of Phase Two. If DCPT opts to do this, all infrastructure required for transitioning to a fully electric fleet, including conduit and equipment pads, could be installed at the beginning of the fleet transition to minimize costs and operational impacts at the garage facility. This approach could help eliminate the need for significant trenching, concrete saw cutting, repair and replacement, and parking lot restriping in the future.

---

[8] This drawing is the final design for the now constructed DCPT facilities. Please note that the parking lot, bus garages, and main building now exist.

If DCPT plans for full build-out, electrical equipment, such as transformers and switchboards, would be sized appropriately for the peak charging load of a fully electrified fleet. Initial construction would include stubbed off conduit runs to all parking stalls that may eventually be electrified with additional chargers in later years as BEVs are delivered. Pull tape would be installed in these conduits to allow for easy installation of conductors in the future. Any conductors required for future chargers beyond the pilot program would need to be procured and installed for each new charger.

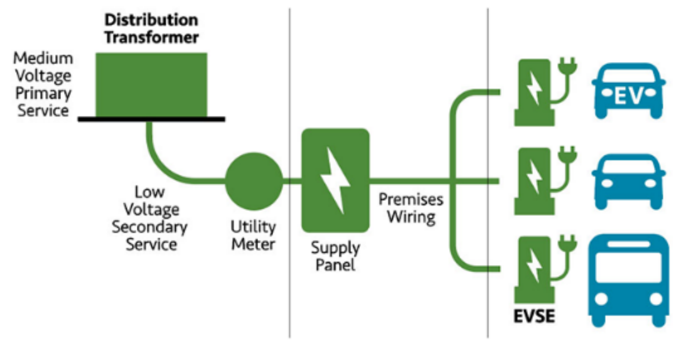
UTILITY PARTNERSHIP

The project team met with representatives from Duke Energy, DCPT's utility provider, to identify their incentives and program offerings that may support fleet electrification. This engagement was also intended to establish communication for further utility coordination between Duke Energy and DCPT at the later stages of fleet transition planning.

CHARGING INFRASTRUCTURE SUPPORT

Utilities have four common approaches to infrastructure ownership associated with charging BEVs, as shown in **Figure 11**. At DCPT's garage site, which is served by Duke Energy, the traditional model would apply.

Figure 11. Utility Approaches to Charging Infrastructure Ownership



	UTILITY SERVICE	PREMISES WIRING	EVSE
1. Traditional	Electric Company	Customer	
2. Make Ready	Electric Company		Customer
3. EVSE Only	Electric Company	Customer	Elecric Company
4. Full Ownership	Electric Company		

Duke Energy will own equipment in front of the meter, including the transformer and the utility meter. Any electrical infrastructure upgrades to support charging after the transformer are the responsibility of customers; however, Duke Energy does offer a make-ready rebate program for nonresidential customers to offset associated costs. Duke Energy is responsible for the installation and maintenance of cabling and hardware before and at the transformer point.

Make-Ready Program

Duke Energy's Commercial Charger Prep Credit, a make-ready rebate program, provides a one-time credit to help cover the cost of preparing a site for chargers on the customer side of infrastructure. It can be used for electrical wiring or other required electrical upgrades to support Level 2 or higher EV chargers. It cannot be used for permitting, EV charger installation, or EV charging equipment costs. The credit amount available is determined by whether new service upgrades (like those discussed in the previous paragraph) are required to support the additional load of charging. If service upgrades are not required, Duke Energy can offer a larger make-ready credit.

Service Upgrade Costs

While Duplin County does not own the transformers on site, they may be required to pay a service upgrade fee when requesting a transformer with additional capacity for the full fleet transition. In some cases, if a customer requests an infrastructure upgrade that necessitates new infrastructure on the utility providers' side of the demarcation point, they may be responsible for covering a portion of the upgrade cost. This is done to avoid passing on unexpected infrastructure costs to other utility customers. In order to determine the cost-of-service upgrades (e.g., a transformer upgrade) for a customer during the engineering phase, Duke Energy will compare the estimated cost of the proposed upgrade to the additional revenue credit for the new added load. Depending on this assessment, Duke Energy's revenue credit may cover the upgrade cost. This would be determined during the engineering period as DCPT and Duke Energy coordinate.

Utility Rate Incentives

Many utility providers offer specific electric vehicle rate schedules, referred to as time-of-use (TOU) rates, designed to incentivize the adoption of BEVs or promote charging at specific times of day (i.e., overnight) when electricity is cheaper and overall demand is lower. While Duke Energy Progress does not offer a BEV-specific TOU rate, their recently modernized TOU rate was developed with charging in mind. This rate schedule offers discounted off-peak rates during the overnight hours when fleet vehicles will typically be parked and charging. Charging costs could be reduced even further if DCPT schedules charging activities for the early morning hours prior to 6 a.m.

TRANSITION COORDINATION

Duke Energy's Customer Fleet Electrification for North Carolina representative recommended that, following the completion of the modeling analysis, conceptual plans, and plan finalization, DCPT and Duke Energy Progress can begin the engineering phase together. During this phase, the utility would be able to confirm the size and age of the existing transformer, the cost of any service upgrades needed to support charging, and its ability to provide the requested service to electrify DCPT's fleet. Given that DCPT's garage facility finalized construction in 2024, it is likely that the existing transformer can support the energy demands of the single Level 2 charger recommended for the pilot study.

FINANCIAL ANALYSIS & FUNDING PLAN

The following section summarizes the methodology and findings of DCPT's financial analysis for the anticipated costs of a fleet transition. This analysis is intended to support DCPT as it plans the budget for its initial pilot and potential fleet transition.

- **Pilot Program Capital Cost Approach**
  The analysis first describes the proposed pilot program's start-up costs for DCPT's selected BEV equivalent, the Ford E-Transit van. This cost consists of all the necessary investments to start DCPT's BEV pilot program including the purchase of a BEV, its charging infrastructure, and estimated installation and construction costs.

- **Lifecycle Cost Forecasting Approach**
  To demonstrate the expected costs of operating and maintaining a BEV on DCPT service from procurement to its last day of service, this financial analysis includes a lifecycle cost analysis. This assessment compares estimated BEV lifecycle costs to the lifecycle costs of an existing DCPT Ford Transit van (determined using historical mileage and cost records provided by DCPT). This existing ICE vehicle fleet is treated as the baseline representation of a DCPT fleet vehicle in the following analysis.

The lifecycle cost analysis considers initial capital costs (e.g., vehicle and charger purchases); annual vehicle and charging infrastructure maintenance; and annual fuel and electricity costs over a fleet vehicle's 5-year lifecycle. These considerations are described in more detail below.

COST ASSUMPTIONS

The following sections summarize the key assumptions and inputs that are used to generate the BEV and baseline ICE vehicle lifecycle cost estimates. The ICE vehicle inputs described below are based on the usage and cost metrics of an existing transit van within DCPT's fleet. Costs are not adjusted for inflation/escalation through the lifecycle.

Capital Cost Assumptions

The key inputs used to estimate initial capital expenditures for the two vehicle types being evaluated are shown in **Table 11** and reflect the following:

- **Vehicle purchase costs:** The ICE vehicle, a Ford Transit vehicle, is estimated to cost $97,888. This price is inclusive of the transit door option and wheelchair access option (Creative Bus's MobilityTRANS uplift) as required for the ADA services DCPT provides. The BEV, a Ford E-Transit, costs $104,500 and is comprised of a base unit cost ($71,160), a cost for the alternative fuel-all electric vehicle option ($24,727), and a rear wheelchair lift ($8,613). These costs come from the North Carolina Department of Transportation procurement list from which DCPT procures its vehicles.

Table 11. Assumed Vehicle Purchase Costs

Veh. Type	Model	Cost* (2024 $)	Notes
ICE	Ford Transit	$97,888	Includes transit door option and MobilityTRANS uplift (sold by Creative Bus Sales)
BEV	Ford E-Transit	$104,500	Includes transit door and wheelchair options

**Vehicle costs obtained from the NCDOT state procurement list.*

- **Charging infrastructure costs:** Operation of a BEV would require purchasing and installing charging infrastructure that must be maintained throughout the lifecycle period. The procurement and installation of the identified charger, an EvoCharge Max 80 Amp EV Charger with a pedestal dispenser is forecasted to cost $20,855 (**Table 12**). This cost includes the charger ($4,965), along with the required underground electric lines, a circuit breaker, cabling, and installation materials and labor costs ($13,994). The analysis assumes the chargers are replaced at the average life expectancy of every 10 years with regular maintenance, lasting for two DCPT fleet vehicle lifecycles.

Table 12. Assumed Charging Infrastructure Costs

BEV Charger Make / Model	Unit Cost (2024 $)	Install Cost (2024 $)	Total Cost (2024 $)
EvoCharge Max 80A* (Charger and Pedestal Dispenser)	$4,965	$15,890	$20,855

**Equipment to be replaced every 10 years based on average expected lifespan.*

- **Utility infrastructure costs:** The analysis does not consider additional infrastructure upgrade costs to accommodate charging activities. Given the nature of the pilot program and the new state of the DCPT facility's infrastructure, the analysis assumes utility infrastructure upgrades would not be required during the pilot program analysis period.

Operations & Maintenance Cost Assumptions

The key inputs used to estimate annual operations and maintenance costs reflect the following assumptions:

- **Vehicle operating costs** are assumed to be equal between vehicle types as there are no anticipated increases to the service level in the pilot program. As a result, operating costs for drivers are not included in the lifecycle cost analysis.

- **Vehicle maintenance costs** are estimated on a per-mile basis and are applied evenly through the vehicle operating years, as the average annual vehicle milage does not change through operation. These costs are summarized in **Table 13**.
    - **ICE:** Annual maintenance costs for the existing vehicle were provided by DCPT over the lifecycle (2018-2024) of the vehicle. These costs where applicable are translated to 2024 dollars using inflation factors sourced from the Bureau of Labor Statistics.[9] These costs are averaged across years to provide an annual average maintenance cost. Finally, this is translated into a per-mile rate based on the vehicle average annual mileage (49,421 miles per year). The ICE vehicle maintenance cost of $0.06 per mile is assumed to cover the standard yearly costs. In addition, it is assumed that this yearly maintenance cost will remain constant over the lifecycle of the vehicle. Statistical analysis was performed on the provided historical maintenance costs and no significant relationship was found between vehicle mileage and maintenance costs, likely because of the regularity of preventative maintenance activities.
    - **BEV:** The per-mile BEV maintenance costs are based on adjustments to the ICE vehicle standard maintenance rate and the mid-life maintenance costs. The standard annual maintenance rate of $0.06 per mile for the ICE vehicle is assumed to be ~30 percent higher than for its BEV counterpart, per the United States (U.S.) Department of Energy Vehicle Technologies Office, making the standard maintenance rate for a BEV approximately $0.04 per mile.[10]
- **Charger maintenance costs** reflect an assumption that this equipment would require yearly preventative maintenance costs that begin accruing after the charger is installed (**Table 13**). The purpose of this maintenance is to support efforts to minimize equipment degradation over time. This cost comes from the project team's electric vehicle supply equipment (EVSE) market information.

Table 13. Assumed Maintenance Costs

Cost Type	ICE Cost (2024 $)	BEV Cost (2024 $)
Vehicle Maintenance	$0.06/mile	$0.04/mile
Charger Maintenance	-	$500/year

Fueling & Charging Cost Assumptions

The key inputs used to estimate fueling and charging costs are shown in **Table 14** and reflect the following assumptions:

[9] CPI Inflation Calculator (Bureau of Labor Statistics)
[10] Battery Electric Vehicles Have Lower Scheduled Maintenance Costs than Other Light-Duty Vehicles (Department of Energy)

- **Gasoline costs** reflect recent costs incurred to fuel an existing van, provided by DCPT. These costs were drawn from the 2023 calendar year fueling log and are presented in 2023 dollars.
- **Electricity propulsion costs** are the costs to charge a BEV. These are calculated based on Duke Energy's existing utility rates and the estimated BEV efficiency. It is important to note that Duke Energy does not currently offer an EV-specific rate. Based on the Ford E-Transit's 89 kWh battery and the stated range of 159 miles per charge,[11] the BEV is assumed to use 0.56 kWh of electricity per mile. Coupled with the yearly vehicle mileage and the electric rate of $0.10 per kWh, which is based on the 05 March 2024 to 02 April 2024 billing period, the energy charge for additional kWh (at $0.098 per kWh) and the storm recovery cost ($0.002 per kWh), the cost for electricity is estimated to be approximately $2,800 per year.

Table 14. Assumed Fueling & Charging Costs

Cost Type	Unit Cost	Vehicle Efficiency	Yearly Mileage	Est. Cost per Year
ICE Fueling	-	-	49,421 miles/year	**$9,875**
BEV Charging	$0.10/kWh	0.56 kWh/mile	49,421 miles/year	**$2,767**

LIFECYCLE COSTS

Based on the assumptions described in the prior section, **Table 15** compares the estimated lifecycle costs associated with the two vehicle types. The BEV scenario capital costs include both the vehicle itself and the charger needed to support propulsion. Vehicle and infrastructure maintenance and energy required for vehicle propulsion account for the Operations and Maintenance (O&M) costs displayed.

Table 15. Lifecycle Cost Comparison (5-Year)

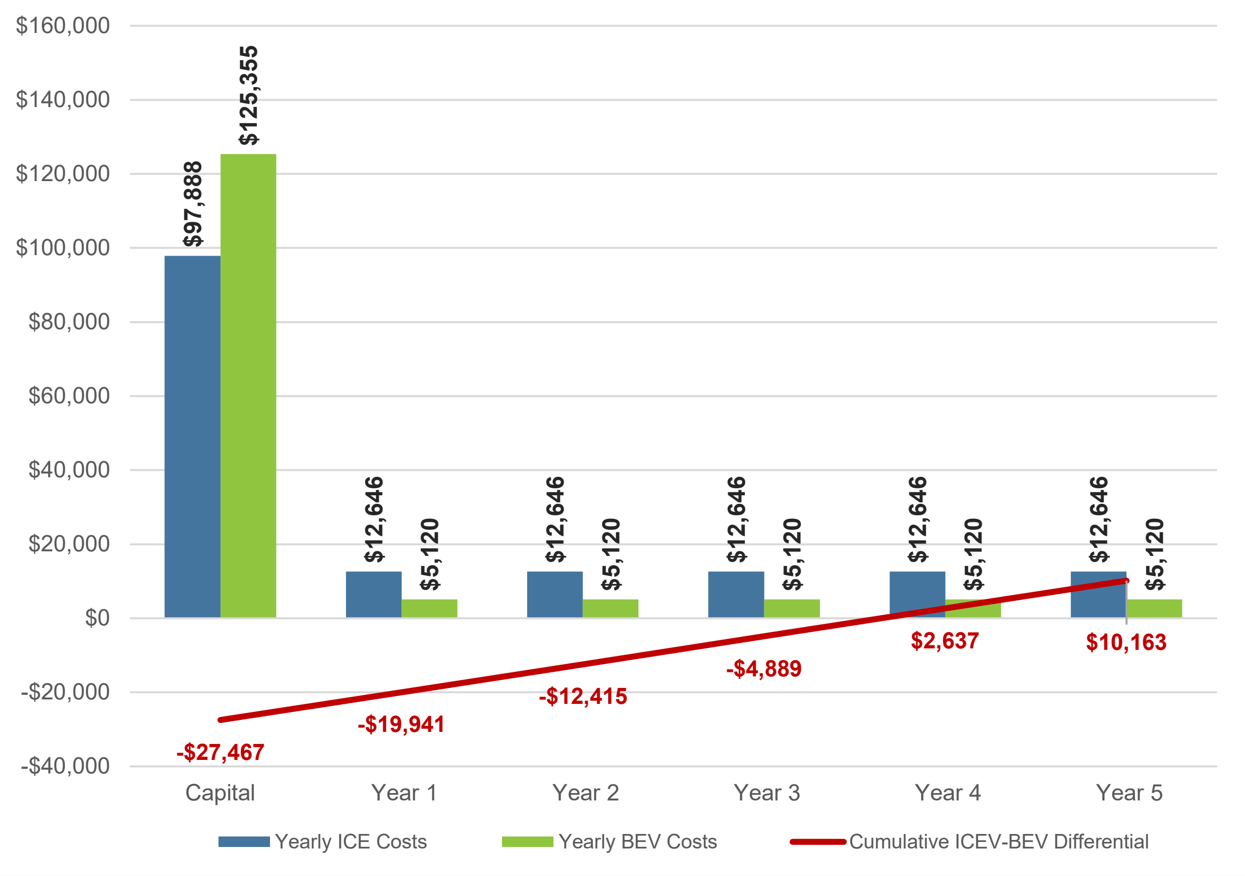
Veh. Type	Capital Cost	O&M Costs		Total Cost
		Annual Cost	5-Year Cost	
ICE	$97,888	$12,646	$63,231	$161,119
BEV	$125,355	$5,120	$25,601	$150,956

Despite the additional $27,000 in initial capital costs to purchase and install the BEV and charging equipment, the annual O&M costs savings, provided by way of vehicle propulsion, offset the initial capital purchase deficit. More specifically, the BEV's annual O&M costs are about $7,500 less per year than the ICE vehicle. Over the 5-year analysis period, total O&M costs are approximately $37,000 less

[11] 2024 Ford E-Transit All-Electric Van Pricing, Photos, Specs, and More (ford.com)

with BEVs compared to ICE vehicles. In terms of total lifecycle costs, the BEV option would be approximately $10,100 less than the ICE vehicle option. **Figure 12** provides a visual comparison of these costs over 5 years.

Figure 12. Lifecycle Cost Comparison (5-Year Analysis Period)



FUNDING OPPORTUNITIES

Federal grant programs offer numerous funding opportunities for fleet transition activities including vehicle purchases, workforce training, and related equipment and facility upgrades. DCPT may consider applying for these funding opportunities to make the transition to BEV technology and charging infrastructure more financially feasible. For the first two programs outlined below, the federal share of eligible capital costs is 80 percent of the net capital project cost, unless DCPT requests a lower percentage. As a result, DCPT must provide the remaining 20 percent of funding through a local match.

Low or No Emission Grant Program- 5339(c)

The Low or No Emission Grant Program (Low or No) is a competitive program that provides funding to state and local governmental authorities for the purchase or lease of zero-emission and low-emission transit buses as well as acquisition, construction, and leasing of required supporting facilities. To be considered for this competitive funding, DCTP must submit a proposal to the FTA in response to a Notice of Funding Opportunity. Eligible projects include:

- Purchasing or leasing low- or no-emission buses
- Acquiring low- or no-emission buses with a leased power source
- Constructing or leasing facilities and related equipment for low- or no- emission buses
- Constructing new public transportation facilities for low- or no-emission buses
- Rehabilitating or improving existing public transportation facilities to accommodate low- or no-emission buses

Applicants like DCPT that are proposing a project related to zero-emission vehicles must spend 5 percent of the award on workforce development and training, unless the applicant proves that their financial need is less. This allocation is intended to encourage applicants to properly prepare their workforce for operating and maintaining zero-emission vehicles.

Grants for Buses and Bus Facilities Competitive Program

The Grants for Buses and Bus Facilities Competitive Program (Bus and Bus Facilities Grants) allocates federal resources to states and direct recipients to replace, rehabilitate, and purchase buses and related equipment to constructed bus facilities. This can include technological changes or innovations to modify low or no emission vehicles or facilities. To be considered for this competitive funding, DCPT must submit a proposal to the FTA in response to a Notice of Funding Opportunity. Eligible activities include the following:

- Capital projects to replace, rehabilitate, and purchase buses and vans
- Purchase of related equipment
- Construction of bus-related facilities, including technological changes or innovations to modify low or no emission vehicles or facilities

Like the Low or No program, the Bus and Bus Facilities Grants also requires that recipients spend 5 percent of the award on workforce development and training if the proposed project is related to zero-emission vehicles.

Commercial Clean Vehicle Credit

The Internal Revenue Service's (IRS) Commercial Clean Vehicle Credit can also be leveraged to reduce capital costs. This credit can fund up to $7,500 per vehicle purchase for vehicles with gross vehicle weight ratings (GVWRs) under 14,000 pounds and up to $40,000 per vehicle purchase for vehicles with GVWRs above 14,000 pounds.

WORKFORCE DEVELOPMENT PLAN

When introducing BEVs into a fleet, it is important to preserve the existing workforce and provide the necessary skills to support electrification. If DCPT moves forward with its transition, DCPT can update the existing training program to include BEVs and work closely with its existing workforce as it implements new training protocol.

The U.S. FTA has issued information addressing a Zero-Emission Fleet Transition Plan Workforce Evaluation Tool to assist agencies with planning for BEV impacts on their workforce. In this tool, agencies will find seven major FHWA-recommended topics they can examine:

1. Identify Skills, Training, and Credentials
2. Assess Skills of Current Workforce
3. Identify Skills Gaps
4. Develop ZEV Transition Workforce Training Program
5. Engage Current Workforce in Planning
6. Incorporate Strategies to Avoid Workplace Displacement
7. Identify Funding for Training Program

With the introduction of BEVs to DCPT's transit fleet, proper training on the vehicle systems and the subcomponents unique to them is critical for the safe, efficient operation and maintenance of the fleet. It is recommended that DCPT work with internal departments and in close coordination with OEMs to acclimate the existing workforce to the new technology by offering new skill sets to those interested in operating or maintaining BEVs. This workforce development plan addresses standard BEV workforce development practices for transit applications and existing workforce development practices at DCPT, identifies gaps in current workforce practices as they relate to BEVs, and outlines strategies aimed at building an effective training program for DCPT's workforce.

BEV WORKFORCE DEVELOPMENT

Additional training would be required for employees working with BEVs and EVSE for a successful transition. There are two distinct areas for BEV training needs: safety practices for high-voltage and arc flash risks, and maintenance and repair of BEVs and EVSE. This section describes typical workforce development practices for maintenance staff and operators as they relate to BEVs.

Maintenance Training & Safety Considerations

Vehicle maintenance mechanics would interact with the BEVs more frequently compared to other staff. As a result, training could be required for mechanics for the sake of safety and reliable repairs for a transitioned fleet. Training for high-voltage and arc flash safety protocols according to National Fire Protection Association (NFPA) 70E standards and Occupational Safety and Health Administration (OSHA) requirements could be a prerequisite to hands-on vehicle training. Vehicle training would include gaining knowledge of the many BEV system functions, including familiarization with its high-voltage subsystems, its battery storage systems, troubleshooting and diagnostics, and its routine preventive maintenance requirements. This is in addition to behind-the-wheel training with the BEVs.

Safety Trainings

BEVs contain high-voltage batteries, requiring all maintenance technicians to be trained to work on high-voltage systems. It is recommended that DCPT work internally to develop a Bus Maintenance and Electrical Safety Program, effectively deploy a comprehensive safety plan, and confirm that all relevant staff properly execute the plan. As DCPT's fleet electrification efforts progress, it is recommended the following elements are routinely reviewed and updated as needed:

- Proper use and inspection of personal protective equipment (PPE)
- Cardiopulmonary resuscitation (CPR), defibrillator, and first aid training
- High-voltage onboard systems familiarization and identification
- Lock-out tag-out (LOTO) training and compliance.

Tools & Equipment

The following expertise, tools, and PPE could be provided to develop the existing workforce and carry out safe practices for maintaining BEVs and EVSE are applied:

- Understand how to identify high-voltage hazards
- Understand what arc flash is and how it can occur
- Understand what PPE must be used
- Understand how to properly inspect required PPE
- Understand how to properly set up a work area (e.g., arc flash barriers)
- Know how to properly make a high-voltage system safe to work on (i.e., de-energizing)
- Understand when a work permit is required and how to obtain one.

Creating an audited process measuring technician performance and keeping a record of incidents in an incident log are both highly recommended. A Training Record System may be implemented (and updated regularly) as an essential part of electrical safety protocols. Insulated tools meeting ANSE 1505 (1,000 volts of alternating current [VAC]/1,500 volts of direct current [VDC]). Standards are required to work on high-voltage systems, even when the system is de-energized; regular inspection of these tools is required and must be documented. PPE would also require routine inspection and the establishment of a tracking system.

Space Requirements

When planning maintenance space for BEV operations, transit agencies must allocate sufficient space for specialized tools and PPE. The following elements could be considered:

- **Tool Storage:** Designate an organized and secure area for specialized vehicle tools, including diagnostic equipment, insulated torque wrenches and hand tools, megohmmeters, and other tools specific to battery electric bus maintenance.

- **PPE Storage:** Provide a designated space for storing PPE including insulated gloves, safety glasses, face shields, arc flash coveralls, electrical footwear, and other PPE needed to work with high-voltage systems.
- **Charging Infrastructure:** Allocate adequate space for a charging station near the facility's maintenance area, outside repair bays to facilitate easy access for charging and maintenance activities. The maintenance garage may procure a portable charger so BEVs can have enough charge to return to DCPT's main garage location.
- **Work Bays:** Design maintenance bays with sufficient space to accommodate the size of BEVs and provide adequate space for technicians to safely access different components of the vehicle.
- **Ventilation:** Confirm the facility's ventilation systems are equipped to process the fumes and emissions associated with battery off-gassing and maintenance to provide a safe and healthy work environment for mechanics.
- **Training Area:** Dedicate an area for ongoing training programs to keep mechanics and operators updated on the latest BEV technologies and safety protocols.
- **Damaged Bus Storage:** If space permits, designate an outdoor parking area at least 50 feet from surrounding buildings, vehicles, or concentrations of people to store any BEV that has experienced damage, off gassing, or thermal runaway.

When designing a maintenance space for BEVs, local regulations and safety standards should be complied with as there are often specific requirements for EVSE. Regulations to consider will include building codes, electrical codes, zoning regulations, environmental regulations, and safety standards.

Operator Training & Safety Considerations

Bus operators are responsible for the safe delivery of passengers. They would directly interact with the BEVs and EVSE daily but are not responsible for their maintenance or repair. Operators would need to be retrained to operate BEVs, which are equipped with regenerative braking systems that are most effective when operators minimize brake usage and instead aim to gradually slow when stopping. BEV OEMs often offer operator training to explain these systems and train drivers to operate the vehicles correctly. It is common for agencies to use a 'train-the-trainer' model for operator training so the OEM training only needs to occur once before the agency can train other operators utilizing internal staff. **Table 16** outlines recommended trainings for operators to encourage familiarity with BEVs and provide direction on how to operate the new vehicles.

Operations staff who interact with vehicles but do not perform vehicle maintenance or operations on them, such as street supervisors or dispatchers, would also require some training as part of integrating BEVs. It is important for this staff to be familiar with the vehicles and their charging systems, and to complete standard trainings offered by the BEV OEMs. In addition to familiarization, operations staff should be aware of safety protocols for BEVs and EVSE. Safety training can be provided by the OEMs and/or DCPT's existing internal programs.

Table 16. Recommended BEV Operator Training

System	Training	Duration	Delivery Method
Electric Vehicle	Inform operators of the layout of BEV systems	2 hours in classroom and walk around the vehicle	In-house trainer
Operator Area	Familiarize operators with BEV controls, warning devices, and appropriate actions	2 hours on the vehicle and provide a printed diagram of all warning lights	In-house trainer
Regenerative Braking System	Train operators on how to maximize driving range using the regenerative braking system	Up to 1 hour behind-the-wheel training per operator	In-house trainer

Training Program Considerations

It is recommended that DCPT develop a training program that integrates BEV and EVSE curricula with existing internal training practices. This program would include maintenance technical training and behind-the-wheel training. Technical training may include system familiarization, operations, safety, troubleshooting, diagnostics, rebuilding and repairs, and preventative maintenance. If implemented, this program may include coordination with internal and external resources, such as:

- BEV and EVSE OEM training curricula purchased as part of new rolling stock procurements
- BEV subsystem/subcomponent OEM training curricula
- Partnership with local first-responding agencies
- Enrollment in the U.S. Department of Energy's (DOE) Federal Energy Management Program's (FEMP's) eight fleet management training courses, including the EV Champion series and Fleet Management/Integration courses. [12]

If DCPT pursues training program development, it must be reviewed routinely so all technical training program curricula are current when moving forward from older systems. This could help DCPT be sure newer systems are appropriately integrated into the program.

EVSE Maintenance Practices

Introducing a new technology often comes with a learning curve for maintenance and operations. This initial learning experience can be used to optimize and improve the rollout plan for workforce development in line with the fleet's transition. By implementing training programs and building a

[12] Federal Energy Management Program Training Catalog (Department of Energy)

skilled team, the transition to BEVs can be made more smoothly. It is essential that routine checks, maintenance, and repairs of EVSE align with OEM-recommended maintenance plans and manuals. EVSE maintenance activities will include, but are not limited to, the following:

1. **Frequent Safety Checks or Inspections**
   It is normal practice to frequently visually inspect EVSE for visible faults. These faults can be electrical, external, display-related, or operational. Key elements to inspect include:
   - Charging station operation (starting and monitoring a charging session)
   - Station displays and indicator lights
   - Electrical (including earthing, voltage, and continuity checks)
   - Inspection of wiring to confirm there are no loose connections.
2. **Preventative Maintenance**
   Charging station owners must commit to a proactive, preventative maintenance program. This may help minimize downtime and revenue loss resulting from any downtime. It could also support uninterrupted fleet operations and may help reduce the occurrence of major repairs. A typical preventative maintenance procedure for EVSE includes cleaning cables, cabinets, and filters as well as completing operation and charging session checks.
3. **Maintaining a Logbook**
   Maintaining a logbook can confirm accurate fault analysis, timely documentation, that the proper corrective measures have been executed, and that the necessary work has been completed to address the issue(s) at hand.

After installation, charging infrastructure will require both preventative and corrective maintenance to keep the systems operational. As the BEV fleet grows, it will become increasingly important for the charging systems to be working as intended. DCPT can opt to maintain its EVSE in-house, through OEM service agreements, or with contractors. This section outlines relevant training and maintenance considerations should DCPT choose to maintain its EVSE in-house. If EVSE is maintained by the OEM or a contractor, this level of training may not be needed but may still be helpful to confirm all parties understand and know how to work with EVSE.

A comprehensive EVSE training program could cover both preventative and corrective maintenance. Special attention should be given to safety protocols so maintenance technicians can safely work with high-voltage components and respond to potential hazards. Staying current with local regulations and collaborating with EVSE OEMs will help maintain regulatory compliance and keep the workforce informed. Developing soft skills, such as adaptability and effective communication, is also essential for navigating the dynamic landscape of BEV technology. This would prepare the workforce to effectively contribute to the installation, maintenance, and operation of EVSE and support the growth of BEV operations at DCPT. Numerous organizations provide EVSE-specific training and certifications for electricians, technicians, engineers, and others, including:

1. **Electric Vehicle Infrastructure Training Program** [13]
   The Electric Vehicle Infrastructure Training Program (EVITP) was created by collaborating with industry stakeholders from the private sectors and educational organizations to certify electricians to perform all maintenance, installation, and upgrade implementation for EV charging stations.
2. **SAE Electric Vehicle Supply Equipment Certification** [14]
   A certification program to establish and verify the skills and knowledge of technicians who maintain, repair, and operate EV charging stations.

Installed stationary high-voltage equipment, safety, and work practice standards are covered in NFPA 70E and should be thoroughly reviewed by technicians.

EXISTING TRAINING PROGRAM

DCPT's existing workforce is skilled in the maintenance, repair, and operation of conventional ICE vehicles. As DCPT transitions to BEVs, Duplin County recognizes the need to equip its workforce with the knowledge and skills needed for continued provision of reliable service. This may allow staff to build upon and advance their existing skills if they choose to do so.

Maintenance Staff

Duplin County's maintenance staff is comprised of three technicians, each of whom is versatile and adaptable to varying maintenance tasks. These technicians hold certification in ICE vehicle repair and have completed the Mobile Air Conditioning Society (MACS) program; the MACS certification marks a technician's training in handling refrigerants and air-conditioning (AC) units used in automotives. Formal trainings for technicians are currently limited and rely on online or dealership-provided resources to troubleshoot and resolve issues. DCPT maintains relationships with dealerships within its jurisdiction, giving DCPT access to relevant industry information and opportunities to collaboratively train technicians.

Vehicle Operators

DCPT employs non-CDL drivers and trains them using a combination of practices and techniques. The first method is paperwork training, which includes independent study, watching videos, taking tests, answering questions, and reviewing materials from the National Rural Transit Assistance Program (RTAP), for which DCPT provides the licensing agreement. DCPT also uses on-the-road training, which involves riding on different routes with a variety of DCPT operators. After this, experienced operators ride with the new driver for an additional 2 weeks. This training meets NCDOT's mandates for annual, new hire, and rehire training for transit operators.

[13] EVITP for Electricians (Electric Vehicle Infrastructure Training Program)
[14] SAE EVSE Certification Program (Society of Automotive Engineers)

To train its operators on new equipment, DCPT conducts a thorough review of the new vehicles and their corresponding manuals to identify any important differences between the previous and new equipment. Afterwards, drivers gather to discuss findings and any resulting changes in their routine operation of the vehicle, so they are prepared to operate the new equipment. In addition, DCPT provides training for road supervisors and dispatch personnel during the initial orientation and paperwork training. The DCPT operations trainer oversees training and currently prefers utilizing off-the-shelf training programs to meet training requirements.

Skill Gaps Analysis

Based on standard BEV and EVSE workforce development practices and DCPT's existing program, the following gaps have been identified as future needs within DCPT's workforce:

1. DCPT should train employees in low-voltage systems before delivering high-voltage training programs to its staff base.
2. As the BEV fleet grows, all staff will require differing levels of high-voltage and arc flash safety training depending on the employee's job description. DCPT will need to continually monitor and assess the skills needed for each staff member.
3. Mechanics will require the most extensive training to conduct preventive maintenance, fault diagnosis, and repair and or replacement of high-voltage components safely and properly. It is recommended that DCPT work to secure more training from vehicle OEMs, and this effort could be continued as the fleet transition proceeds.

FUTURE WORKFORCE STRATEGIES

DCPT can continue to refine workforce development practices over time so BEVs may be effectively operated and maintained. Ensuring the existing workforce is not displaced and that DCPT builds capacity for existing staff to operate and maintain BEVs will be a priority as the fleet transition progresses. Below are strategies that DCPT may consider building into its existing workforce efforts as BEVs are introduced to the fleet.

Staffing & Recruitment

As the fleet transition begins, DCPT would need to update its workforce development plans to account for advanced technology systems, varying BEV manufacturers and models, and different battery chemistries. As mentioned previously, high-voltage training will be required for technicians working on BEVs. Training for existing staff on operations and maintenance for newly acquired BEVs will help avoid displacement of the existing DCPT workforce. DCPT intends to train and/or promote existing staff before considering external labor where new skills are required. After training its existing staff, DCPT may need additional staff to support vehicle maintenance. As BEVs are introduced to the fleet, DCPT can reevaluate staffing needs on a rolling basis based on overall fleet growth.

Procurement Guidelines

Effective maintenance strategies can be specified before the BEVs, and chargers are procured and included in procurement documents for a successful working relationship with the BEV and charger OEMs. When issuing a request for proposal (RFP), DCPT can include language that specifies maintenance needs for BEVs and EVSE. DCPT can then include more detailed specifications once an OEM is selected and procurement contracts are created. These specifications could include the following items:

- Providing detailed training to DCPT employees so they can diagnose basic maintenance issues with BEVs and EVSE and specify a training completion date
- Disclosing charger troubleshooting codes to DCPT
- Providing a preventative maintenance checklist as well as recommendations for any specialty equipment required for maintenance
- Specifying BEV and EVSE spare parts to be delivered and stored on site
- Allowing DCPT to bill the OEM for repairs done under warranty by DCPT or a third party
- Specifying acceptable downtime for BEVs and EVSE, along with penalties if not repaired in a specified timeframe.

Specifying these aspects in the RFP, procurement contracts, and service agreements can allow DCPT to clearly define its needs and establish repercussions if those needs are not promptly met or if fleet operations are impacted.

WORKFORCE FUNDING

The anticipated cost of workforce training will likely fluctuate in response to the adoption of BEVs in DCPT's fleet. Funding for workforce development activities can come from many sources, including procurements, where the cost of training can be included in the budgeted cost of the BEV or charger purchase; existing sources used for training; and/or federal or local funding shares, such as:

- The FTA Bus and Bus Facilities Grant Program – 5339(b)
- The FTA Low- or No-Emission Grant Program – 5339(c)
- The Congestion Mitigation and Air Quality (CMAQ) Infrastructure Law

The labor cost to train vehicle maintenance personnel is expected to be high, but this cost is only one aspect of the total costs related to workforce development. As highlighted by the International Transportation Learning Center, budgeting should include costs related to classroom training hours, on-the-job training hours, instructor hours, wages and benefits, facilities, training materials, software, and simulations. [15]

[15] Resources and Best Practices for a Zero-Emission Workforce Fleet Transition Plan (Int. Transportation Learning Center)

CONCLUSION & NEXT STEPS

This Zero Emission Fleet Transition Plan may serve as a roadmap for DCPT to bring battery electric vehicles into the fleet. This study included modeling of DCPT's service based on mileage logs, infrastructure and facility analyses, utility coordination, a cost analysis, stakeholder outreach, and a phased fleet transition strategy. This Zero Emission Fleet Transition Strategy also meets the federal requirements to apply for FTA funding, including:

1. Policy and Legislative Impacts
2. Fleet Transition Plan
3. Facility and Infrastructure Plan
4. Utility and Fuel Partnerships
5. Funding Plan
6. Workforce Transition Plan

DCPT's service has a variety of challenges that make a 100 percent zero-emission fleet infeasible today; however, there are a variety of ways DCPT can reduce fleet emissions and slowly move toward a zero-emission future. All DCPT vehicles experience average mileage requirements that far exceed the current range of market available BEV equivalents. With time, BEV technology in shuttle vans and cutaways will improve and range will grow, making a full fleet transition possible in the future. In the interim, DCPT could pilot a BEV within the boundaries of its range on on-demand service. This would allow operators and maintenance to build familiarity with BEVs and charging technology and eventually successfully apply lessons learned to a full fleet transition in the future.

Internal support, local support, and grant support would be essential to the electrification of DCTP's service. A transition toward BEVs could initially result in additional capital costs to build new infrastructure and purchase more expensive but cleaner vehicles; however, DCPT can expect to see operational and maintenance savings. These O&M savings would result in overall savings over the life of a vehicle. This plan may serve as a mechanism to guide DCPT through their first BEV deployment and secure funding to make a cleaner transit fleet possible for Duplin County.