Growing North Carolina's Zero-Emission Vehicle Market

Infrastructure Needs Assessment

SEPTEMBER 2023

Executive Summary

This report has been prepared in response to Governor Cooper's Executive Order 271 – Growing North Carolina's Zero-Emission Vehicle Market to develop a Needs Assessment associated with North Carolina Zero-Emission Vehicle (ZEV) infrastructure. This Needs Assessment evaluates the charging and fueling needs to support the implementation of the proposed North Carolina Advanced Clean Trucks (ACT) rule program and the achievement of ZEV adoption targets established in Executive Order No. 246 – North Carolina's Transformation to a Clean, Equitable Economy.

Executive Order 246 identifies two targets to increase the number of ZEVs in North Carolina's light-duty vehicle sector by 2030. The first is to increase the total number of registered ZEVs to at least 1,250,000 by 2030 and the second is to increase the sale of ZEVs so that 50 percent of in-state sales of new vehicles are zero-emission by 2030. Meeting these targets requires exponential growth in electric vehicle (EV) adoption across the light-duty sector between now and the end of the decade. However, this level of growth for North Carolina is occurring both nationally and internationally and is supported by significant investments from the public and private sectors in EV's and EV charging infrastructure.

A light duty EV adoption forecast conducted as part of this study determined that Executive Order (EO) 246 which sets a goal of 50 percent of vehicle sales to be EV by 2030 would lead to approximately 556,110 light-duty EVs on the road by that year, with the 1.25M EVs on the road forecast to occur in 2034. The EV industry is evolving rapidly, and changes in public policy and technology have the potential to accelerate this adoption curve.

North Carolina will need over 45,000 publicly-available charging ports by 2030 to serve the forecasted 503,374 light duty EV's on the road. Over 350,000 residential charging ports (both Level 1 and Level 2) will likely be added, and peak charging for light-duty vehicles is likely to occur in the early evening to midnight hours (6 pm-12 am). As the EV industry evolves, active charging management may help mitigate load issues in specific geographies across the state, by shifting the time of charging to non-peak times and lowering the amount of power delivered and extending the length of charge time.

The proposed ACT rule would require an increasing percentage of medium and heavy-duty (MHD) vehicles to be sold in North Carolina as zero emission. The NC Department of Environmental Quality (NCDEQ) estimated MHD sales associated with the proposed ACT rule. For vehicle model year 2027, NCDEQ estimates 4,500 sales, rising to 17,600 for vehicle model year 2035 sales, equating to 61 percent of new MHD vehicle registrations. By 2035, the number of MHD ZEV in the NC inventory associated with ACT sales, would be approximately 91,300 vehicles representing between 12 and 16 percent of the state's MHD inventory.

Successful use of MHD ZEVs means matching vehicle duty cycles[1] with the capabilities of the technology, which for battery electric MHDs is mainly associated with range. To companies delivering goods and services, often to strict time windows, the time and location of vehicle charging infrastructure will be critical. It is expected that most of the battery electric MHDs will be charged where the vehicles are domiciled in garages, depots, or at residential addresses for lighter MHD vehicles used by contractors and trades people, rather than publicly accessible facilities. Companies and individuals would assess the necessary investments not only in the ZEVs themselves, but the charging infrastructure and any grid

1 Duty cycle is an industry term that describes how much a vehicle is used.

distribution upgrades that may be required to bring more power to their facilities.

To support the MHD ZEV inventory associated with the proposed ACT rule , the Needs Assessment estimated 32,853 Level 2 chargers in use by 2035 and the number of Direct Current Fast Chargers (DCFC) chargers in use in 2035 could range from 19,339 chargers to 58,016 chargers, depending upon the ratio of vehicles to chargers. The annual number of DCFCs deployments required to keep pace with MHD sales from 2030, could range from 2,700 to nearly 8,100. Annual charger costs to procure and install this infrastructure, range from $181M to $497M in 2027 and as the MHD fleet grows, this increases to a range of $438M to $1.2 Billion in 2035. In 2030, electric demand to support the MHD ZEV fleet ranges from 1.1 million Megawatt-hours (MWh) per year to 2.2 million MWh and by 2035 the demand ranges from 3.3 million MWh to 6.4 million MWh per year. These ranges reflect low, medium, and high use scenarios. Light duty and medium/heavy duty vehicle electrification is estimated to increase the retail sales of electricity by 12.5 million MWh by 2035, resulting in total retail sales of 151.5 million MWh, a 9 percent increase.

This additional power consumption is likely to have impacts at the local, distribution level, where infrastructure upgrades will be required to support higher power loads associated with MHD charging. Upgrading distribution infrastructure presents cost and timeline challenges for companies adopting MHD ZEVs. Depending upon the local electric utility's business program, upgrade costs may have to borne by the fleet operator requesting the upgrade. Some upgrades may take many months or even years to be implemented, due to supply chain issues and utility upgrade lead times. Furthermore, if the vehicle operator leases their vehicle operating site, it may not be cost-effective or even possible to install charging infrastructure. For example, the lease on a vehicle operating site may only have a short time left, and the current operator may not be willing to invest in new infrastructure at that site. These challenges could ultimately influence if, and when, companies adopt battery powered ZEVs.

In addition to battery electric MHD vehicles, fuel cell electric vehicles (FCEV) powered by hydrogen are expected to a have a role to play in the decarbonization associated with MHD vehicle use.

While trials and pilots are underway, this technology lags battery electric by several years, and it will be some time before we see significant volumes of FCEV MHD vehicles on the road network. A key challenge influencing FCEV adoption is the cost of hydrogen. However, this could change if the Southeast Hydrogen Hub coalition[2], which includes Duke Energy and Dominion Energy, is successful in its plans to establish a hydrogen network of producers and consumers in the Southeast.

In addition to the Needs Assessment, this report identifies several recommendations that are intended to assist in creating the right environment for MHD operators to purchase and operate ZEVs in North Carolina. They seek to streamline the adoption process, reduce costs and time for deploying charging and fueling infrastructure and incentivize the uptake of ZEVs.

Utilities are a key stakeholder in the transportation electrification process. Developing points of contact, establishing communication channels and producing guidance materials will help potential MHD ZEV users navigate the charging implementation process and working with utilities. Implementing State and utility initiatives to reduce a user's electric charging infrastructure costs, spreading user costs over time and assessing different ways of investing in charging and related infrastructure will also support MHD operators' financial decision making.

Funding programs should also be explored. Despite a closing gap in total cost of ownership (TCO)[3] between MHD conventional fueled vehicles and ZEVs, the higher ZEV capital cost represents a challenge for MHD adoption. MHD ZEVs can

2 Members of the coalition include Dominion Energy, Duke Energy, Louisville Gas & Electric Company and Kentucky Utilities Company (LG&E and KU), Southern Company, the Tennessee Valley Authority (TVA) and Battelle, the coalition lead entity.

3 Total Cost of Ownership includes the vehicle purchase price, operational costs such as fuel, maintenance costs and depreciation. Electric vehicles have lower fuel and maintenance costs than ICE vehicles.

be two to four times more expensive than their diesel counterparts. Additionally, the cost of charging infrastructure and paying for any potential electricity distribution system upgrades can represent significant financial barriers associated with MHD ZEV adoption and the deployment of associated infrastructure.

Alternative fuel systems especially batteries, can reduce a truck's payload. A natural gas or battery electric truck may exceed the federal weight allowance by up to 2,000 pounds to a maximum gross vehicle weight of 82,000 for vehicles traveling on the Interstate Highway System and within reasonable access to the Interstate. North Carolina law allows any additional weight allowance authorized by 23 U.S.C. § 127, and applicable to all interstate highways, to also be applicable to all State roads.[4]

Emerging business models, such as Charging as a Service[5] (CaaS), may help alleviate this upfront capital investment for some MHD vehicle operators. A further recommendation is to work with industry, utilities and state agencies to support the implementation of a CaaS pilot facility in an area where many fleets are located. This has potential to support operators wanting to use MHD ZEVs, but who do not have the financial resources, or who cannot install charging infrastructure at their depots.

4 NC General Statute 20-118 https://www.ncleg.gov/enactedlegislation/statutes/pdf/bysection/chapter_20/gs_20-118.pdf

5 Charging as a Service (CaaS) is a business model where a third party operator installs, operates and maintains electric charging infrastructure, for one or more fleet operators. The fleet operator pays the CaaS provider a user fee to supply the charging service.

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The North Carolina EV Landscape

INTRODUCTION

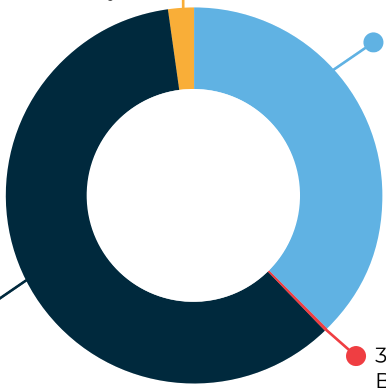
This report has been prepared in response to Executive Order 271 to develop a Needs Assessment associated with North Carolina Zero-Emission Vehicle (ZEV) infrastructure. This Assessment evaluates the charging and fueling needs to support the implementation of the proposed North Carolina Advanced Clean Trucks (ACT) Rule program and the achievement of ZEV adoption targets established in Executive Order No. 246, namely that the State of North Carolina will increase the total number of registered light duty ZEVs to at least 1,250,000 by 2030 and increase the sale of light duty ZEVs, so that 50 percent of in- state sales of new vehicles are zero-emission by 2030.

BACKGROUND INFORMATION AND EXISTING CONDITIONS

OVERVIEW OF VEHICLES IN NORTH CAROLINA

Vehicle registration counts from July 1, 2021 to June 30, 2022 compiled by NCDOT show a total of 10.3 million motor vehicles registered in the state of North Carolina and a total of 7.3 million licensed drivers.[1] A breakdown of vehicle registrations by type of vehicle is shown in **Figure 1**.

FIGURE 1. Total Motor Vehicle Registrations in NC
Source: FHWA Highway Statistics 2021



1 https://www.ncdot.gov/about-us/our-mission/Documents/2022-annual-report.pdf

According to sales data from Edmunds, the SUV Toyota RAV4 was the top-selling vehicle in North Carolina in 2022, followed by the Chevrolet Silverado and Ford F-Series trucks.

LIGHT, MEDIUM AND HEAVY-DUTY VEHICLE CLASSIFICATIONS

Vehicles are classified according to their gross vehicle weight rating (GVWR), with different weight ratings grouped into vehicle classes and categories as shown in **Figure 2**.

FIGURE 2. Vehicle Classification

Vehicle Class	Gross Vehicle Weight Rating	Category	Vehicle Examples			
Class 1	< 6,000 lbs	**Light Duty**	SEDAN	SUV		
Class 2a	6,001- 8,500 lbs		SUV	PICKUP		
Class 2b	8,501-10,000 lbs	**Medium Duty**	MINIVAN	CARGO VAN	FULL-SIZE PICKUP	STEP VAN
Class 3	10,001-14,000 lbs		WALK-IN	BOX TRUCK	CITY DELIVERY	HEAVY-DUTY PICKUP
Class 4	14,001-16,000 lbs	**Heavy Duty**	LARGE WALK-IN	BOX TRUCK	CITY DELIVERY	
Class 5	16,001-19,500 lbs		BUCKET TRUCK	LARGE WALK-IN	CITY DELIVERY	
Class 6	19,501-26,000 lbs		BEVERAGE TRUCK	SINGLE-AXLE	SCHOOL BUS	RACK TRUCK
Class 7	26,001-33,000 lbs		REFUSE	FURNITURE	CITY TRANSIT BUS	TRUCK TRACTOR
Class 8	≥ 33,001 lbs		CEMENT TRUCK	TRUCK TRACTOR	DUMP TRUCK	

Light-duty vehicles include passenger cars and light pickup trucks, while medium and heavy-duty vehicles include heavier pickup trucks, delivery vans, garbage trucks, buses and truck tractors. The ACT program applies to vehicles with a GVWR greater than 8,501 lbs and the term medium and heavy-duty (MHD) is used to describe this category of vehicles in this report.

TYPES OF ZERO EMISSION VEHICLES

Battery Electric Vehicles

Battery electric vehicles (BEVs) primarily utilize a lithium-ion battery, the same battery technology used in cell phones and computers, to store the power needed to propel a vehicle. A BEV's electric battery stores and outputs direct current (DC) power. The DC power gets converted into alternating current (AC) power by the vehicle's inverter, which powers the vehicle's electric motor by alternating between positive and negative charges and utilizing electromagnets to ultimately rotate the vehicle's drive shaft and turn the wheels. BEV technology is rapidly progressing, and while many vehicle options exist on the market today, the expectation is that more vehicle categories and classes will be electrified and scaled for mass production in the next few years.

BEVs can be developed in two different ways. The first is to have a vehicle designed and constructed by an original equipment manufacturer (OEM) with an integral electric power-train that is sold as a complete vehicle from the production plant. Virtually all battery-electric passenger cars and light-duty trucks are manufactured in this manner, and this allows for the whole vehicle to be covered by a single factory warranty. The second method, known as repowering, is by taking an internal combustion engine (ICE) vehicle and replacing the engine with an electric drive train, reusing the original chassis and body. Electric repower vehicles are typically MHD trucks or buses.

Fuel Cell Electric Vehicles

Like BEVs, hydrogen fuel cell electric vehicles (FCEV) are also powered by an electric motor and include a battery pack, but the battery packs are much smaller. Rather than store the majority of electricity needed to power the vehicle in a battery, FCEVs generate electricity by splitting hydrogen gas into positive hydrogen ions and negatively charged electrons within the fuel cell, with the resulting electrons traveling along a circuit to create an electric current and power the motor.

The hydrogen ions then combine with oxygen from the air to form water as the system exhaust. Water vapor is the only emission since the hydrogen is not combusted and there are no other emissions than water vapor. On- board, pressurized hydrogen storage tanks are used to supply hydrogen to the fuel cell.

FCEVs possess some advantages particularly when it comes to powering MHD vehicles. Since FCEVs rely less on electricity stored within a battery to power the electric motor, they are not as susceptible to losing driving range in very cold temperatures, which decrease the efficiency of battery charging and storage. Additionally, the on-board hydrogen storage tanks needed to power large FCEV vehicles can be scaled up to deliver more vehicle range, with a relatively low additional increase in the weight and size of the storage tank, resulting in little loss of cargo space and a minimal increase in overall vehicle weight, unlike BEVs. FCEVs also typically take significantly less time to refuel than charging BEVs. For commercial vehicles this is similar in time to natural gas vehicles currently in use taking approximately 10 - 15 minutes.

ZEV CURRENT MARKET READINESS

Light Vehicles

Just as BEV technology has rapidly progressed over the last two decades, so has the adoption of BEVs by mainstream consumers. The first mass-produced hybrid-electric vehicle, the Toyota Prius, entered the U.S. market in 2000, and, just over two decades later, Tesla's Model Y was the sixth most popular sold car sold in the United States in 2022.[2,3] An estimated 800,000 BEVs and 190,000 plug-in hybrid electric vehicles (PHEV) were sold in the U.S. in 2022, according to data from the International Energy Agency (IEA) and Electric Vehicles Initiative (EVI).

In North Carolina, approximately 38,700 light-duty BEVs and PHEVs were registered in 2021, with roughly 25,200 being BEVs and 13,500 PHEVs. By July of 2023, that number has increased to 53,316 registered BEVs, 18,362 PHEVs, for a total of 71,678 plug-in electric vehicles, representing an almost doubling of electric vehicle registrations over the two year period.

Electric vehicle sales in the United States reached a market share of five percent this year, generally considered to be the threshold marking the start of 'mass adoption'.

In 2018, it was estimated that 21 percent of new car sales in the United States would be EVs by 2030 (including PHEVs). Now, it is estimated that they will make up 53 percent of those sales, indicating a significant acceleration in American EV adoption.

Adoption rates will continue to accelerate with market variety, technological improvements, financial incentives, and vehicle cost reduction.

Conversely, light-duty FCEVs have yet to be widely produced and marketed in the U.S. The two sole FCEVs currently in production, the Toyota Mirai and Hyundai Nexo, are only available for purchase in California. 2,707 FCEVs were sold in California in 2022, a decrease from the 3,341 sold the previous year.

2 https://www.energy.gov/articles/history-electric-car
3 https://www.cnbc.com/2023/01/07/americas-top-10-bestselling-cars-of-2022-tesla-makes-the-cut.html

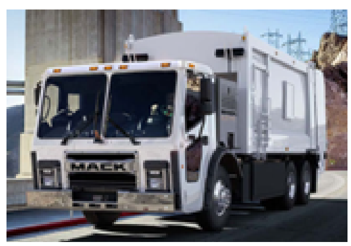
No light-duty hydrogen vehicles were registered in North Carolina in 2021 as per vehicle registration data compiled by the National Renewable Energy Laboratory (NREL). Public hydrogen fueling stations are also few, with only 57 in the United States and all but one located in California.

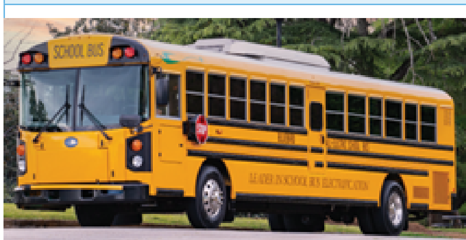
Medium and Heavy-Duty Vehicles

3,510 MHD zero emission trucks were deployed across the nation in 2022. California accounted for 63 percent of these deployments. It is estimated that 30 zero emission MHD trucks have been deployed in North Carolina from 2017 to 2022. 2,043 electric school buses have been awarded,

FIGURE 3. Example MHD ZEVs

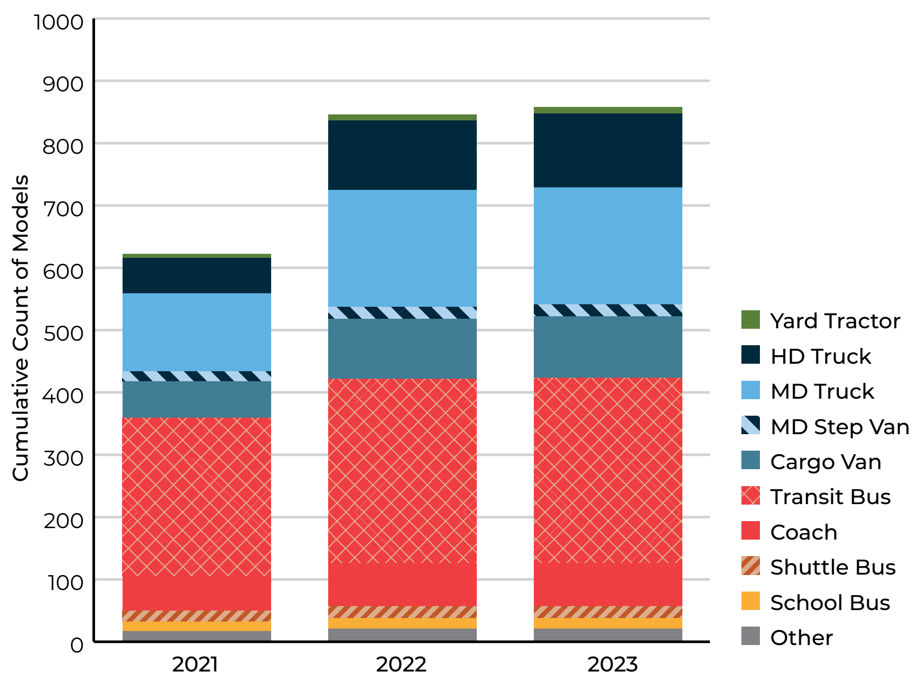
Ford E-Transit	Mercedes E-Sprinter	Freightliner MT50e
		
GVWR 9500 lbs	GVWR 9,370 lbs	GVWR 16,000 - 23,000 lbs
68 kWh battery	113 kWh battery	226kW battery
126 mile range	248 miles range	150 - 170 miles range

Lion 6	MACK LR Electric	Freightliner eCascadia
		
GVWR 26,000 lbs	GVWR 68,000 lbs	GVWR 82,000 lbs
252 kWh	376 kWh	Options: 194/291/438 kWh
218 mile range	100 mile range	230 mile range

All American Electric School Bus	Saf-T-Liner C2 Jouley Electric School Bus	ZX5 40-foot bus
		
GVWR 33,000 lbs	GWVR up to 33,000 lbs	GVWR 43,650 lbs
155 kWh	226 kWh	Up to 738 kWh
120 miles range	138 miles range	340 miles range

ordered, delivered, or deployed in the U.S. by December 2022 with 54 of these associated with North Carolina schools.[4] By September 2022, 135 Zero Emission transit and airport buses had been funded, ordered, or delivered in North Carolina.[5] According to CALSTART, the average annual growth rate in the past six years for MHD ZEVs has been 149 percent. These vehicles are becoming increasingly available as OEMs respond to market demand and add a greater number of ZEV vehicles to their product portfolio. Manufacturers such as Daimler, whose vehicle brands include Freightliner, Thomas Built Buses (who are based in High Point, NC), Rizen, Fuso and Mercedes Benz; Volvo and MACK Trucks (North American headquarters are located in Greensboro); PACCAR with vehicle brands Kenworth and Peterbilt; Tesla, Nikola, BYD, Rivian, Arrival (headquarters in Charlotte), XOS Trucks, Lion, Toyota, Hyundai, Proterra, Ford, and Orange EV are bringing to market a wide range of MHD ZEVs. Examples of MHD ZEVs are shown in **Figure 3**.

FIGURE 4. MHD Vehicle Models
Source: CALSTART (2023): Drive to Zero's Zero-Emission Technology Inventory Data Explorer



While many OEMs have deployed MHD ZEVs for pilots and trials, they are also increasingly scaling investment in production facilities, including new manufacturing facilities in North Carolina, such as Arrival, to meet increasing market demand. As shown in **Figure 4,** the number of MHD ZEV models available for purchase in North America has continued to grow over recent years.

BEV technology is more mature in the MHD sector than FCEV. As a study from McKinsey and Company identifies and is illustrated in **Figure 5**, FCEVs lag behind the sale and operation of BEVs by several years. Multiple OEMS are conducting proof of concept and trials of FCEV vehicles in the MHD sector in both buses and trucks. According to CALSTART, there were 5,269 full size transit battery electric buses (BEB), funded, ordered, or delivered in the US, compared with 211 fuel cell electric buses (FCEB).[6]

MHD FCEV developments include:

- In the latter half of 2023, Nikola expects to begin US commercial production of FCEV trucks.
- In August 2022, Kenworth Trucks and Toyota concluded a pilot study employing 10 FCEV vehicles in California. In May 2023, Kenworth and Toyota announced their continuation of partnering on FCEV development with the intention of customer deliveries in 2024.
- Hyundai Motor anticipate operating 30 Class 8 XCIENT FCEV trucks in California starting in 2023.

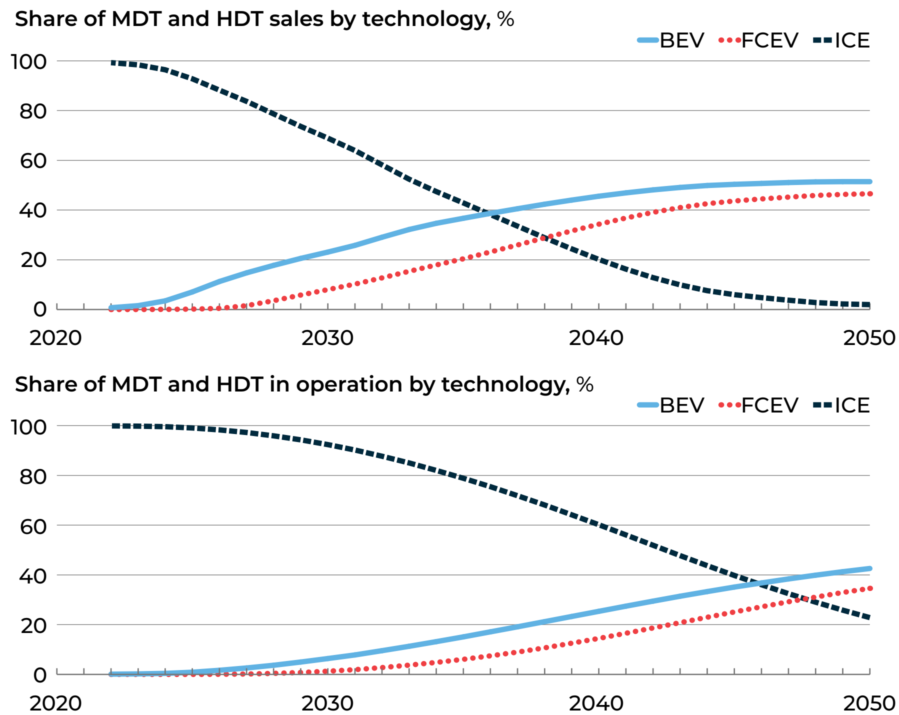
FCEV is a maturing technology and is being used in a variety of applications across the globe. As the technology is commercialized and there are

4 https://calstart.org/wp-content/uploads/2023/05/ZIO-ESBs-final-with-May-cover-4.28.23.pdf
5 https://calstart.org/wp-content/uploads/2023/02/Zeroing-in-on-ZEBs-February-2023_Final.pdf
6 Zeroing in on ZEBs: February 2023 (https://calstart.org/wp-content/uploads/2023/02/Zeroing-in-on-ZEBs-February-2023_Final.pdf)

increasing numbers of MHD OEMs selling this technology, the overall cost of FCEV vehicles is expected to fall.

However, technology continues to evolve and companies such as Cummins are exploring other alternatives related to hydrogen, such as hydrogen internal combustion engines, but these would not be considered as ZEVs, as they produce emissions such as NOx.

FIGURE 5. FCEV Sales and Operations Predictions
Source: McKinsey & Company



CHARGING AND FUELING INFRASTRUCTURE

Electric Chargers

There are three types of charging equipment used to charge EVs—Alternating Current (AC) Level 1, AC Level 2, and Direct Current (DC) Fast Chargers.

PHEVs can use Level 1 and Level 2 charging only, while BEVs can use Level 1, Level 2, and DC Fast Charging. Typically, when using Level 1 and Level 2 charging, the vehicle's on board charger (OBC) would need to convert AC power supplied by the electric grid into DC power before it can be stored in the battery.

Level 1 is the slowest, but most inexpensive charging option. It uses a standard 120-volt (V) outlet and can usually replenish a battery at a rate of up to five miles of range per hour. Vehicles may not be able to reach a full charge overnight using Level 1 chargers, but may reach a sufficient charge to satisfy the next day's usage. No electrical upgrades are usually needed to support Level 1 charging.

Level 2 charging stations are most common in daily EV charging. Level 2 charging increases the rate of charge to 12-60 miles per hour with power outputs ranging from 3.9 kW (a typical household cooking oven consumes 2-5 kW) up to 19.2 kilowatts (kW). This is attributed to the increase in the voltage of the system to 208-240 volts and increased current at 30/32A. The most common Level 2 chargers (7.2kW) can replenish about 20 miles of range per hour of charging. The installation of Level 2 chargers requires an electrician to safely install the breaker and wall outlet and complete the proper permitting process. Level 2 chargers can be installed at residential and commercial premises, with commercial chargers being more robust and higher capacity than residential chargers. Residential chargers may cost $500, plus installation, while Level 2 commercial chargers may cost $20,000.

DC Fast Chargers (DCFC) represent the fastest, but most expensive, method of charging vehicles. DCFCs, as their name suggests, supply direct current (DC) electricity straight to the vehicle's battery, bypassing the need to route electricity through the vehicle's onboard charger (OBC). The term DCFC is an industry standard, and essentially describes a high-power charger. However, the actual speed of charging will be dependent upon many factors including the size and capabilities of the vehicle's battery, the power output of the charger, ambient temperature, and the battery's state of charge. For MHD vehicles, a DCFC charger may not be considered "fast," as the large batteries will extend the time needed to charge.

The power output of a DCFC can range up to 350 kW, though the most common size for these chargers is between 50 kW and 150 kW. With a 50 kW DCFC, roughly 145 miles of range can be added through an hour of charging, while a 150 kW DCFC could replenish roughly 430 miles per hour of charging. The maximum DC fast charging rate of an electric vehicle is determined both by the power output of a DCFC, as well as the maximum charge acceptance rate of the vehicle. DCFCs are typically used for public highway charging or in fleet locations, and they require engineering, permitting, construction, and possibly electrical system upgrades such as a larger transformer with three-phase power. It can cost $100,000 to install a 50 kW charger.

The speed with which energy is delivered and batteries recharged is a key factor associated with vehicle duty cycle, energy required, the cost of charging infrastructure and overall cost of charging. A general rule is that the slower EVs are charged, the less expensive the charging infrastructure. Vehicles with a smaller battery capacity and having a longer dwell time, may be able to utilize slower (and cheaper) charging equipment, such as Level 2 chargers. Conversely, a vehicle with a higher battery capacity will need a faster charger to ensure the battery is full at the end of the dwell time, and vehicles with a higher battery capacity and a very short dwell time may need a very fast charger. **Table 1** illustrates the time taken to charge a selection of MHD vehicles with different charging speeds from a battery capacity of 20 percent to 80 percent. It should be noted that vehicles will have an upper limit for the rate it can accept electricity. For example, a Freightliner e-Cascadia can accept up to 270kW. It can connect with a 350kW charger, but the vehicle's communication protocol with the charger will ensure no more than 270kW is delivered to the vehicle. The rate at which a battery is charged using DCFC is not constant. Several factors influence charging speed such as battery temperature, capacity and state of charge. A vehicle's charging curve represents the variation in charging speed over the duration of a charging session. The battery charging rate increases when a battery is typically filled at around 20 percent and reduces when the battery reaches 80 percent to protect the battery.

The peak charging rate occurs in a window between 20 and 80 percent of the battery capacity and may only be for a short duration of time. This variation in charging differs between vehicle makes and models.

TABLE 1. MHD Vehicles and Sample Charging Speeds

		Delivery Van	School Bus	Class 6 Straight Truck	Tractor Unit	Transit Bus
Battery Size (kWh)		113	226	252	438	738
Charger Type	**Charger Power (kWh)**	**Time to Recharge**				
Level 2	7.2	12-13 hours				
	19.2		8 hours			
DCFC	50	1 ½ hours	2 ¾ hours	4 ½ hours	5 ½ hours	9 hours
	150	-	-	1 ½ hours	2 hours	3 hours
	350	-	-	-	-	1 ½ hours

Charging Management Software

Charging management software is available to help EV charging sites manage and optimize energy usage. A key feature of charging management software is the ability to limit energy usage during periods of peak demand when rates for electricity are typically highest. Charging management software can also balance the amount of power that is supplied to a site at any given time by staggering charging schedules for vehicles, so that high demand charges, which result from a high amount of power being supplied at once, can be avoided. However, some MHD use cases, especially those with a short vehicle dwell time or multiple vehicles sequentially using the same charger, would not support managed charging.

Some charge management software can also offer BEVs with bi-directional charging capabilities, those able to send as well as receive electricity, the ability to respond to vehicle-to-grid (V2G) events and return energy stored in the battery back to the electrical grid. Charge management software also exists which monitors the usage of charger locations and time of day chargers are most frequently visited, which can assist utilities with planning for future electrical grid infrastructure improvements.

Electric Rate Design

How electricity rates are designed for all different types of users across the light and MHD spectrums will have a significant role to play in the adoption and growth of EVs in the state. The National Association of Regulatory Utility Commissioners (NARUC) identified that traditional commercial and industrial (C&I) electricity rates may present a barrier to EV adoption, because they erase the EV fuel cost savings relative to gasoline or diesel transportation. Traditional commercial rates were generally designed for large buildings, rather than for public fast charging of passenger vehicles or for depot charging of truck and bus fleets.

The 2022 Infrastructure Investment and Jobs Act (IIJA) amended the Public Utility Regulatory Policies Act (PURPA) Section 111(d) to require non-regulated cooperatives, municipal utilities, and state regulators (for regulated utilities) to consider new rates to support transportation electrification. Regulators and utilities across the country must consider rates that promote greater electrification of the transportation sector, including the establishment of rates that—

A. Promote affordable and equitable electric vehicle charging options for residential, commercial, and public electric vehicle charging infrastructure;
B. Improve the customer experience associated with electric vehicle charging, including by reducing charging times for light-, medium-, and heavy-duty vehicles;
C. Accelerate third-party investment in electric vehicle charging for light-, medium-, and heavy-duty vehicles; and
D. Appropriately recover the costs of delivering electricity to electric vehicles and electric vehicle charging infrastructure.

The amended PURPA section applies to electric utilities with annual retail sales greater than 500 million kWh.

As this Needs Assessment was being produced:

- The North Carolina Utilities Commission addressed PURPA 111d regarding the investor-owned utilities, Duke Energy Progress, Duke Energy Carolinas and Dominion Energy. It issued an order for a hearing in May of 2023. Ongoing activities are tracked on the NCUC Dockets at the link in this footnote.
- A web search revealed that several North Carolina electric cooperatives and municipal utilities have initiated a hearing notice and a request for member input. These include:
  - Energy United Elec Member Corp
  - Brunswick Electric Member Corp
  - Blue Ridge Elec Member Corp (NC)
  - Four County Elec Member Corp
  - City of Concord (NC)
  - South River Elec member Corp
  - Wake Electric Membership Corp
  - Carteret-Craven El Member Corp
  - French Broad Elec Member Corp

THE ELECTRIC GRID

Overview

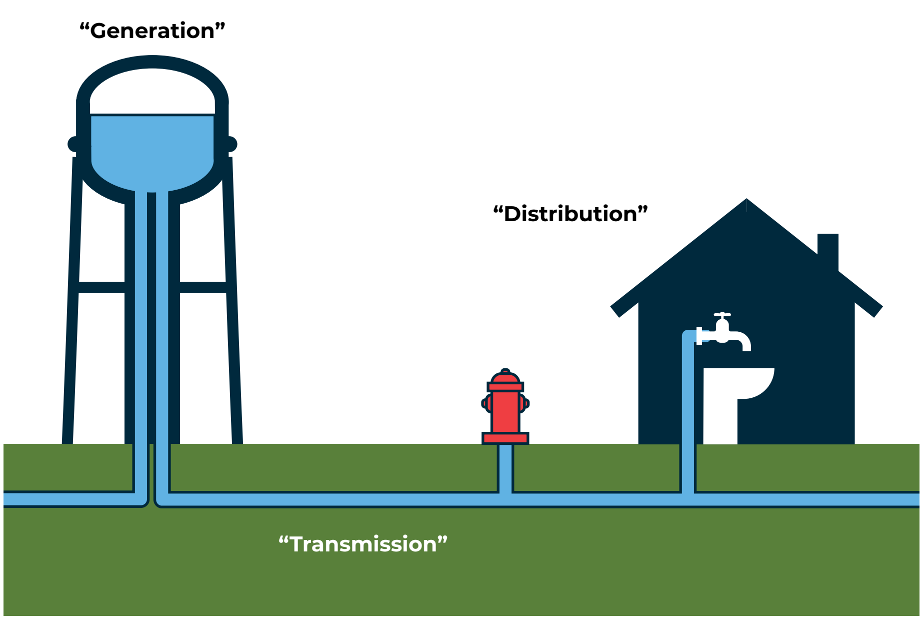
One of the important questions asked about the adoption of electric vehicles is what the impact will be to the electrical grid. Answering this question requires an understanding not only of how electric vehicles operate and charge, but also an understanding of the electric grid. The grid is actually made up of three distinct parts: generation, transmission, and distribution, and the answer to the question is different for each part of the system.

Generation is the source of power for the electrical grid. Generation consists of all types of power plants, including nuclear, coal, natural gas, hydro, and solar power generation. The transmission network is used to move the power that is generated over long distances to the places where the power is used. Electrical power transmission is done at very high voltages, and these are the tall towers with large wires on them that can be seen typically carrying power in relatively straight lines over very long distances. Distribution is the final piece of the electric grid. The transmission network brings power to substations, where the voltage is stepped down to lower levels and then distributed over a local area to the consumer's location. Most of the electrical infrastructure that you see, such as utility poles and pad and mounted transformers, are part of the distribution network.

Consider a municipal water supply as an analogy to the power grid **(Figure 6)**. Pumping stations move water up into large water towers, which are like the generation system in the power grid. The city has large pipes that run underground and bring high-pressure water to the individual houses, which are like the transmission system in the electrical grid. Finally, there is a pressure regulator that is analogous to a substation, and then the water lines that distribute water throughout individual houses are like the distribution network in the electrical grid. One big difference from this analogy is that the municipal water supply covers the area of a city, while the electrical grid covers the entire country.

With this analogy in mind, we can quickly see why the impact from electric vehicles to the grid can have different answers, depending on which part of the grid is being considered. Consider the question "Can the grid support the amount of power needed

FIGURE 6. The Electric Grid Systems: Generation, Transmission, and Distribution



to charge electric vehicles?" An equivalent question in our analogy might be "Can the water system provide enough water to fill a swimming pool?"

Certainly, the water tower contains enough water to easily fill several swimming pools nearly instantly. The large pipes that run through the city can also easily provide the water needed to quickly fill a swimming pool. However, the hose in the backyard of a house can't quickly fill a swimming pool. A fire hydrant would not have the same difficulty filling a pool as a hose would. Similarly, the charging load for EVs may not pose a problem for the generation or transmission systems of the grid, but the ability of the local distribution system to fill this need can be very dependent on the specific details of the location where the power is being used.

Understanding the difference between power versus energy is also important. Within this document, both of these concepts are specific to electricity.

Electricity is the flow of electrical charge or power. Electricity is measured in units of power called watts (W). Power defines the amount of electrical charge that can be delivered at a specific point of time under specific conditions. Vehicle charging is typically described in kilowatts (kW) and is equal to one thousand Watts. Larger applications such as power plants are described in megawatts (MW) and is equal to a thousand kilowatts. For example, a Level 2 charger has a maximum power of 19.2 kW, a NEVI DCFC charging port is required to have a minimum power of 150 kW, and megawatt chargers are being developed for maritime, aviation, and freight applications.

The amount of electricity produced, stored, or consumed over time, which refers to the system's energy, is measured in kilowatt-hours (kWh) or megawatt-hours (MWH), and a megawatt-hour is equal to one thousand kilowatt-hours. Vehicle battery sizes are described in kWh which defines how much energy the battery can store. For example, a 2023 Tesla Model 3 Long Range has a 75-kWh battery pack, a 2023 Ford F150 Lightning has a 131-kWh battery pack, and a standard forty-foot transit bus may have a battery pack from 440 kWh up to 700 kWh or larger.

Tying these two concepts together, a vehicle charging for an hour at 50 kW of power will have 50 kWh of energy added to its battery.

Capacity and Generation

Electricity capacity refers to the maximum amount of electricity a power plant can produce in megawatts (MW). Electricity generation systems are generally sized to provide power to meet the highest electricity demand levels, which is during daytime hours. Electric vehicles are anticipated to charge mostly overnight when existing power generation equipment currently has excess capacity.

North Carolina's electricity capacity mix has changed over recent years. Duke Energy retired numerous coal plants, replacing them with highly efficient combined cycle natural gas plants starting in 2010. In addition, North Carolina currently has about 5,000 MW of nuclear power, 2,000 MW of hydroelectric, 6,000 MW of solar and 208 MW of on shore wind. The current mix of electricity generating plants in the state is provided in **Table 2**.[7]

Over the last 5 years, North Carolina has averaged around 136 million MWh in retail sales of electricity.[8] North Carolina sold 139 million MWh of electricity to customers in 2022. The average annual growth rate in sales since 2005 is only 0.5%, despite substantial growth in both population (1.2% annually)[9] and the economy (3% annually)[10] in that same time period. This is primarily due to the State's efforts around energy efficiency.

7 Energy Information Administration, Form 860 detailed data, 2021, https://www.eia.gov/electricity/data/eia860/#:~:text=The%20survey%20Form%20EIA%2D860,greater%20of%20combined%20nameplate%20capacity.

8 Energy Information Administration, North Carolina Electricity Profile, Table 8, https://www.eia.gov/electricity/state/northcarolina/state_tables.php

9 US Census Bureau, https://www2.census.gov/programs-surveys/popest/tables/

10 NC Office of State Budget and Management, https://linc.osbm.nc.gov/explore/dataset/state-comparisons-business-and-industry/table/?disjunctive.area_name&disjunctive.year&disjunctive.variable&refine.variable=Gross+State+Product+($Bil,+Chained+09+Dollars)

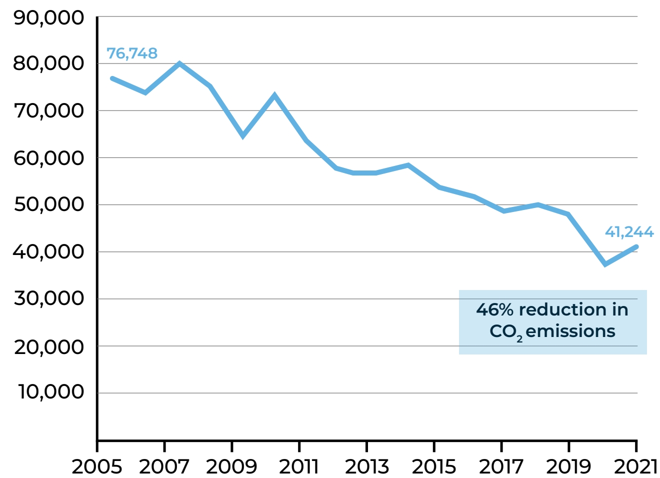
TABLE 2. North Carolina Power Generation Capacity

Class	Technology	Capacity (MW)
Fossil Fuel	Steam Coal	4,594
	Natural Gas Steam Turbine	4,636
	Natural Gas Fired Combined Cycle	5,579
	Natural Gas Fired Combustion Turbine	5,939
	Petroleum Combustion Turbines	436
Non-Emitting	Nuclear	5,150
	Hydroelectric	2,090
	Solar Photovoltaic	5,956
	Onshore Wind Turbine	208
	Batteries	36
Biofuel	Biofuel	114
Total		34,738

TABLE 3. North Carolina Electricity Generation

Type	Fuel Type	2021 Generation (MWh)	Share of Total (%)
Nuclear	Nuclear	43,118,000	34%
Fossil Fuel	Coal	20,228,000	16%
	Natural Gas	47,127,000	37%
	Petroleum	176,000	<1%
Renewable	Solar	10,011,000	8%
	Hydro	5,799,000	5%
	Wind	515,000	<1%
Biofuel	Biofuel	604,000	<1%
Other	Other	133,000	<1%
Total		127,711,000	

FIGURE 7. North Carolina Electricity Power Industry Emissions



Electricity generation refers to the amount of power produced over a given time period, in this case annually. In 2021 North Carolina generated about 128 million MWh of electricity (see **Table 3**). The state generally consumes about 10 percent more than it generates and imports this power from neighboring states. In 2021, the state generated about 53% of its electricity from fossil fuels while nuclear generated 34%. Non-emitting renewables, including hydro, solar and wind, represented 13% of the electricity produced, with solar now dominating over hydro at 8% of the electricity produced.

This shift in the use of natural gas which emits significantly less carbon dioxide than coal, combined with an increase in the use of resources that do not emit carbon dioxide such as nuclear and solar has significantly reduced CO_2 emissions from the electricity sector. **Figure 7** gives the historic reduction in CO_2 emissions over time.[11] Overall CO_2 emissions from the electricity sector have been reduced by 46% from 2005 to 2021. Emissions will continue to decrease under Session Law 2021-165 which sets a goal for Duke Energy, the primary electricity generator in the state, to reduce greenhouse gases by a 70 percent from 2005 levels by 2030, and achieving net-zero greenhouse gas emissions no later than 2050.

11 Energy Information Administration, North Carolina Electricity Profile, Table 7, https://www.eia.gov/electricity/state/northcarolina/state_tables.php

Transmission

The transmission network is more location dependent with different areas of the country better prepared for the additional load that EVs will present. According to a recent report from the Department of Energy,[12] the Southeast region where North Carolina is located will need to see an increase in transmission capacity by 77 percent over 2020 levels by 2035. However, there is a significant amount of uncertainty in these estimates, with increases between 12 percent and 102 percent over 2020 levels being needed by 2035, depending on the scenario assumptions. The report also identifies that exponential growth of building and transportation electrification is forecasted to require transmission expansion within the contiguous United States of approximately 195 GW, over three times the business-as-usual scenario.

Planning and constructing transmission infrastructure is critical to bringing electricity to load centers. This infrastructure ensures power supply reliability, enables interconnection of new generation and storage facilities, as well as meeting load growth. Duke Energy Carolinas (DEC) and Duke Energy Progress (DEP) are the primary Transmission Owners and Transmission Service Providers in North Carolina that independently own and operate transmission systems and provide transmission service. Note that these systems provide transmission to the DEC and DEP balancing areas, which include both North Carolina and South Carolina.

DEC has approximately 12,957 miles of transmission and sub-transmission lines in North Carolina and South Carolina at voltages ranging from 44 kV to 500 kV. DEP has approximately 6,306 miles of transmission lines in North Carolina and South Carolina at voltages ranging from 69 kV to 500 kV. **Table 4** provides DEC's and DEP's installed miles of transmission by voltage level.

DEP and DEC both have long range transmission planning out to the 2034 time-frame that identifies specific projects for upgrading or constructing transmission lines, ties to lines, large transformers and switching stations. Transmission planning has been an ongoing issue in North Carolina primarily due to the large amounts of solar resources being integrated onto the grid, especially in the eastern portion of the state. Much of the transmission planning in North Carolina has focused on this issue. The number of DEC's and DEP's transmission projects that are under construction or have approved construction plans are summarized in **Table 5**.

New large load centers to support electrification of medium and heavy duty trucking, with demands greater than 10 MW , may drive new transmission level projects or require upgrades to existing systems. Planning of these larger electrification projects may require coordination with DEC and DEP transmission planning staff as well as discussions with the NCUC staff to ensure these projects are included in the long-range planning around transmission and reliability services.

TABLE 4. Duke Energy Existing Transmission Line Miles for Various Voltage Levels

Circuit Voltage	44 kV	66-69 kV	100-199 kV	230 kV	500 kV
DEC	2,752	121	6,848	2,660	576
DEP	-	12	2,569	3,433	292

TABLE 5. Number of Duke Energy Transmission Projects Under Construction or Approved, 2023-2034

Circuit Voltage	New	Upgrade	Total
DEC	22	35	57
Line	15	12	27
Tie	6	16	22
Transformer	1	22	8
DEP	8	17	25
Line	6	15	21
Transformer	1	2	3
Switching Station	1	-	1

12 https://www.energy.gov/sites/default/files/2023-02/022423-DRAFTNeedsStudyforPublicComment.pdf

Distribution

Around 74% of the electricity is distributed to customers by investor-owned utilities (see **Figure 8)**, Duke Energy and Dominion Energy. Another 24% is distributed by North Carolina's 29 rural electric cooperatives and 21 municipal electric distributors.

The rural electric cooperatives face flat or negative electricity sales while the distribution system covers a large area. In addition, approximately 70% of their electricity sales is to residential customers, as opposed to IOUs and municipal providers where only 40% of sales is residential, as shown in **Figure 9**. This makes it difficult for rural electric cooperatives to invest in distribution infrastructure to support transportation electrification without impacting its members with rate hikes.

A location looking to install fast chargers and/or multiple Level 2 chargers may require additional power to be brought to the site requiring line upgrades, new lines, or even substation and transformer upgrades. The exact extent of the upgrades required will depend heavily on the power required, and the available or spare capacity within the distribution network providing the supply. Returning to the water analogy, consider how easy it would be to add a bathroom to a house in a location where there is already a kitchen on the other side of the wall, but how difficult it would be to add the bathroom if it was surrounded by bedrooms that had no water. Even though both locations are inside the same house, their ability to provide access to water is very different. Similarly, the availability of power is very location dependent.

A joint study conducted by utility provider National Grid and Hitachi Energy examined the impacts of 100 percent fleet electrification of school buses and medium and heavy-duty trucks on distribution systems in National Grid's Service.

FIGURE 8. North Carolina Electricity Retail Sales by Ownership Type (MWh)

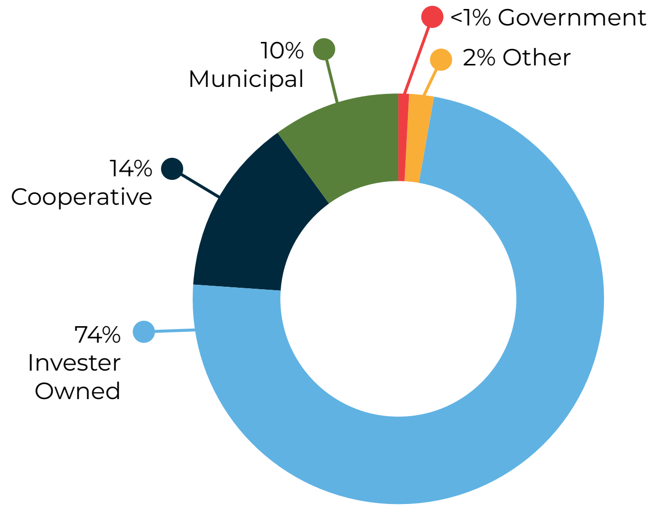


FIGURE 9. North Carolina Rural Electricity Sales by Sector (MWh)

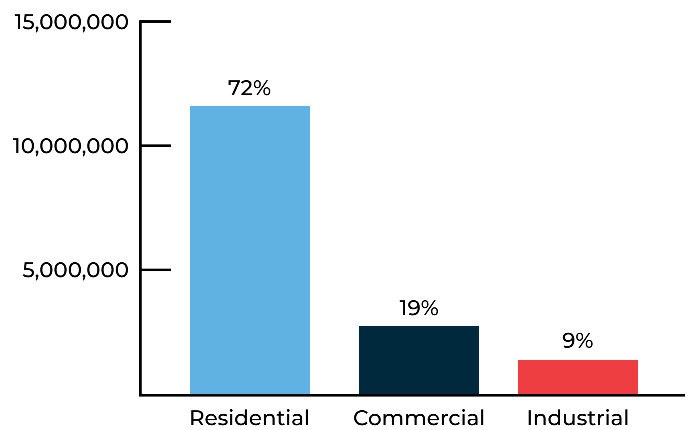
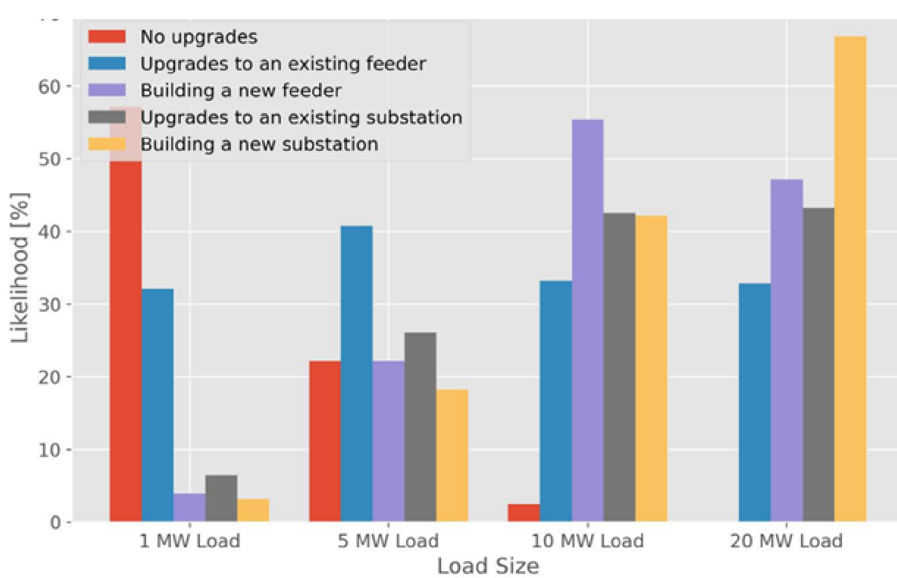


FIGURE 10. EPRI Survey Findings Related to Utility Distribution Networks Upgrades 2021



Fifty-one major fleet operators were identified in the study with all charging assumed to occur at the depot. The study concluded that significant investments in the distribution system for large-scale fleet electrification are needed. Of the nineteen distribution feeders examined in the study, over 68 percent were projected to be overloaded or at risk of overload (defined as over 80 percent of rated load) with 100 percent major fleet electrification assuming a maximum charging strategy. The risk of overload was especially great in areas with significant clustering of transportation industries.

Figure 10 illustrates the findings from a survey of utility companies by EPRI and how those utilities are anticipating upgrades to their distribution networks based upon higher power demands associated with EV charging. Increasing electrical loads at individual locations by small amounts, may be feasible to support the initial introduction of BEV vehicles. As illustrated in **Figure 10,** the likelihood of distribution system upgrades increases as more electrical load is required.

HYDROGEN

Production and Sourcing

A key challenge with producing hydrogen is extracting it from different sources, such as water, biomass and natural gas, cost effectively. Most hydrogen in the US is produced using natural gas reforming/gasification where synthesis gas—a mixture of hydrogen, carbon monoxide, and a small amount of carbon dioxide—is created by reacting natural gas with high-temperature steam. The carbon monoxide is reacted with water to produce additional hydrogen. Electrolysis is another method which uses an electric current to split water into hydrogen and oxygen and is typically viewed as the greenest form of hydrogen if the electricity is produced by renewable sources. The major hydrogen-producing states are California, Louisiana and Texas, with most of the hydrogen being used for industrial purposes. Hydrogen's properties also present some challenges with pipeline materials and compressor design.

Distribution

There are two options to get hydrogen distributed to the dispensing point for transportation-related operations: on site generation or delivered hydrogen via "truck-and-tank." Each has its own merits with varying scales of production costs and investments in production infrastructure versus distribution costs.

On site production

Larger fleets or higher volume retailers of hydrogen, such as truck stops, could produce hydrogen themselves, using scalable, modular systems thereby avoiding hydrogen transportation costs. Considerations include space for the system, supply of deionized water and supply of electricity for electrolysis-produced hydrogen and access to natural gas supplies for hydrogen produced via Steam Methane Reforming (SMR). A key consideration for the placement of the hydrogen station equipment is the required distances from flammable liquids and gas storage, buildings, public roads, sidewalks, and property lines. These setback requirements for gaseous and liquid storage are defined by the National Fire Protection Association (NFPA) and have recently been updated from the 2020 versions. The setbacks in the most recent version of NPFA 2, Hydrogen Technologies Code, released in 2023, have been significantly reduced from previous versions.

Delivered Hydrogen

The delivery of hydrogen consists of distribution to a fueling location using trucks with trailers equipped with hydrogen storage tanks. Vehicles are fueled using a separate dispensing unit. Other solutions incorporate a storage and dispensing solution on one trailer. When hydrogen runs low, the trailer is swapped for a full one. These solutions are suitable for small fleets with facilities that have limited space and can result in reduced upfront costs, when compared to on-site generation. Users would typically pay per kilogram of hydrogen dispensed, which would include a charge for equipment use. However, according to the Department of Energy (DOE) Hydrogen Program, due to its relatively low volumetric energy density, transportation, storage and final delivery to the point of use can be one of the significant costs and energy inefficiencies associated with using hydrogen as an energy carrier.

Hydrogen can be delivered as either a gas or a liquid:

- LH2: Liquid hydrogen (LH2) stations are composed of five main components: LH2 tanks, LH2 pumps, vaporizers, gaseous hydrogen (GH2) tanks, and dispensers. The dispenser functions like a diesel dispenser; operators simply insert the nozzle into the vehicle's fuel tank and hydrogen is dispensed.
- GH2: stations eliminate much of the infrastructure required, but require more space to store the same volume of hydrogen than its liquid counterpart. Stations can consist of either permanently installed infrastructure or mobile infrastructure that can be moved with a trailer. Mobile options have much smaller storage capacities, typically only supporting the operation of 5 to 10 vehicles.

Advantages and disadvantages of the two options are summarized in **Table 6**.

A mobile station on a trailer can provide 350 to 400 kg of LH2 storage capable of refueling 13[13] regional haul trucks and 5 long-haul trucks . Mobile systems use LH2 instead of GH2 to reduce the overall footprint to make the mobile system cost effective. Larger portable stations are available that would be well suited to larger applications. These systems can be trailer mounted and moved around, but are then placed on the ground at the fueling location, making them slightly more permanent than a trailer-mounted mobile solution. These systems provide 1,100 to 1,200 kg of LH2 storage and could refuel up to 40 regional haul trucks or 17 long-haul trucks.

Mobile fueling facilities examples are shown in **Figure 11**.

TABLE 6. Advantages and Disadvantages of Liquid and Gaseous Hydrogen

	Advantages	Disadvantages
Gaseous	• Correct form for vehicles • Stored at normal ambient temperatures • Requires less equipment to produce, store, and dispense	• Much lower energy density • Stored at very high pressures • More frequent deliveries are needed • Storage volume increase as storage pressure decreases, resulting in more land area required
Liquid	• Much higher energy density – 4 times more than gaseous trailers • Stored at 1 atm pressure	• Stored at very low (cryogenic) temperatures • Must be converted for use by vehicles • Requires more equipment and energy to produce, store, and dispense

13 Based on 30kg tank size for a regional haul truck and 70kg for a long-haul truck

FIGURE 11. Examples of Mobile Hydrogen Fueling Infrastructure
Sources: Air Liquide & OneH2

Executive Order 246

North Carolina's Transformation to a Clean, Equitable Economy

Light Duty Needs Assessment

OVERVIEW

On January 27, 2022, Governor Roy Cooper issued Executive Order 246, which included targets for the number of zero emissions vehicles registrations and sales by 2030. Specifically, EO 246 states that North Carolina should "increase the total number of registered, ZEVs to at least 1,250,000 by 2030 and increase the sale of ZEVs so that 50 percent of in-state sales of new vehicles are zero-emission by 2030."

This section of the report identifies the light duty charging needs associated with EO 246's ZEV sales and adoption targets.

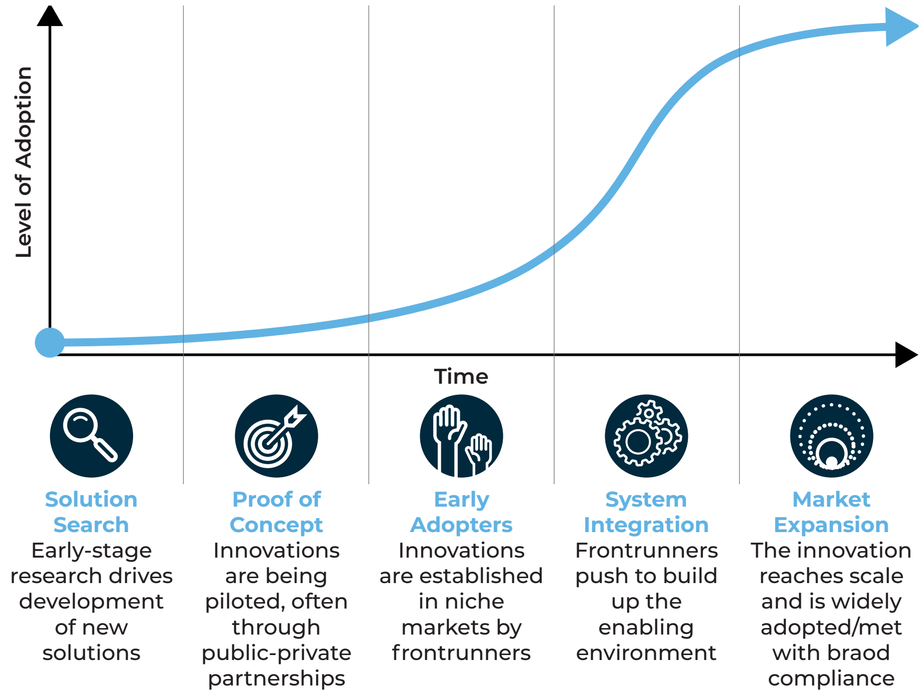
LIGHT DUTY EV ADOPTION MODEL

A light duty EV adoption model was developed that benchmarks North Carolina's current light duty EV registrations today, the goals of EO 246 by 2030, and provides a realistic projection model for how the state's light duty ZEV market will grow to reach the EO 246 targets. This light duty adoption model was used to project public and private charging infrastructure necessary statewide to support the goals of EO 246.

EV ADOPTION MODEL APPROACH

The light duty vehicle adoption model uses an "S-Curve" model to project how North Carolina's current zero emission vehicles inventory will grow to reach EO 246's sales goals by 2030. **Figure 12** from the Rocky Mountain Institute provides a helpful framework in understanding the stages of technology adoption for a variety of new technologies. The model notes that many technologies experience modest, linear growth in their early stages, followed by periods of exponential growth. As observed in both national and international markets, the level of EV adoption tends to accelerate into exponential growth when local EV's sales represent approximately 5 percent of new vehicle sales. The sales target for EO 246, which targets 50 percent of in-state sales of new vehicles are zero-emission by 2030, anticipates exponential growth in North Carolina's EV market.

FIGURE 12. Five Stages of Disruptive Technology Adoption
Source: Rocky Mountain Institute.



The EV industry nationally has progressed from the early stages of R&D and proof of concept to the "early adopters and system integration phases," which accompany exponential growth. Recent announcements from across the private sector support the notion that EVs nationally are being systematically integrated within the automobile industry:

- General Motors has announced plans to only sell electric vehicles by 2035,
- Ford has announced plans for up to 50 percent of global sales to be electric by 2030,[14]
- Seven major automakers announced a joint venture to invest at least $1 billion to build 30,000 DC fast charging ports throughout the country.[15]

NORTH CAROLINA LIGHT DUTY EV ADOPTION MODEL ASSUMPTIONS

The sales target for Executive Order 246 is 50 percent of in-state sales of new vehicles by 2030 are zero emissions vehicles. The 50 percent sales target was selected as the goal to benchmark the light duty EV adoption model.[16]

Model Definitions and Assumptions:

- A zero emissions vehicle is assumed to be a full battery-electric vehicle (does not include hydrogen fuel cell or PHEV).
- New light-duty (LD) vehicle sales are assumed to be light duty vehicles, including sedans, SUV's and light-duty pick-up trucks.
- New LD vehicle sales will follow an S-Curve adoption trend.

14 Ford to Lead America's Shift to Electric Vehicles with New Mega Campus in Tennessee and Twin Battery Plants in Kentucky; $11.4B Investment to Create 11,000 Jobs and Power New Lineup of Advanced EVs | https://media.ford.com/content/fordmedia/fna/us/en/news/2021/09/27/ford-to-lead-americas-shift-to-electric-vehicles.html#:~:text=Overall%2C%20Ford%20expects%2040%25%20to,of%20battery%20business%2C%20SK%20Innovation.

15 G.M. and Other Automakers Will Build 30,000 Electric Vehicle Chargers - The New York Times (https://www.nytimes.com/2023/07/26/business/energy-environment/electric-vehicles-fast-chargers-automakers.html). The automakers include BMW Group, GM, Honda, Hyundai, Kia, Mercedes-Benz Group and Stellantis

16 See the Adoption model

Adoption Forecasting Methodology

The projection model uses the current (July 2023) EV registration data as the baseline and maps the S-Curve to the EO 2030 50 percent sales goal. It assumes that new sales of EVs match the national average of 5 percent near the end of 2022. It also assumes, using data from the National Automotive Dealers Association (NADA) that new vehicle sales will account for 2.4 percent of the total number of vehicles registered within North Carolina[17]. Estimated number of EV sales are then calculated by forecasting the total number of vehicle registrations, calculating the number of new vehicle purchases anticipated, and calculating the portion of those sales that will be battery electric at any given year. The S-Curve model **(Figure 13)** maps anticipated annual sales needed to meet EO246 and assumes sales of EVs continue to increase, leveling out at 95 percent of sales around the year 2037. While these estimates are aggressive, they highlight the percentage of yearly EV sales that will be needed to meet EO246.

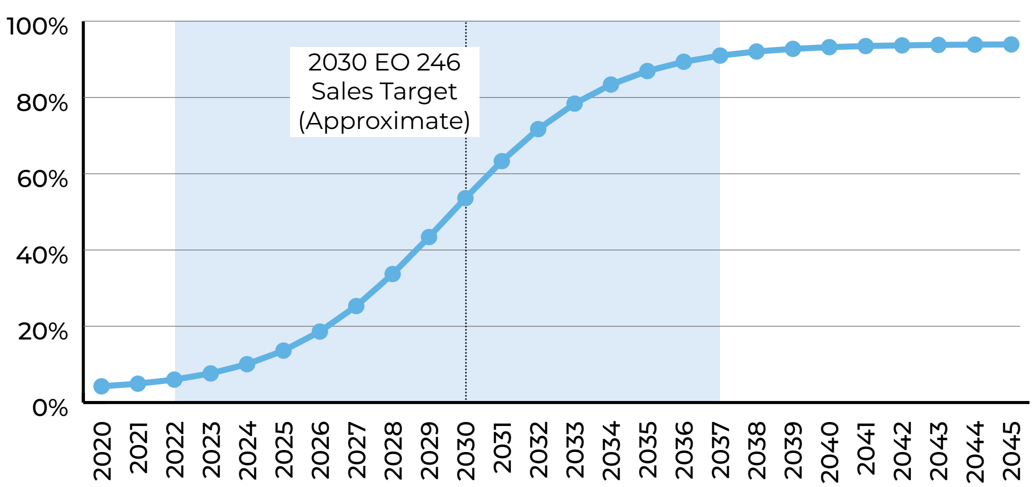
It should be noted that EO246 also targets 1.25M EVs registered in the state by 2030. However, EV sales would need to increase substantially over the 50 percent 2030 target to meet that portion of the EO. For example, all vehicle sales would need to be EVs starting in 2026 in order to meet the 1.25M EV registration target. Using the 2030 50 percent target, EVs will make up over 1.25M of total registered L/D vehicles in North Carolina by 2034.

The annual EV sales are then fed into a fleet adoption model **(Figure 14)** that accounts for salvage rates and the compiling number of both EVs and internal combustion engines (ICE)s. Because vehicles may stay within the overall fleet for a number of years (the nationwide average is 12 years), even substantial percentages of EV sales will take time to become a substantial part of the overall vehicle fleet in North Carolina. For example, in 2030 when sales of EVs are targeted to hit 50 percent, the overall number of EVs in the North Carolina fleet is estimated to be just over 6 percent. For this reason, internal combustion engine vehicles are estimated to remain the majority of registered vehicles for the foreseeable future. Using the estimated sales data and increased registration projected out, it is estimated that EVs would make up 50 percent of all registered light-duty vehicles in the year 2050 **(Table 7)**.

Registration Assumptions:

- The number of North Carolina EV registrations in 2022, is just over 38,000 vehicles.
- The Average Annual Growth Rate (AAGR) of North Carolina light duty vehicle registrations is 2.8 percent.[18]

FIGURE 13. S-Curve Adoption Model, North Carolina EO 246



17 https://www.nada.org/media/4695/download?inline
18 FHWA Statistics 2017-2021 average

NORTH CAROLINA'S LIGHT DUTY ELECTRIC VEHICLE CHARGING NEEDS

The National Renewable Energy Laboratory's EVI-ProLite[19] tool was used to estimate both the number and type of electric vehicle chargers needed for the year 2030, as well as an estimate of the daily load profile for the light duty fleet.

EV CHARGING NEEDS ASSUMPTIONS

The following assumptions have been used in this process:

- 75 percent of electric vehicles will have access to at-home charging[20]
- The vehicle mix of light-duty vehicles includes:
  - Plug-In Electric Sedans: 38 percent
  - Plug-In Electric C/SUV's: 37 percent
  - Plug-In Electric Pickups: 21 percent
  - Plug-In Electric Vans: 4 percent

FIGURE 14. EV Penetration Based on Sales Benchmark at 2030

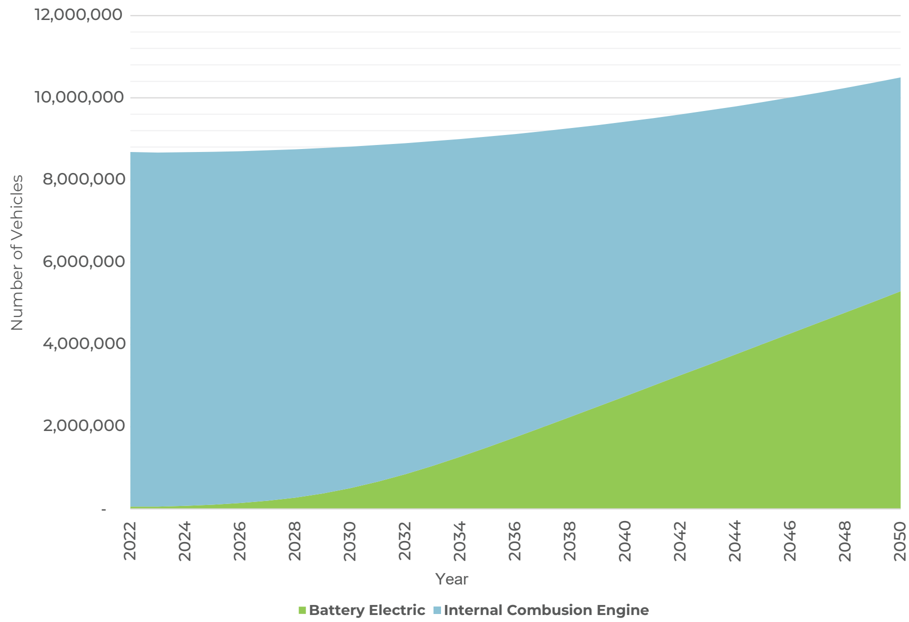


TABLE 7. Projected Number of EV's and ICEs by key year

Year	Projected Light Duty EVs Registered in NC	Projected Light Duty ICEs Registered in NC
2023	53,316	8,614,544
2030	503,347	8,308,100
2034	1,269,486	7,728,439
2050	5,292,437	5,201,690

19 EVI-Pro Lite is a tool for projecting consumer demand for electric vehicle charging infrastructure, and was developed through a collaboration with the National Renewable Energy Laboratory and the California Energy Commission.

20 The majority of light-duty EV charging will take place at home. The model assumes 75 percent of electric vehicles have access to at-home charging (which accounts for single-family homeowners and multi-family owners and renters with access to garage charging).

NORTH CAROLINA CHARGING INFRASTRUCTURE

North Carolina will need approximately 401,670 charging ports in 2030 to support the 503,347 vehicles needed to reach the targets outlined in Executive Order 246. They are broken down into four charging port types. **Table 8** and **Figure 15** through **Figure 18** indicate the level of ports (kW) and recommended location for shared private charging ports, public level 2 charging, and public DCFC. As most EV drivers will charge at home, approximately 88 percent of all charging ports for light duty vehicles will be at home Level 1 and Level 2 charging equipment.

TABLE 8. Charging Ports Required by 2030 to Support 50 Percent Sales Adoption Model

Charging Port Type	# of Ports Required by 2030 for 50 percent Sales Adoption model
Single-Family Charging Ports	356,369
Shared Private Charging Ports	17,488
Public Level 2 Charging Ports	23,993
Public DC Fast Charging Ports	3,820

FIGURE 15. Number of Single-Family Charging Ports Required to Support 50 percent of Light Duty Vehicle Sales by 2030

356,369 **Single Family Charging Ports**

- **266,493** Single Family home — Level 2 Charging Ports
- **89,876** Single Family Home — Level 1 Charging Ports

FIGURE 16. Number of Apartment and Workplace Charging Ports Required to Support 50 percent of Light Duty Vehicle Sales by 2030

17,488 **Shared Private Charging Ports**

- **668** Multi-Unit Dwelling — Level 1 Charging Ports
- **1,980** Multi-Unit Dwelling — Level 2 Charging Ports
- **14,840** Private Workplace — Level 2 Charging Ports

FIGURE 17. Number of Public Level 2 Charging Ports Required to Support 50 percent of Light Duty Vehicle Sales by 2030

23,993 **Public Level 2 Charging Ports**

- **3,552** Retail — Level 2 Charging Ports
- **1,057** Recreation Center — Level 2 Charging Ports
- **2,558** Healthcare Facility — Level 2 Charging Ports
- **1,645** Education Facility — Level 2 Charging Ports
- **1,320** Community Center — Level 2 Charging Ports
- **1,917** Transportation Facility — Level 2 Charging Ports
- **5,853** Neighborhood — Level 2 Charging Ports
- **6,007** Office — Level 2 Charging Ports

FIGURE 18. Number of Public DC Fast Charging Ports Required to Support 50 percent of Light Duty Vehicle Sales by 2030

3,820 **Public DC Fast Charging Ports**

- **1,416** Retail – 150 kW — DC Fast Charging Ports
- **607** Recreation Center – 150 kW — DC Fast Charging Ports
- **617** Retail – 250 kW — DC Fast Charging Ports
- **302** Recreation Center – 250 kW — DC Fast Charging Ports
- **537** Retail – 350+ kW — DC Fast Charging Ports
- **296** Recreation Center – 350+ kW — DC Fast Charging Ports

NORTH CAROLINA'S ESTIMATED ELECTRIC LOAD

The EVI-ProLite tool was also used to estimate what a typical weekday electrical load might look like across the state associated with light duty vehicles. This level of analysis estimates at a generation and transmission level how much electricity might be required and the time of day it might be required, in 2030 to support the EO's 246 goals.

Assumptions for Estimated Electrical Load

- 45 miles traveled per day per vehicle (average)
- 68 degrees F avg. temperature
- 20 percent of plug-in vehicles are sedans (with the remaining 80 percent as SUV's, light-duty pickups, vans)
- 75 percent access to at home charging
  - 100 percent of residents prefer to charge at home wherever possible
  - 20 percent of at home charging is Level 1, and 80 percent is Level 2.
- Workplace Charging.
  - 20 percent Level 1 Charging and 80 percent Level 2 Charging

Daily Electrical Load

The estimated daily electric load that will be required to support the 565,110 EVs forecast to be on the road in 2030 is identified in **Figure 19**. There are a few key takeaways:

- Residential charging is likely to continue to be the preferred approach to light duty EV charging.
- As people return home from work at the end of the day, they are likely to plug their vehicle in immediately, drawing power from the grid and contributing significantly to a peak load.
- There may be opportunities for the state and utilities to incentivize active charging management, that may shift load to later on in the evening.

Publicly accessible DCFC accounts for a small amount of daily load but serves an important function for both long-distance traveling and other vehicles and fleets that require short-duration charging time.

FIGURE 19. 2030 Estimated Daily Electrical Load Required to Support 50 percent Sales Target in EO 246

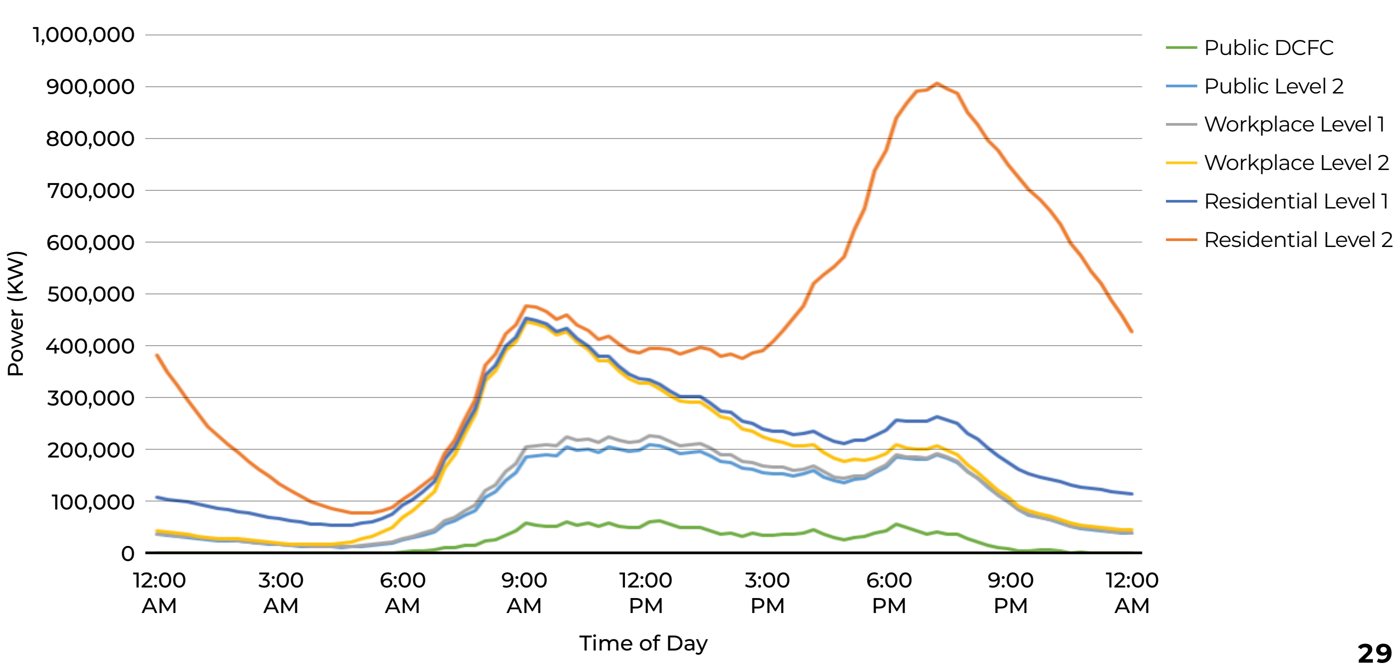


FIGURE 20. Average Light Duty Vehicles Weekday Hourly Load

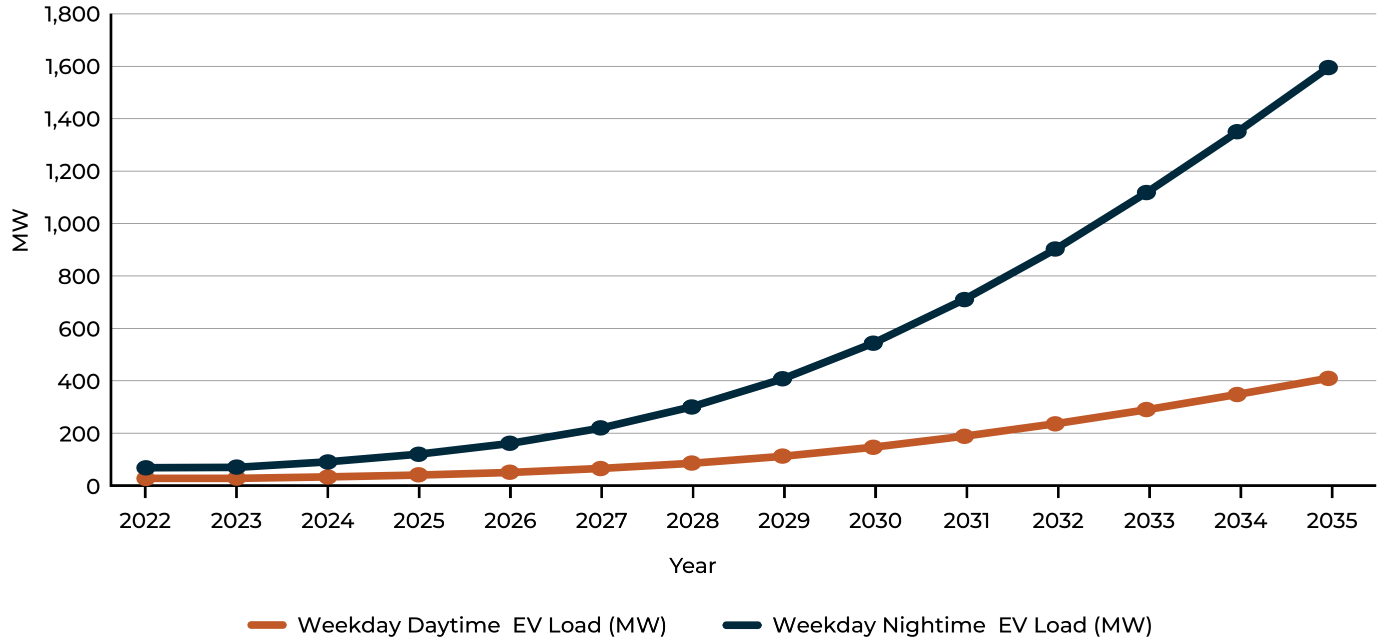
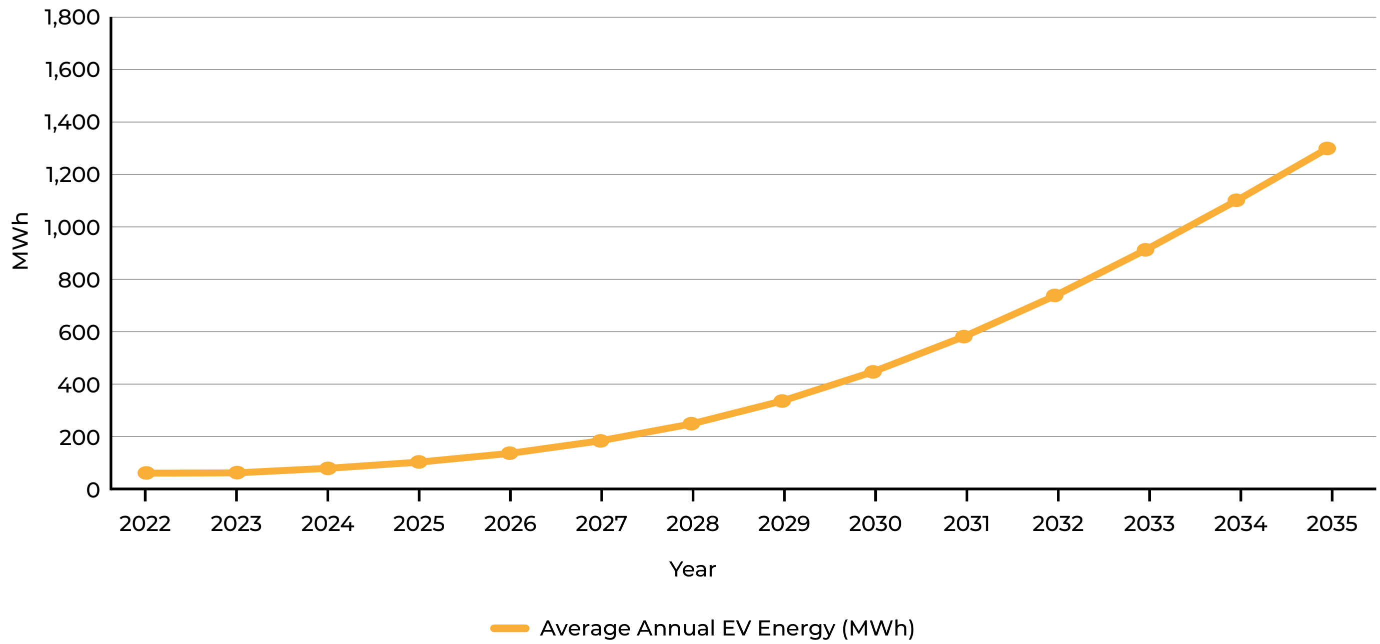


FIGURE 21. Average Light Duty Vehicles Annual EV Load



Executive Order 271

Growing NCs Zero-Emission Vehicle Market Medium and Heavy-Duty Vehicles *Needs Assessment*

On October 25, 2022, Governor Roy Cooper signed Executive Order 271, charging the Department of Environmental Quality (DEQ) to initiate the rule-making process for a proposed Advanced Clean Trucks (ACT) program. ACT requires vehicle manufacturers to sell an increasing percentage of ZEVs in North Carolina. The ACT program applies to vehicles with a gross vehicle weight rating of at least 8,501 pounds, covering a variety of vehicles, including heavier pick-up trucks, buses, delivery vans, box trucks, garbage trucks and semi tractors. ACT would not apply to consumer passenger vehicles or off-road vehicles. ACT rules have also been adopted in California, Oregon, Washington, New York, New Jersey, Massachusetts, and Vermont. It should be noted that national and regional fleets may purchase and register their vehicles outside of North Carolina, but base and operate them in the state.

NC Department of Air Quality estimated MHD sales as part of the proposed ACT Rule fiscal impacts analysis. These sales are shown in **Table 9** and the ZEV and Non-ZEV MHD total sales is illustrated in **Figure 22**.

FIGURE 22. ZEV and Non-ZEV MDH Sales Projections

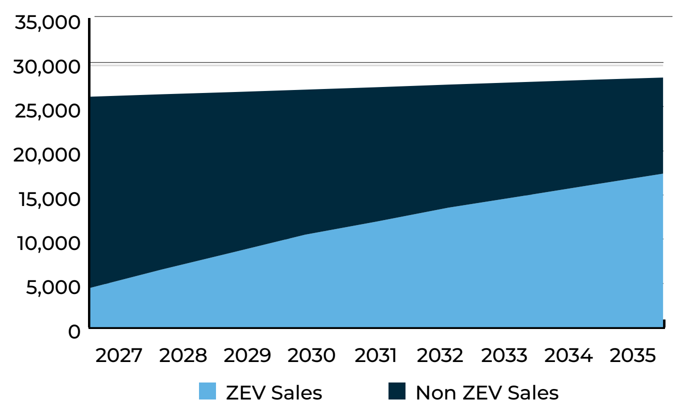


TABLE 9. Proposed ACT Rule MHD Sales Projections

Year	Class 2b-3	Class 4-8	Class 7-8 Tractors	Totals	Percent of Total New Registrations
2027	1,500	2,400	600	4,500	17%
2028	2,000	3,700	900	6,600	25%
2029	2,600	4,900	1,100	8,600	32%
2030	3,100	6,200	1,300	10,600	39%
2031	3,700	6,900	1,500	12,100	44%
2032	4,200	7,700	1,800	13,700	49%
2033	4,800	8,400	1,800	15,000	53%
2034	5,400	9,100	1,800	16,300	57%
2035	6,000	9,800	1,800	17,600	61%

Note: These preliminary projections may be overestimated because they include new vehicle registrations associated with vehicle owners that purchased their vehicle in another state and registered their vehicle in NC when they moved to NC. In addition, the projections do not account for any trading of credits between vehicle classes by vehicle manufacturers once the ACT rule is in effect.

APPLICATION OF ZERO EMISSION VEHICLES

This needs analysis considers how fleets, companies and vehicle operators are expected to use MHD ZEVs, as well as considering other factors associated with vehicle purchasing and operations. This section of the report identifies different characteristics connected with companies' and individuals' decision making related to adopting ZEVs and categorizes these uses as Readily Supports, Some Challenges and Significant Challenges.

Vehicle Duty Cycle. Successful deployments of ZEVs occur when the vehicle duty cycle meshes with the capabilities of the ZEV. Distance traveled, elevation, driving conditions, payload and how long the vehicle is on the road and in the depot, will influence what routes can be transitioned to ZEV and the type of charging or fueling infrastructure that is most applicable and cost effective. Characteristics associated with vehicle duty cycle are shown in **Figure 23**.

FIGURE 23. Vehicle Duty Cycle Characteristics

Readily Supports

Daily vehicle range <250 miles

Companies operating daily routes less than 250 miles are within the range of today's BEVs with regional and multi stop delivery routes being the most suitable. Multiple OEMs operating in this sector.

Vehicles return to same base every day

Ensures charging of vehicle is within the control of the vehicle operator.

Some Challenges

Daily vehicle range >250-300 miles

Less vehicles being produced for this range. As range increases, so does the weight of the battery which reduces maximum vehicle payload. Range anxiety will also influence BEV adoption for higher mileage routes.

Significant Challenges

Daily vehicle range >300 miles

Very few OEMs are producing BEVs with ranges greater than 300 miles. These vehicles may be cost prohibitive for most of the trucking sector at current prices. Evolution of FCEV technology and associated refuelling infrastructure may support ZEV adoption at these vehicle ranges, but this technology is still maturing.

Vehicle does not return to same base everyday/ No fixed vehicle base

Operator needs to plan and invest time and effort into where and when vehicle will be charged.

Vehicle User. Financing the upfront cost of ZEVs is a significant consideration when they are currently more expensive than traditional fueled vehicles. An electric school bus costs three to four times as much as its diesel equivalent[21] and this cost differential also applies to heavier trucks. Vehicle user characteristics are shown in **Figure 24.**

FIGURE 24. Vehicle User Characteristics

Readily Supports

Private Company – Large and Medium Fleets

Company likely to have access to capital and implements a fleet replacement program. Vehicle Total Cost of Ownership (TCO) is important. Customer sustainability requirements may influence the uptake of ZEVs. Companies are also willing to trial and pilot new technologies and have staff to support these.

Government/Local Agencies

Sustainability requirements help drive ZEV adoption. Access to grants and funding.

Some Challenges

Private Company – Small Fleets

May purchase used vehicles in the heavier weight classes. Access to capital to purchase new vehicles maybe challenging.

Significant Challenges

Owner-Operator

Sector tends to purchase used vehicles. No significant Medium and Heavy-Duty used vehicle market to date. Access to capital for more expensive ZEVs is challenging. TCO is less important than the upfront capital cost of vehicle purchases.

21 https://electricschoolbusinitiative.org/sites/default/files/2022-09/electric-school-bus-us-market-study-buyers-guide.pdf

Vehicle Ownership. How MHD operators own or lease their vehicles will also influence adoption. Some operators purchase new vehicles, while others lease. Some operators can't afford new vehicles and purchase used vehicles. Characteristics associated with vehicle ownership of an electric MHDV are detailed in **Figure 25**.

FIGURE 25. Vehicle Ownership Characteristics

Readily Supports

Vehicles purchased by vehicle user

Easier to ensure compatibility of vehicles and charging infrastructure.

Emerging Business models

Emerging business models, such as Truck as a Service (TaaS) can help operators with their ZEV acquisition and operating strategies.

Some Challenges

Leased by vehicle owner

Owner will need to work with leasing company to ensure compatibility of vehicles and charging infrastructure. Leasing company may also be able to support the implementation of charging infrastructure.

Significant Challenges

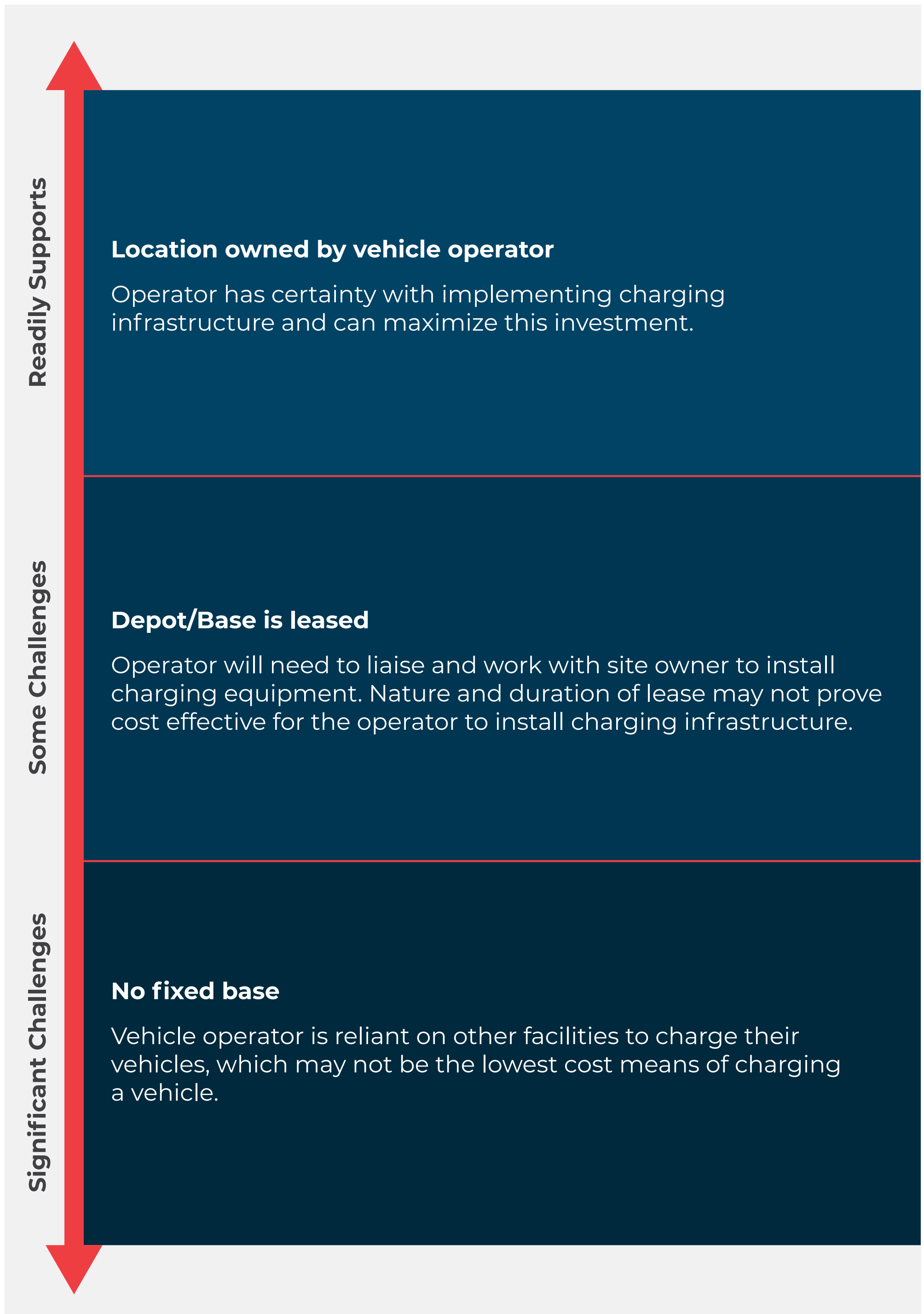
Lack of Mature Used MHD ZEV Market

Some trucking sectors are reliant on used vehicles. With no established used MHD ZEV market, those sectors will find it challenging to purchase affordable ZEVs.

Depot/Base. Where the vehicle is based will influence decisions associated with charging infrastructure. Fleet operators want certainty as to when and where the vehicle will be charged and fueled, and certainty that charging infrastructure will be available and operational when needed. With publicly accessible chargers, this certainty is not guaranteed and could require drivers to wait for a charger to become available in addition to waiting for the vehicle to be charged. For drivers operating on fixed delivery schedules, this could have ramifications on the timing of customer deliveries and also a driver's Hours of Service[22]. According to the American Transportation Research Institute, the driver's salary and benefits account for the largest costs associated with operating a truck. Keeping the driver as productive as possible is important for truck operators. Many companies looking to use BEVs will therefore be installing dedicated charging infrastructure in their depots, garages, and fleet bases to make use of the "downtime" associated with vehicles that return to base and can be charged, typically overnight, until the next delivery round.

It is anticipated that 90 percent of MHD electric vehicle charging will be undertaken at home, depots, and fleet bases where vehicles will start and finish their journeys. However, other business models such as Charge as a Service and Truck as a Service (described later in the report) and publicly accessible facilities with reservable time charging slots, can combine

FIGURE 26. Ownership of Depot/Base Characteristics



22 "Hours of service" (HOS) refers to the maximum amount of time drivers are permitted to be on duty including driving time, and specifies number and length of rest periods, to help ensure that drivers stay awake and alert. https://www.fmcsa.dot.gov/regulations/hours-of-service

certainty of charging at off-site facilities. Characteristics associated with Depot/Base ownership are shown in **Figure 26**.

Ancillary Equipment. Some trucks are equipped with ancillary equipment requiring power such as refrigerators, concrete mixers, waste compaction, cranes or bucket lifts. These types of equipment could represent a partial electrification of the vehicle. Technology continues to evolve and truck OEMs are producing electric trucks with power take-off capabilities to support a wide variety of uses. However, the more widespread use of these type of vehicles is limited. It is worth noting that powering some ancillary equipment with clean technology is also being progressed, especially in the transportation refrigeration sector. Mainstream OEMs such as Thermo King and Carrier Transicold, are deploying both fully electric and hybrid refrigeration units suitable for both single unit trucks and trailers.

The characteristics identified above may evolve over time as MHD ZEVs become cheaper, there is greater availability of publicly accessible quick chargers and hydrogen, and a greater supply of new and used ZEVs proliferate on the market.

EXAMPLE USE TYPES

Several use cases have been identified to illustrate the charging needs and requirements associated with different types of MHD ZEV users within North Carolina.

Contractors and Tradespeople

Class 2b-3 represents 32 percent of the vehicles that are projected to be sold under the proposed ACT rule in North Carolina. A significant market for these vehicles will be contractors and trades people using vans and larger pickup trucks[23].

Duty Cycle	• Travel from home or depot to the construction site/workplace. Travel distance can be highly variable.
Depots/Garages	• Likely to be a mix of users owning their vehicles or owned by a company and taking them home, as well as larger companies/fleets hosting their vehicles at depots.
Chargers	• Home charging - likely to use a more powerful, professionally installed Level 2 home charger (approximately 25 miles range per hour), than a Level 1 charger. • Publicly accessible or depot based fast chargers could also be utilized.
Considerations	• Permitting for electric charger installations. • Access to at-home charging if living in a multi-occupancy building or other building where home-based charging is not possible. • Potential to locate Level 2 and Fast Chargers at sites, where contractors may visit, such as construction supply stores. • Power and supply associated with depot-based charging.

23 Note that some models of pickup trucks may be associated with both Class 2A and Class 2B. A standard range F-150 Lightning with a Super Crew cab is categorized as Class 2A (GVWR 8,250 lbs), while the extended range version is Class 2B (GVWR 8,550 lbs).

Package Deliveries

Package delivery companies use a range of vehicles including Class 2b through to Class 5 trucks depending upon configuration and payload.

Duty Cycle	• Delivery companies will purchase BEVs that match route requirements e.g. range and dwell time • Range will vary – urban and metropolitan routes with greater delivery density are likely to be shorter than less dense, rural routes. • Routes usually operated in the working day, with minimal routes operated in the late evening or overnight.
Depots/Garages	• Most vehicles likely to be charged at depots, but some vehicles operated by owner drivers could be charged at home.
Chargers	• Predominately Level 2 chargers. Large fleets such as UPS and FedEx may need to supplement Level 2 with fast chargers for larger delivery vehicles.
Considerations	• Permitting for electric charger installations. • Access to at home charging if living in a multi-occupancy building or other building where home-based charging is not possible. • Capacity of existing power supply to support depot-based charging, especially at large fleet locations. • National and large fleets may purchase and register their vehicles outside of NC. • Access to charging infrastructure for delivery company contractors. Many package delivery companies, such as Amazon and FedEx, sub-contract some or all the delivery routes from their distribution depots.

Regional Food and Beverage Distributors

North Carolina hosts many food and beverage companies with regional distribution centers. These include Sysco, US Foods, Gordon Food Service, PepsiCo, Coca Cola Consolidated, Empire Distributors, NDCP and Coastal Beverage Company to name a few. Operators will typically use Class 4 to Class 8 vehicles including both straight trucks and tractor trailers.

Duty Cycle	• Delivery companies will purchase BEVs that match route requirements e.g. range and weight of goods carried. • Range will vary – urban and metropolitan routes with greater delivery density are likely to be shorter than less dense, rural routes. • Delivery routes operated during the working day with some early starts. Some routes may return back to the depot during the day for re-loading the delivery truck.
Depots/Garages	• Anticipated that all vehicles will charge at depots.
Chargers	• Predominantly fast chargers, though some of the Class 4 – 6 vehicles could be charged with Level 2 if the dwell time is sufficient. • Expect significant use of demand management systems for cost effective charging.
Considerations	• Permitting for electric charger installations. • Capacity of existing power supply to support depot-based charging, especially at large fleet locations. • Scale of charging equipment required for large fleet locations. • National and large fleets may purchase and register their vehicles outside of NC. • Not all routes will be suitable for BEVs.

Waste Haulers

There are multiple methods associated with trash collection in North Carolina. These include:

- Towns contracting with private contractors, such as Waste Management and Waste Industries
- Towns operating their own collection fleets
- Residents organizing their own collections with private contractors
- Businesses contracting with private contractors

Duty Cycle	• Route length and weight of trash collected during the collection round will influence which routes are suitable for BEVs. • Urban routes are expected to be the earliest adopters.
Depots/Garages	• Anticipated that all vehicles will charge at depots.
Chargers	• Predominantly fast chargers, though this will be dependent upon vehicle dwell time
Considerations	• Permitting for electric charger installations. • Existing site power associated with depot-based charging, especially at large fleet locations. • Scale of charging equipment required for large fleet locations. • National and large fleets may purchase and register their vehicles outside of NC. • Not all routes will be suitable for BEVs. • Cost of electric waste collection vehicle currently 60-70 percent more than diesel.[24]

School Buses

There are 14,104 school buses operating daily in North Carolina, transporting 794,950 students and traveling 181,285,181 route miles per year[25]. Forty-three electric school buses have been funded under the N.C. Volkswagen Settlement Program. In 2022, five school districts were awarded $12.2M to deploy 31 electric school buses funded by the EPA Clean School Bus Program. Twenty other school districts in the state are on a wait list for additional EPA support to fund 154 electric buses.

Duty Cycle	• School buses typically operate 2 runs per day. • Additional ad hoc trips may be needed for other activities, such as field trips and sports. • Average mileage per bus of 70 miles per day,[26] but duty cycle varies across the state.
Depots/Garages	• School buses can be domiciled at schools and garages.
Chargers	• Bus staging locations could be equipped with Level 2 Chargers or a mix of Level 2 and Fast Chargers, depending upon volume of buses to be charged and dwell time. • The dispersed nature of small numbers of buses based in some schools is an advantage for low power loads and Level 2 charging, with potential minimal upgrade to the grid infrastructure required. • Ad hoc journeys such as field trips, may require access to either publicly accessible or destination charging facilities.
Considerations	• Space for chargers at schools and depots. • Permitting for electric charger installations. • Access to power supply and connections. • Potential to offer staff workplace charging when buses are not charging during the day or vehicle to grid opportunities. • FCEV buses for locations where BEV is impractical due to grid connections or duty cycles of the buses. • Cost of Zero Emission Buses (ZEB) versus cost of traditional bus - 400 percent premium • Cost and funding of charging infrastructure – school bus replacement funds cannot pay for infrastructure.

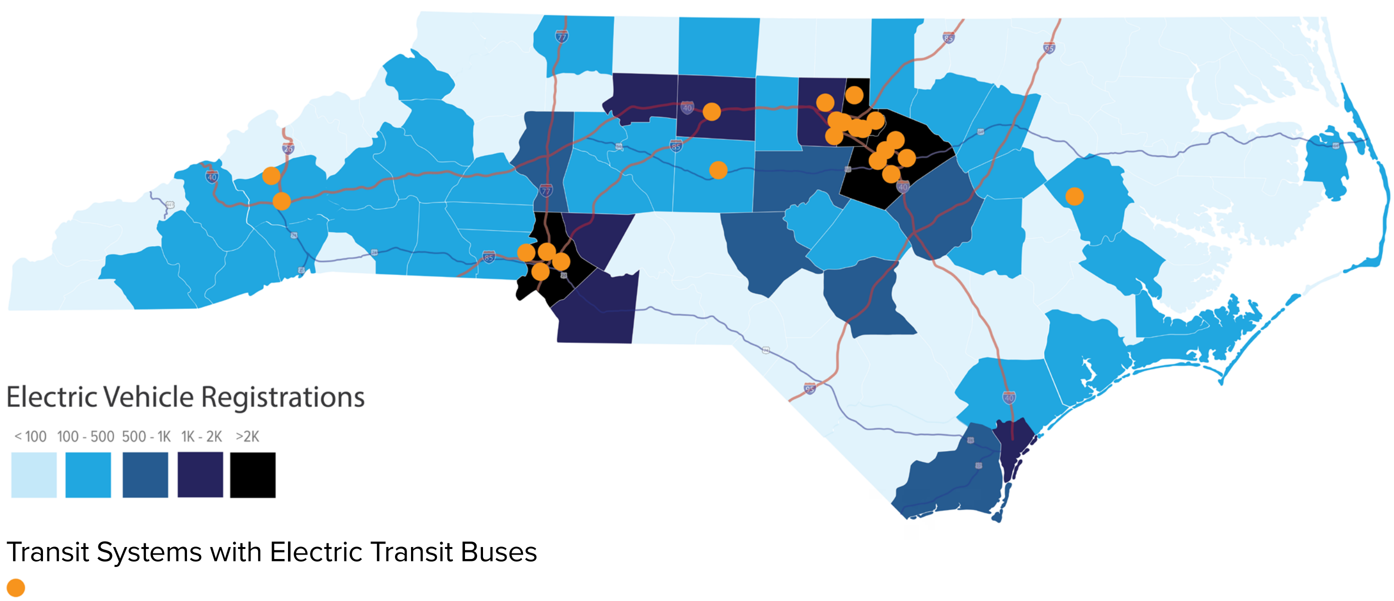
24 https://www.utilitydive.com/news/swana-alternative-fuel-refuse-trucks-cng-electric-hydrogen-fuel-cell/631813/
25 http://www.ncbussafety.org/LovethebusNC/documents/LovetheBusFacts_ae.pdf
26 HDR analysis based on 185 school days

Transit

Transit operators are a good fit for electric buses, due to the fixed nature of the bus routes and their schedules. Since 2018, North Carolina bus operators have been adding electric buses to their fleets and locations are shown in **Figure 27**. The City of Greensboro has 17 electric buses with recent funding increasing this to 21, and the Charlotte Area Transit System (CATS) has 18, soon to be increased to 25 of its fleet of 304 buses.

Duty Cycle	• Depends upon schedule, timings and routes served. CATS identifies 70 percent of their current routes are suitable for battery technology[27]
Depots/Garages	• Buses are mostly domiciled in bus depots
Chargers	• Bus staging likely to be equipped with DCFCs.
Considerations	• Space for chargers in bus depots • Access to power supply and connections, especially large numbers of buses requiring simultaneous charging • FCEV buses for locations where BEV is impractical due to grid connections or duty cycles of the buses • Cost of Zero Emission Buses (ZEB) versus cost of traditional bus • Cost and funding of charging infrastructure, though access to Federal Transit grants can support infrastructure installation

FIGURE 27. North Carolina Transit Systems with Electric Transit Buses
Source: Pluginnc.com, published October 17, 2022



27 https://www.charlottenc.gov/files/sharedassets/cats/v/1/mtc-meeting-summaries-amp-agendas/mtc_final_agenda_march_22_2023.pdf

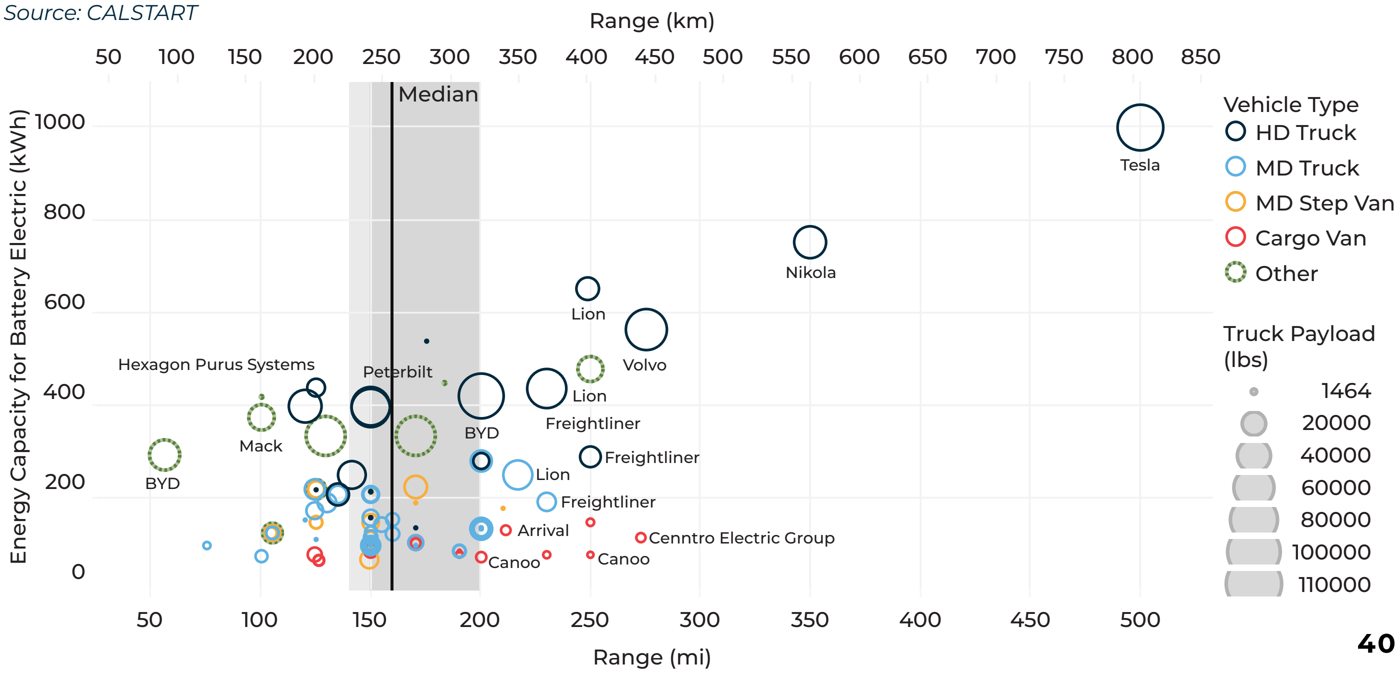
Long Distance Trucking

Many trucks on the North Carolina highway network will be moving goods over long distances, either collecting or delivering goods to or from North Carolina's freight facilities or just passing through the state. With trips up to 500-600 miles per day, a vehicle's range and time taken to refuel/recharge are critical. **Figure 28** illustrates that apart from Tesla, there are very few BEV OEMs developing solutions in the longer haul sector. Longer range requires higher capacity batteries, which will then require faster, high-capacity chargers to maximize charging during a driver's hours of service breaks.

Not all MHD vehicle batteries will be able to accept higher charging rates. However, both battery and charging technology continues to evolve. To support longer distance trucks, charging facilities will need to charge at speeds of greater than one megawatt. The development of the Megawatt Charging System (MCS), capable of a peak charging power of 3.75 megawatts (equivalent to an average power demand of 3,200 homes) was launched in 2022 and is designed to be a global standard, which includes standardizing the location of the vehicle charging port on the left-hand side of the vehicle.

Duty Cycle	• Route length can be variable with distances of up to 500-600 miles per day • Delivery or collection times for freight can be throughout the day, with some facilities operating a timed slot system • Trips may be operated on a fixed pattern, e.g. regular movement of goods between two sites, or random where a truck driver decides to take loads based on highest financial return • Hours of service will dictate distance driven and where the driver will take their daily rest
Depots/Garages	• Anticipated that most longer distance trucks will refuel/recharge at truck rest stops or company facilities
Chargers	• Predominantly fast chargers for charging overnight, or extreme fast chargers for charging during the 30 minute rest stop
Considerations	• Speed of charging and refueling; FCEV vehicles have the advantage with much quicker refueling times • Availability of charging facilities at rest stop locations; to provide certainty, reservation systems to allow drivers to book chargers are likely • Electrical loads and grid capacity for rest stops deploying chargers • A network of charging locations and hydrogen dispensing facilities will be required • Cost of ZEV vehicles in a market sector with a high proportion of owner operators • Lack of ZEV vehicles in this market sector

FIGURE 28. Truck Model Range Comparison
Source: CALSTART



CHARGING INFRASTRUCTURE TO SUPPORT ACT SALES PROJECTIONS

This section of the report identifies the charging infrastructure necessary to support the proposed ACT rule sales projections.

Number of Chargers

The preliminary estimate of ZEV sales by model year associated with the proposed ACT rule is the baseline for the calculation of the number of chargers required. To identify the number of chargers required, a number of assumptions were made and several steps undertaken. These are outlined below.

Step 1. A VIN decoder was used to analyze DMV data (approximately 10 million entries) to provide a greater breakdown of the preliminary sales estimates for Class 4-8 vehicles.

Step 2. Converted model year sales to a calendar year in which the vehicle sale occurs. This recognizes that models can be sold in multiple years. For example, Model Year (MY) 2027 has 15 percent of sales in 2026, 75 percent in 2027 and 10 percent in 2028. Sales associated with MY 2036 were also estimated to reflect MY2036 sales in calendar year 2035. **Table 10** identifies the MHD ACT sales by calendar year based on NCDEC sales ACT rule sales estimates.

TABLE 10. MHD Vehicles Sales by Sales Year

Sales Year	Class 2b-3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 7- 8 tractors	Total Vehicles
2026	225	26	30	38	36	230	90	675
2027	1,425	171	198	249	235	1,502	585	4,365
2028	2,040	272	315	397	375	2,392	900	6,690
2029	2,615	361	418	526	497	3,173	1,110	8,700
2030	3,140	448	519	653	617	3,938	1,310	10,625
2031	3,715	504	584	735	694	4,432	1,525	12,190
2032	4,240	561	649	817	772	4,926	1,770	13,735
2033	4,830	612	708	892	843	5,379	1,800	15,065
2034	5,430	663	767	966	913	5,826	1,800	16,365
2035	5,949	716	829	1,045	987	6,297	1,874	17,697

Step 3. Assumed that 20 percent of ZEVs are removed from the NC vehicle inventory every year after 5 years, to reflect fleet turnover, irreparable vehicles and sales of used vehicles outside the state and a 1 percent growth in sales volumes from 2036. **Table 11** details the total NC MHD ZEV inventory by year based on DEQ's proposed ACT rule projected sales and the above assumptions. In 2035 MHD ZEVs represent between 12 and 16 percent of the state's MHD registered inventory[28].

Step 4. Accounted for a proportion of ACT sales being hydrogen FCEV. It is estimated that FCEVs will be adopted in 2031 for Class 4 - 8 MHDs and account for 4 percent of these vehicles through to 2035[29]. The number of estimated FCEV vehicles are identified in **Table 12**.

28 A high growth MHD vehicle inventory is based on a 3.1 percent annual growth rate which was derived from MHD registrations in NC from 2019 to 2022 and a low growth rate of 1 percent sourced from truck sales associated with the California ACT Regulation.
29 Information based upon NREL. Decarbonizing Medium & Heavy Duty On-Road vehicles: Zero Emissions Costs Analysis

TABLE 11. MHD ZEV Inventory by Year

Year	Class 2b-3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 7- 8 tractors	Total
2026	225	26	30	38	36	230	230	815
2027	1,650	197	228	287	271	1,731	815	5,180
2028	3,690	469	543	684	646	4,123	1,715	11,870
2029	6,305	830	961	1,210	1,143	7,296	2,825	20,570
2030	9,445	1,278	1,480	1,864	1,760	11,234	4,135	31,195
2031	13,115	1,777	2,057	2,591	2,447	15,620	5,859	43,467
2032	17,025	2,298	2,661	3,351	3,165	20,200	7,466	56,166
2033	21,117	2,794	3,234	4,074	3,847	24,558	8,852	68,477
2034	25,286	3,266	3,781	4,763	4,498	28,709	10,015	80,319
2035	29,346	3,701	4,284	5,396	5,096	32,526	10,990	91,339

TABLE 12. FCEV by Sales Year

Sales Year	Class 2b-3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 7- 8 tractors	Total
2026	-	-	-	-	-	-	-	-
2027	-	-	-	-	-	-	-	-
2028	-	-	-	-	-	-	-	-
2029	-	-	-	-	-	-	-	-
2030	-	-	-	-	-	-	-	-
2031	-	-	-	-	-	-	-	-
2032	-	22	26	33	31	197	71	380
2033	-	24	28	36	34	215	72	409
2034	-	27	31	39	37	233	72	437
2035	-	29	33	42	39	252	75	470

TABLE 13. Distribution of Chargers by Vehicle Class

	Class 2b-3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 7-8 Tractors
Level 2	95 percent	60 percent	40 percent	20 percent	-	-	-
DCFC	5 percent	40 percent	60 percent	80 percent	100 percent	100 percent	100 percent

Step 5. Calculated the number of vehicles that would be charged by Level 2 and DCFC chargers. Vehicle type and their use typology will determine the type of charger to be used. Lighter vehicles with smaller battery capacity will typically be charged with Level 2 chargers and heavier vehicles with larger battery capacity will be charged by DCFC. However, Class 7 and 8 vehicles will only be charged by DCFC. This analysis reflects different charger applications and that there is expected to be a mix of Level 2 and DCFC as shown in **Table 13** which is based upon the Consultant's team assessment.

Step 6. Assessed the number of chargers required to charge the projected sales volumes. To reflect these factors, the following ratios have been used, informed by vehicle duty cycles such as dwell time, overnight charging, charging speeds, and costs.

- A ratio of 1 vehicle per Level 2 charger (to reflect overnight charging)
- A range of 1 to 3 vehicles per DCFC charger.

Analysis Results

The number of chargers required to support the ACT projections are outlined below.

By 2035, there is expected to be approximately 32,787 Level 2 chargers within North Carolina associated with MHD charging and ACT vehicle sales (**Figure 29**).

The number of DCFC chargers in 2035 to support ACT sales ranges from 19,339 chargers (based on a ratio of 3 vehicles per DCFC) to 58,016 chargers (ratio of 1 vehicle per DCFC), as shown in **Figure 30**.

FIGURE 29. Level 2 Chargers Required to Support ACT Projections

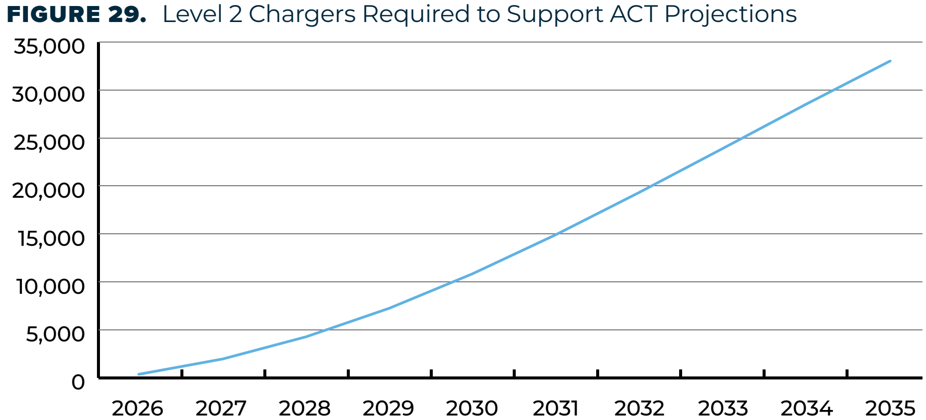
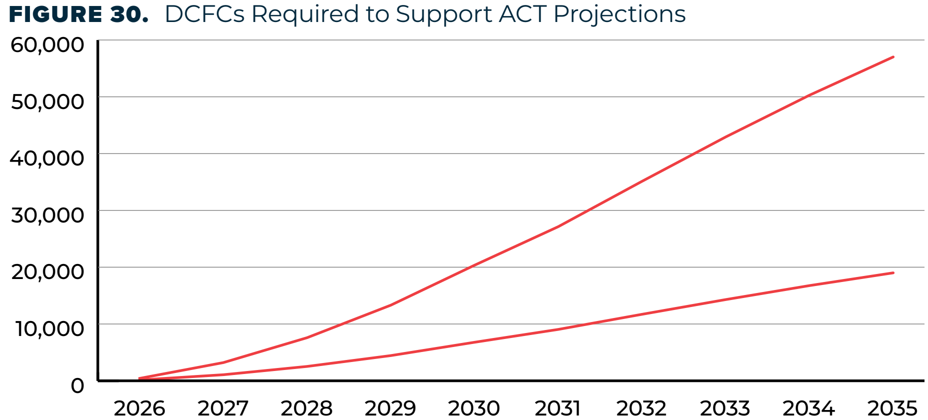


FIGURE 30. DCFCs Required to Support ACT Projections



Cost of Charging Infrastructure

Charging infrastructure and installation costs have been estimated by HDR using recent project experience. These costs and assumptions are identified in **Table 14**.

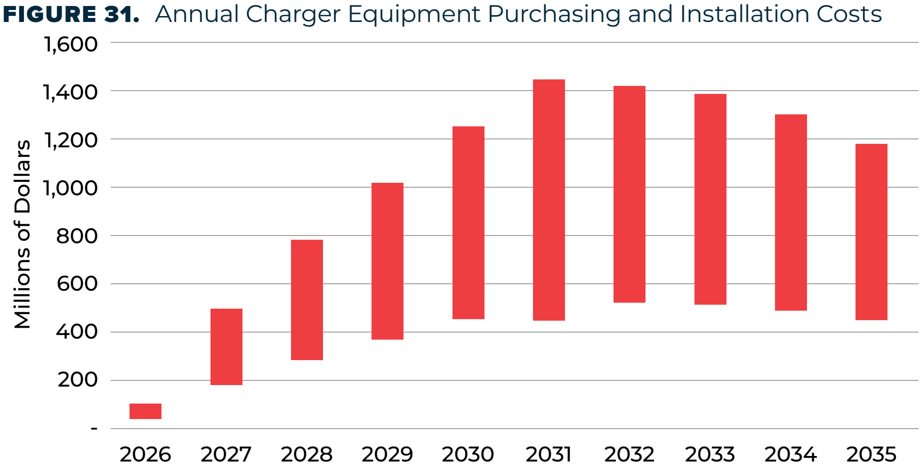
TABLE 14. Charging Equipment and Installation Costs

Charging Category	Charger	Distribution	Cost	Comments/Assumptions
Level 2	Residential	25 percent	$1,500 per charger	$500 charger costs and $1,000 installation costs
	Commercial	75 percent	$20,000 per charger	More robust chargers than residential, typically weather proof and higher installation costs associated with wire, conduit, excavation, concrete, utility connection, etc
DCFC	50 kW	80 percent	$2,000 per charger kW	Indicative cost includes permitting, charger equipment purchases, construction of customer infrastructure such as conduits and pads, utility connection, minor upgrades to utility grids such as new meters and commissioning of equipment
	150 kW	15 percent		
	350 kW	5 percent		

The annual costs for Level 2 and DCFC charger purchasing, and installation are shown in **Figure 31**. These costs are shown as a range to reflect the variability of different vehicle to charger ratios.

These costs do not include any substantial upgrades associated with electricity distribution system infrastructure. While distribution system upgrades are expected, due to the location specific nature of distribution system infrastructure, the other non-MHD demand characteristics at potential locations (both of which the project team does not have any visibility) and the load associated with MHD charging demand, it has not been possible to assess a cost associated with significant electricity distribution system upgrades associated with the ACT rule sales projections.

FIGURE 31. Annual Charger Equipment Purchasing and Installation Costs



Location of Charging Infrastructure

As mentioned previously in this report, it is expected that chargers will be located in most instances where the vehicle is domiciled to take advantage of off-peak electricity cost, typically overnight and to provide certainty of charging the vehicle. To assess the likely location of vehicles domiciled in North Carolina, several Federal, North Carolinian and trip data sources have been used:

Data set 1. NC DMV data. Individual vehicle records were identified for vehicle body types classified as Truck, Van and Truck Tractor. A VIN decoder was used to analyze 2.6 million vehicle records to identify the gross vehicle weight class according to the National Highway Traffic Safety Administration (NHTSA) classifications (which have a slightly different categorization for Class 2 vehicles), which is contained within the VIN code.

- Class 1: 6,000 lb or less
- Class 1A: 3,000 lb or less
- Class 1B: 3,001 - 4,000 lb
- Class 1C: 4,001 - 5,000 lb
- Class 1D: 5,001 - 6,000 lb
- Class 2: 6,001 - 10,000 lb
- Class 2E: 6,001 - 7,000 lb
- Class 2F: 7,001 - 8,000 lb
- Class 2G: 8,001 - 9,000 lb
- Class 2H: 9,001 - 10,000 lb
- Class 3: 10,001 - 14,000 lb
- Class 4: 14,001 - 16,000 lb
- Class 5: 16,001 - 19,500 lb
- Class 6: 19,501 - 26,000 lb
- Class 7: 26,001 - 33,000 lb
- Class 8: 33,001 lb and above

Nearly 1.8 million vehicle records with zip code information associated with Class 2G and greater were identified.

Data set 2. Federal Motor Carrier Safety Administration Records. Motor Carrier Census Information was downloaded from the FMCSA Safety Measurement System.[30] Companies that operate commercial vehicles transporting passengers or hauling cargo in interstate commerce must be registered with the FMCSA and must have a USDOT Number. Also, commercial intrastate hazardous materials carriers who haul types and quantities requiring a safety permit must register for a USDOT Number. USDOT numbers are required if the company has vehicles that:

- Have a gross vehicle weight rating or gross combination weight rating, or gross vehicle weight or gross combination weight, of 4,536 kg (10,001 pounds) or more, whichever is greater; or
- Are designed or used to transport more than 8 passengers (including the driver) for compensation; or
- Are designed or used to transport more than 15 passengers, including the driver, and is not used to transport passengers for compensation.

Analysis of the FMCSA data set associated with North Carolina is summarized below in **Table 15**.

TABLE 15. FMCSA Data

Fleet Size	Number of Companies	Number of Vehicle Power Units
1	23,672	23,672
2-5	12,373	34,334
6-10	2,054	15,461
11-20	1,099	16,008
21-50	588	18,377
51-100	189	13,184
101-200	86	11,652
201-500	45	13,482
501-1000	12	7,989
1001-1500	5	5,885
>1501	9	36,570
No Vehicles Registered	728	-
	40,860	196,614

30 Safety Measurement System - Downloads (https://ai.fmcsa.dot.gov/SMS/Tools/Downloads.aspx)

It should be noted this is the raw dataset which has not been cleansed by FMCSA. A subsequent cleansing exercise was undertaken and removed entries where the MCS-150[31] date was prior to 2020 and where there were anomalies with the number of power units registered. Records with fleet sizes above 300 vehicles at the same location were also removed, as there was a high correlation with the company registered address not being an operational facility where trucks were domiciled. For example, the Old Dominion Freight Line has its national fleet of over 10,000 vehicles registered at its headquarters in Thomasville, NC.

Data set 3. Streetlight data. Trip information from the Streetlight dataset was analyzed for medium and heavy-duty vehicles that had a start time between 5 a.m. and 9 a.m. Streetlight data is a commonly used data set for transportation planning purposes and is sourced from mobile devices such as smart phones, connected cars, and trucks with commercial fleet management systems including navigation-GPS records. The start-time period was chosen to reflect that a high proportion for MHDs will start their daily journey between these times.

An activity index and activity rank based on the sum of the normalized values for the streetlight combined medium and heavy vehicle count, the FMCSA power unit count, and the DMV count at the zip code geographical level was undertaken. This indexing and ranking identifies zip code locations with a greater propensity for medium and heavy-duty charging are shown in the figures below as lighter green shades.

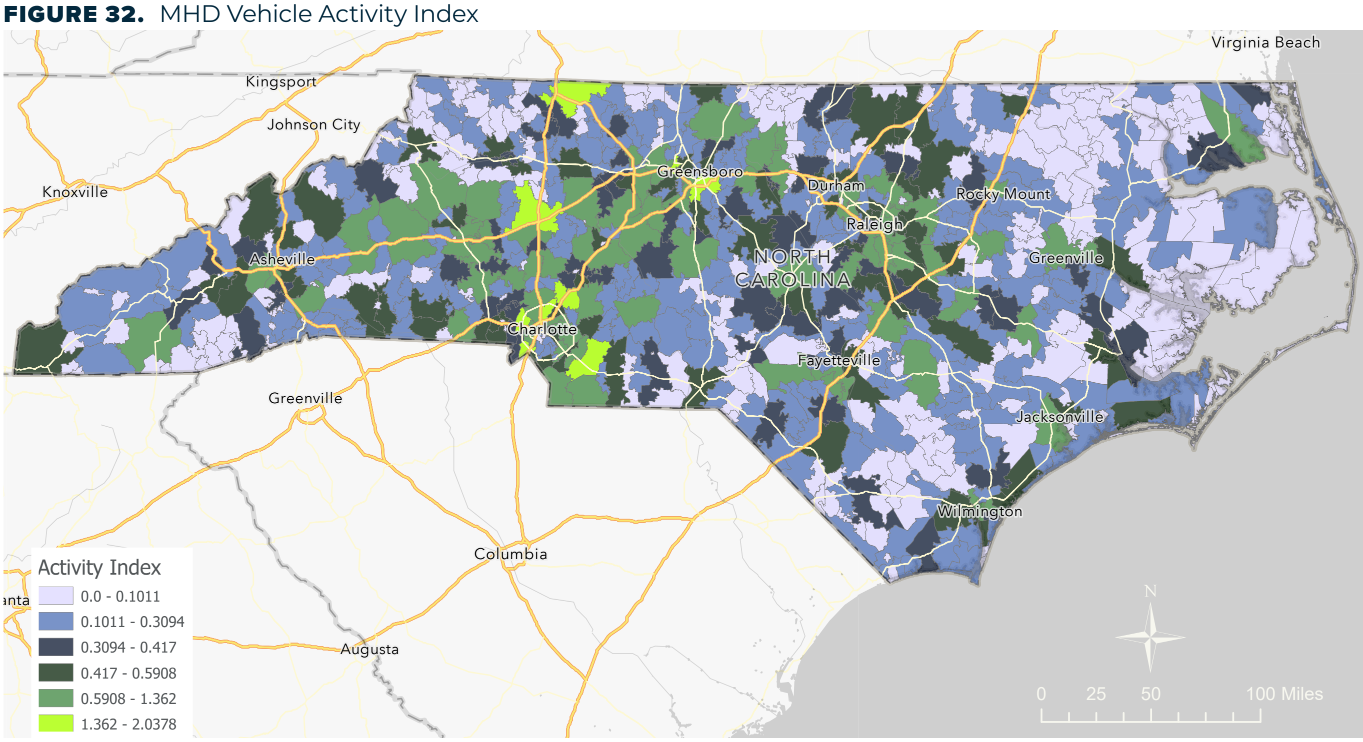
As **Figure 32** illustrates, there are several zip codes where there is a concentration of activity (lighter green shades represent a higher potential for MHD operating locations).

Table 16 identifies the top 10 high concentration zip codes.

TABLE 16. Top 10 High Concentration Zip Codes

Zip Code	Locality	Zip Code	Locality
28269	Charlotte	27406	Greensboro
28273	Charlotte	28027	Concord
28214	Charlotte	27409	Greensboro
28110	Monroe	28625	Charlotte
27030	Mount Airy	27284	Charlotte

FIGURE 32. MHD Vehicle Activity Index



31 MCS-150 is a mandatory filing requirement for all motor carriers, completed on two yearly basis.

TABLE 17. MHD BEV Daily Demand (kWh)

	Class 2B -3	Class 4	Class 5	Class 6	Class 7	Class 8	Class 7- 8 tractors
GVWR	8501-14,000	14001-16000	16001-19500	19501-26000	26001-33000	>33001	>26,001
Battery Size (kWh)	113	123	226	252	291	376	565
Example Vehicle	Mercedes E-sprinter	Rizon e16L	Freightliner MT50e	Freightliner eM2	Freightliner eM2	Mack LR Electric	Volvo VNR Electric Tractor (6 batteries)
Daily Demand (kWh)							
Lower	56.5	61.5	113.0	126.0	145.5	188.0	282.5
Medium	67.8	73.8	135.6	151.2	174.6	225.6	339.0
Higher	90.4	98.4	180.8	201.6	232.8	300.8	452.0

Electricity Demand

Electricity demand associated with the ACT sales projections has been estimated for both daily and annual demand using lower, medium and higher volume scenarios. The basis for the demand scenario is the power demand for each vehicle class, estimated by how much the vehicle battery needs to be replenished daily as shown below:

- Low demand scenario – from 20 percent to 70 percent
- Medium demand scenario – from 20 percent to 80 percent
- High demand scenario – from 20 percent to 100 percent

Table 17 identifies the daily power demand and representative vehicle for each vehicle class and scenario.

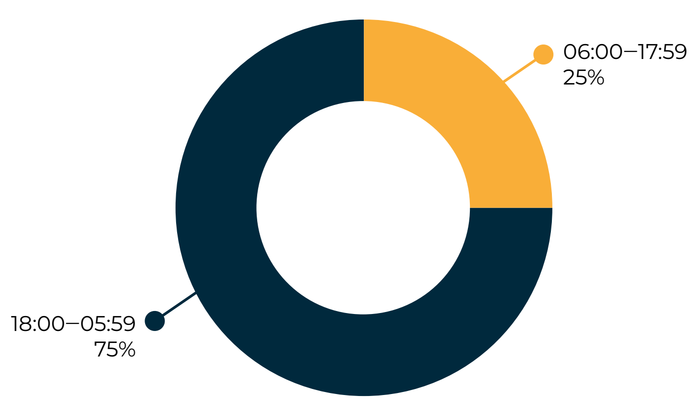
The annual higher demand also uses a planning factor that MHD vehicles will be used on average 6 days per week, while the annual medium and lower demand factors use 5.5 and 5 days per week respectively. This is intended to reflect that there are different use cases as to how vehicles will be used and use at weekend is varied.

Time of Day Demand

Using depot data[32] charging profiles, daily demand was assessed for vehicles using DCFC infrastructure, typically the heavier weight vehicles with 27 percent of demand associated between 06:00 and 17:59. Demand associated with vehicles using Level 2 chargers was assessed at 15 percent between 06:00 and 17:59, as most use cases in these vehicle classes are expected to have a higher share of overnight charging.

The overall demand by time of day is illustrated in **Figure 33**.

FIGURE 33. MHD BEV Demand by Time of Day



32 Borlaug, B., Muratori, M., Gilleran, M. et al. Heavy-duty truck electrification and the impacts of depot charging on electricity distribution systems. Nat Energy 6, 673–682 (2021)

FIGURE 34. Daily Load Consumption (Megawatts per Day) Scenarios

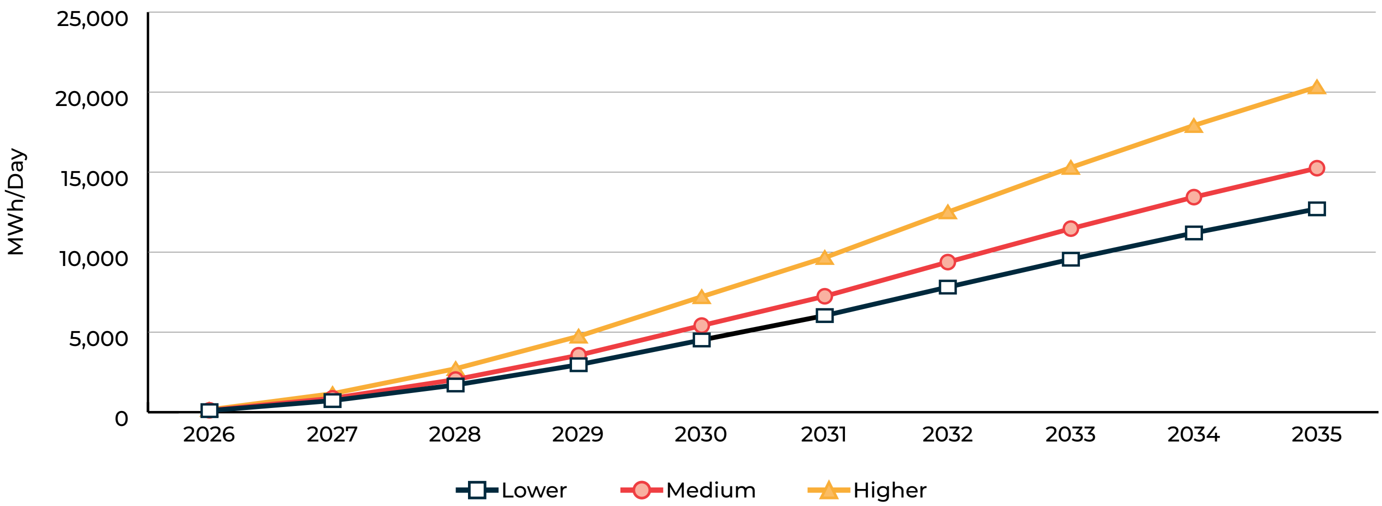
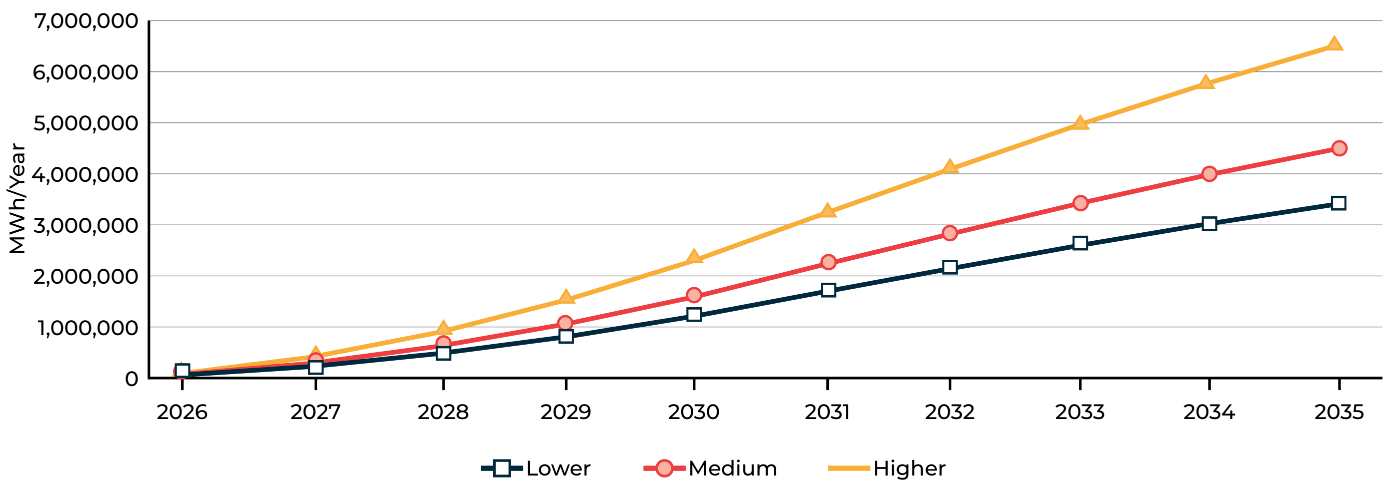


FIGURE 35. Annual Power Demand (Megawatts Per Annum) Scenarios



Daily Demand

The daily power demand associated with each scenario to recharge the volume of MHD associated with ACT rule sales in North Carolina between 2026 and 2035 is shown in **Figure 34**.

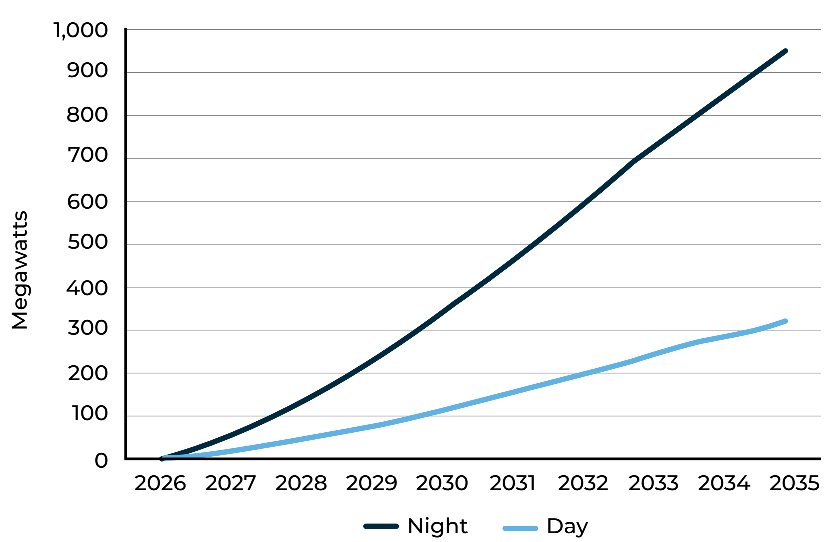
Annual Demand

The estimated annual power demand for each scenario is shown in **Figure 35**.

Hourly Demand

The average hourly demand for day and night related to MHD charging for the medium demand scenario is shown in **Figure 36**.

FIGURE 36. MHD BEV Average Hourly Power Demand



BUSINESS MODELS TO SUPPORT ZEVS

The emerging ZEV market and associated charging infrastructure is leading to several business models associated with the ownership and operation of charging infrastructure. These business models could be applied in North Carolina and are outlined in the following sections.

Own and Operate Charging Infrastructure

The traditional business approach to charging infrastructure is for a fleet owner to own and operate it. The fleet owner is typically responsible for designing, procuring and installing the charging equipment, paying for utility infrastructure upgrades (but this is dependent upon individual utilities), having a repair/maintenance program in place and paying for the electricity used. Vehicle OEMs may also have preferred charger relationships with charger manufacturers and the vehicle buyers may make use of these relationships to purchase chargers.

Charging as a Service

Unlike the traditional approach, with Charging as a Service (CaaS) the fleet operator does not own the charging infrastructure. A CaaS company would be responsible for designing, procuring and installing the infrastructure as well as paying for the electricity used. The fleet operator pays a fee to the CaaS company which will cover capital and operational costs as well as overhead and profit charges. This service may be more expensive in the longer term, but it means a fleet operator isn't confronted with a large upfront capital cost and can also delegate responsibility for performance of their charging infrastructure. CaaS can be deployed in several ways. A fleet owner could adopt a CaaS solution at their depot or garage. This may be on exclusive basis, where only the vehicles using the charging infrastructure are based at the site, or a semi exclusive operation, that allows the CaaS provider to sell unused capacity to other electric truck operators. Another option is an off-site facility, where the CaaS provider has their own site and offers charging services to multiple fleet operators. Fleet operators may base their vehicles here, but if involved in the delivery or movement of goods, a driver is likely to start their shift at this location and then travel to the warehouse or distribution center to load their vehicles for the delivery round.

An example of a charging provider is Greenlane, a joint venture between Daimler Truck North America, NextEra Energy Resources and BlackRock. They aim to design, develop, install and operate a U.S. nationwide, high-performance zero-emission public charging and hydrogen fueling network for MHD battery-electric and hydrogen fuel cell vehicles. A commercial vehicle reservation system would be used to provide certainty of charging for operators.

CaaS would appear to have some potential for use in North Carolina in the early stages of MHD adoption as fleets transition to ZEV. Fleet operators are typically risk adverse and want to trial and pilot new vehicles and technologies to ensure the vehicles are reliable and can satisfy their customer needs. Fleets who are trialing small numbers of vehicles are unlikely to commit significant investments in charging infrastructure, until they are committed to an EV transition plan. CaaS facilities, serving multiple users could therefore be deployed in areas which have high concentrations of MHD fleets such as near Charlotte Airport, the north, east and south sub-markets in Charlotte, and Greensboro. This solution may work for fleets that are confronted with utility connection challenges, but still want to deploy BEVs until the challenges are overcome.

Truck as a Service

Truck as a Service (TaaS) is an all-inclusive, one stop shop service whereby a driver or company pays a fee for the use of an electric truck, but the charging of the truck is also the responsibility of the TaaS provider. A driver or company may operate the vehicle, but the vehicle is returned back to the TaaS provider at the end of the working shift for charging. The driver then picks up the vehicle the next day. Similar to CaaS, TaaS provides an entry mechanism for fleets and users into the EV market. WattEV and Zeem are two companies offering this service in California. One of Zeem's charging facilities will host 132 Level 2 and DCFC charging stations.

Utility Investment

Typically, utility investments end at the customer's electricity meter. Utilities own the infrastructure up to the meter and customer's own the infrastructure after the meter. However, utilities could develop business models that support the development, implementation, operation and financing of customer charging infrastructure and gaining revenue from it. This could potentially be applied in certain sectors such as school or transit buses were there is less commercial risk.

MHD CONSIDERATIONS, CHALLENGES AND ISSUES

This section identifies the considerations, challenges and issues associated with the uptake of MHD ZEVs and has been informed by the research undertaken and discussions and feedback from a wide variety of stakeholders. Stakeholders engaged in this study include:

OEMs	Charger manufacturers	Member Organizations	Fleet Companies/ MHD Users	Charging Facility Operators	Utilities
• Volvo Trucks • Cummins • Arrival	• Proterra • Heliox	• NC Electric Cooperatives • NC Trucking Association	• Food Lion	• Travel centers of America • Greenlane	• Duke Energy

PUBLICLY ACCESSIBLE CHARGING FOR MHD VEHICLES

It is expected that the focus of charging infrastructure during the early years of the ACT rule will be in fleet depots, bases and garages. Publicly accessible or opportunity charging for MHD vehicles are expected to have a role to play in NC's transition to ZEVs, especially in the lower weight class associated with Class 2B, and over time, the heavier, longer distance trucking sector where facilities are potentially deployed at truck stops and other locations where drivers take their Federally mandated rest breaks. Publicly accessible facilities with reservable charging time slots may offer operators an entry method into BEV operations.

CHARGING AND FUELING

When, where and how ZEV vehicles will be fueled or charged is the most significant consideration facing fleet managers and vehicle operators in their decision-making process associated with adopting ZEVs. The wide availability of diesel and petroleum fuels, be it purchasing fuel from gas stations, truck stops or companies owning fuel facilities in their depots or bus garages, and the time taken to refuel a vehicle are key advantages associated with using fossil fueled vehicles. However, fueling and charging MHD ZEVs is significantly different to traditional vehicle fueling and, also the charging of light duty vehicles. This presents a steep learning curve for vehicle operators and fleet managers.

Charging BEVs requires fleet managers and operators to consider multiple factors, including:

- The number of vehicles that will require charging, potentially multiple vehicles at the same time
- The type of vehicle and specifically the size of battery that needs to be recharged
- The time available to recharge the vehicle
- When the vehicle can be charged (time of day)
- Where charging infrastructure is located
- Ensuring chargers are compatible with the vehicles they operate and considering connector types, communication protocols, voltage ratings etc.
- Access to the power, connections to the electricity distribution system and working with utility companies
- Electricity costs

It is important for the fleet operator to "right size" their charging infrastructure to ensure their fleet's charging needs are met and not over invest in charging equipment - especially fast chargers.

Fleet operators will also need to consider and plan for potential future expansion of their EV fleets ensuring charging infrastructure can be scaled and implemented to meet those future needs.

ACCESSING POWER SUPPLY

Fundamentally this is the most important consideration associated with BEV MHD fleet transition. Fleet operators will need to consider the provision of power supply in their financial and planning timeline decision making process associated with adopting a BEV fleet. This includes:

- Identifying the power load associated with vehicle charging including, type and number of chargers.
- Working with utilities to identify any utility infrastructure upgrades, including distribution infrastructure and the site's existing service connection that may be required, and also cost, who pays for what upgrade, as well as timelines.
- Designing and constructing the site to accommodate vehicle chargers including revisions to parking, power supply routes, etc.
- Secure any necessary permits
- Installing vehicle chargers
- Commissioning and testing

Deploying EVSE charging infrastructure associated with MHD fleets can be a lengthy and costly process. Where electricity distribution system upgrades may be required, depending upon the utility and the project, some of the upgrade costs may be borne by the utility if they have line extension policies, or the whole project costs could be incurred by the customer. There is risk for the utility as well. If the utility supports major upgrades to a site for transportation electrification, and the site closes, or the operator leaves, the site may not generate any revenue or be able to pay the utility for the upgrades. This is even a greater risk for more rural locations.

Electricity distribution system upgrades can range from months to years. Upsizing a new distribution line may take 6-36 months, a substation upgrade 18-36 months and a new substation 24-48 months,[33] all depending upon existing utility workload, right of way acquisition etc. Utilities have also indicated equipment supply chain challenges are impacting project timelines, with the lead time for large transformers in the region of 2-3 years.

Upgrade costs can also be significant, even for Level 2 chargers A Rocky Mountain Institute Report[34] identified that under Southern California Edison's Charge Ready Pilot Program, which aims to support deployment of charging facilities in long dwell time locations such as workplaces, fleets and destination centers, the utility-side infrastructure upgrade costs alone in Q2 2019 were $2,452,656 for 75 sites, or $32,702 per site. The report also indicated that for higher-powered sites and remote sites, utility-side infrastructure costs can be upwards of $1 million per site.

The electricity distribution system connection process is a crucial element in the overall adoption plan for a fleet operator and is a prerequisite prior to any substantial vehicle purchase contract finalization. However, the timeline for any electricity distribution system upgrades may present challenges with a fleet operator's procurement process for new vehicles as to when they place an order to when they can begin operating the new vehicles.

33 Black & Veatch. 2019. Electric Fleets: 8 Steps to Medium and Heavy-Duty Fleet Electrification.
34 https://rmi.org/wp-content/uploads/2020/01/RMI-EV-Charging-Infrastructure-Costs.pdf

UTILITY LIAISON

Working with utilities will be a key requirement for fleet operators in adopting, scaling and operating their MHD vehicle fleets. Factors in this relationship include:

- Establishing points of contacts. Many fleet operators' current relationship with utilities will be transactional and often the only point of contact between the two organizations will be via the electricity bill. Utilities may have to manage relationships differently for fleet operators and help educate and inform operators through the BEV transition.
- Utilities supporting investment decisions associated with charging infrastructure and working with fleet operators to identify solutions if there are limitations on grid capacity.
- Fleet operators accessing credits and other financial support from utilities in the provision of grid upgrades and charging related infrastructure, such as Duke Energy's Line Extension and Make Ready programs.

ELECTRICITY COST

For fleets transitioning to BEVs, electricity costs will form a significant part of their vehicle operating budget, and they will view electricity as a cost that needs to be managed as efficiently as possible, which will influence how fleets integrate charging into their operations and the charging infrastructure they choose. Electricity costs are typically composed of the following:

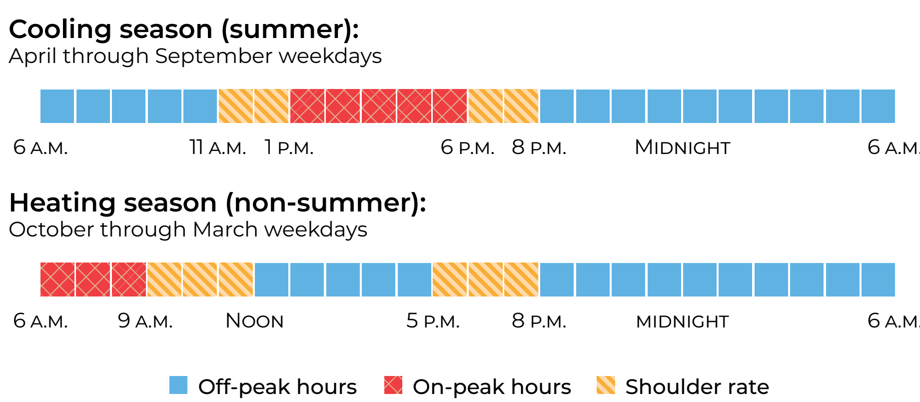
- Facility or service charges. A fixed charge related to the cost of providing service to a consumer's location.
- Energy or usage charges. The cost for the electricity used is measured in kWh. The cost can vary according to the time of day, with peak and off-peak charging times and also season as shown in **Figure 37**.
- Demand charges. The rate at which electricity is consumed. Peak or spikes in demand, will influence the demand charge for a given billing period.

Options to minimize electrical costs associated with EV charging include:

- Minimizing demand charges by:
  - Using slower, rather than fast chargers.
  - Utilizing charging management software to lower power demand and maximize cheaper time of use time windows.
  - Adding on site energy generation and storage systems e.g. solar panels on warehouses to charge on site batteries, which supplements grid charging and can also be used to reduce peak demand.
- Maximizing utility tariffs that provide differential pricing according to time-of-day use.

Anything that reduces a fleet's electrical costs will help incentivize the uptake of MHD ZEVs in the state.

FIGURE 37. Duke Energy's Peak and Off-Peak Hours



CHARGING A GROWING EV FLEET

Fleets transitioning to ZEVs are unlikely to swap all their conventional vehicles for ZEVs overnight. Most fleets have an annual fleet replacement program where a percentage of the fleet, typically the older vehicles, are replaced. This gradual transition process does present some challenges to fleet operators and utilities. As reported by the North American Council for Freight Efficiency Council, the more vehicles that are added to a location for charging, the greater the complexity of planning the charging infrastructure as shown in **Figure 38**.

This complexity also extends to utilities and in some cases, this has implications associated with power supply to a fleet user. For example, a user is looking to add 10 BEVs to their fleet every year. Each vehicle requires 300 kWh over an 8-hour duration to charge the battery. Depending upon how utilities charge for electricity distribution system upgrades to their customers, the utility's regulatory environment and other load demands on the local electricity distribution system, each increase in load may require an upgrade.

Most utilities are unable to invest in infrastructure upgrades unless there is a firm customer commitment, which means they cannot invest in longer term upgrades that make sense from a construction and future proofing perspective. Furthermore, a customer may not be willing to commit to infrastructure upgrades associated with future loads because they may have to pay for the load capacity they are not using. In summary, fleet transitions may be implemented incrementally, while utilities favor less frequent, but larger upgrades, which are more cost effective.

Striking the right balance with ensuring utilities can recover their costs associated with grid investments, while supporting timely grid expansion to grow MHD EV adoption will be a key facet in North Carolina's MHD EV journey. For regulated utilities, this will require engagement with NCUC and the exploring of business models to support MHD EV adoption. However, the divergent timescales of utilities upgrading grid infrastructure and fleets acquiring vehicles, should not be underestimated.

FIGURE 38. Complexity of Growing an EV Fleet
Source: NACFE

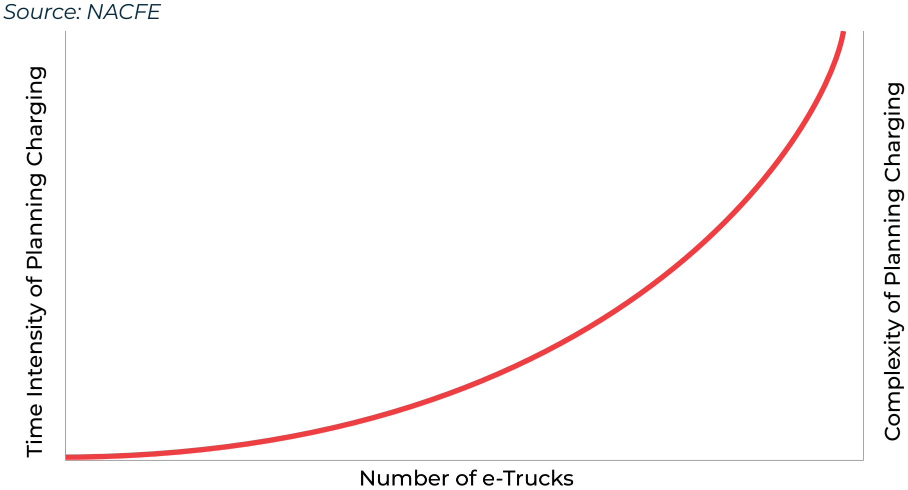
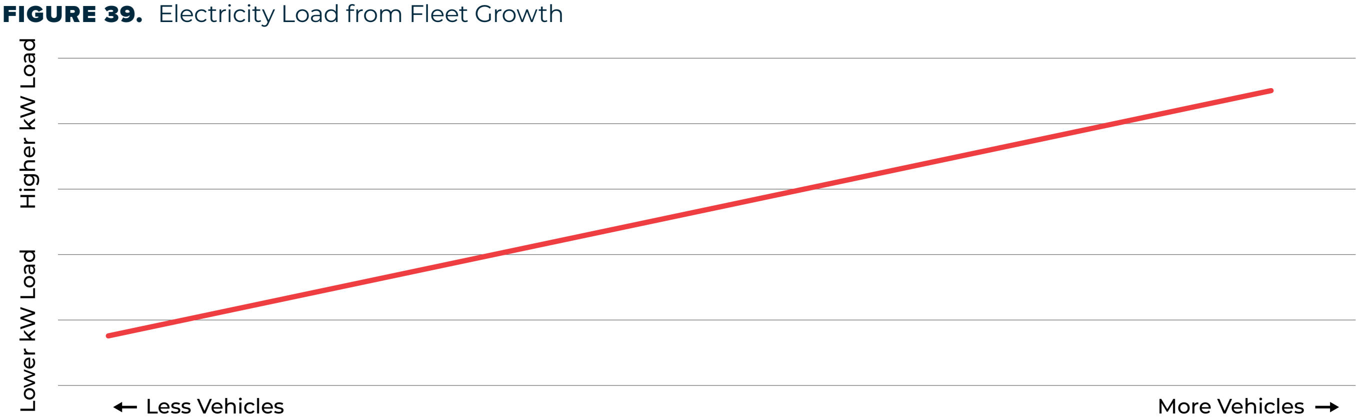


FIGURE 39. Electricity Load from Fleet Growth



UTILITY PLANNING

A significant challenge facing utilities is the lack of visibility as to where, when and the volume of uptake associated with the adoption of MHD BEVs. This lack of visibility means it is difficult for utilities to be proactive in their longer-term distribution system planning and are instead reactive to additional demands on their electricity distribution systems as fleet operators come to them with their individual plans.

HYDROGEN SUPPLY AND COST

Hydrogen hubs are a concept where multiple partners align to concentrate efforts on creating new infrastructure focused on producing, processing, delivering and storing hydrogen fuel. Federal funding has recently been approved for hydrogen hub exploration as part of the Bipartisan Infrastructure Law (BIL) to create 10 hydrogen hubs around the country. These plans can advance regional and multi-state economies, strengthen energy independence, and potentially lower costs for households and businesses.

The development of a hydrogen hub in the southeast could provide hydrogen to North Carolina to fuel FCEVs. The Southeast Hydrogen Hub (SEHH) is being proposed by a coalition of major utility companies including Dominion Energy, Duke Energy, Louisville Gas & Electric Company and Kentucky Utilities Company (LG&E and KU), Southern Company and the Tennessee Valley Authority (TVA)[35]. The aims of this and other initiatives is to not only improve the supply of hydrogen, but also reduce the cost, which is currently approximately $13 per kg. A separate Department of Energy (DOE) program called the Hydrogen Earth shot aims to reduce the cost to produce H2 reduce to $1/kg over 10 years.

The success of the Southeast Hydrogen Hub or other hydrogen developments in the region,including small-scale production, is critical for a reliable and cost-effective supply of hydrogen to support FCEV adoption in North Carolina. As this report was being produced, the Southeast Hydrogen Hub was encouraged to submit a full application by the DOE and a decision on the hub's funding is due later in 2023.

COST OF MHD VEHICLES AND CHARGING INFRASTRUCTURE

The higher capital cost of ZEVs and capital costs associated with charging infrastructure, including paying for electricity distribution system infrastructure upgrades, represents a barrier to adoption for the MHD sector. For example, a diesel-fueled school bus costs approximately $100,000, but its battery equivalent with charging infrastructure is about $420,000 and heavy-duty BEVs can be between two to four times more expensive that their equivalent diesel counterparts. The Inflation Reduction Act tax credits will support overall cost, but not necessarily support the upfront cost challenge. Companies across the MHD spectrum, but especially smaller companies and owner operators, may be challenged to access funding at affordable rates or finding sufficient funding or down payments to invest in new, higher cost ZEVs. Despite the higher upfront cost, the Total Cost of Ownership (TCO) is expected to be lower for BEVs when compared with their ICE counterparts due to lower maintenance and fuel costs. Operating costs may also further decrease as fleets and drivers learn about regenerative braking and employ other efficiency measures. Furthermore, battery costs and the retail price are expected to fall as more OEMs expand manufacturing capacity and more OEMs expand into the ZEV market. Analysis by the International Council on Clean Transportation, identified that the payback period (the amount of time it takes fuel savings to offset the higher purchase cost of a ZEV) for BEV Class 2b-3 trucks with ranges up to 200 miles, was less than five years by 2029, but this was likely to fall to 3 years by 2032.[36] Another report by ICCT[37] assessing the TCO costs of Class 8 Trucks, identifies a lower TCO for diesel trucks associated with model year 2022 at $1.91 per mile for diesel

35 SEHH includes utilities with operations in Kentucky, Tennessee, North Carolina, South Carolina, Georgia, and Alabama
36 https://theicct.org/wp-content/uploads/2022/01/cost-ev-vans-pickups-us-2040-jan22.pdf
37 tco-alt-powertrain-long-haul-trucks-us-apr23.pdf (theicct.org)

versus $2.31 for a BEV truck. By 2030 the TCO for a diesel truck is $1.78 per mile and $1.75 for the BEV truck. Some companies do however acknowledge the higher costs of BEVs, but ESG commitments to reduce GHG are compelling and decarbonizing the transportation function is required by buyers of transportation and freight services.

RECOMMENDATIONS FOR MHDVS

The recommendations outlined below are intended to assist in creating the right environment for MHD operators to purchase and operate ZEVs in North Carolina. They seek to streamline the adoption process, reduce costs and time for deploying charging and fueling infrastructure and incentivize the uptake of ZEVs.

UTILITIES

North Carolina's utilities will play a crucial role in the state's transportation electrification pathway.

Acknowledging that the utilities supply electricity to multiple customers day-in and day-out, transportation electrification, especially at scale, does present the utilities and their customers with some challenges. To help smooth and facilitate the transition, the following are recommendations for North Carolina utilities.

Primary Point of Contact for MHD Fleets

Establishing and promoting a primary point of contact within the utility for MHD fleets makes it easier for prospective fleets to engage with the utility and access support and advise. Ideally, this point of contact should be promoted and advertised externally on utility websites and promoted internally within the organization to help streamline internal processes from concept to installation.

Establish Channels of Communication with OEM Dealers Selling BEV MHD Vehicles

Engaging with OEMs and their dealers selling BEVs in North Carolina will help educate them on the role of utilities in the ZEV adoption process. It can also help establish relationships between the dealer's customers and utilities and getting utility engagement early in the fleet operator's decision-making process. This could be an ongoing process between dealers and utilities, or a formalized program or engagement event that is coordinated by the state.

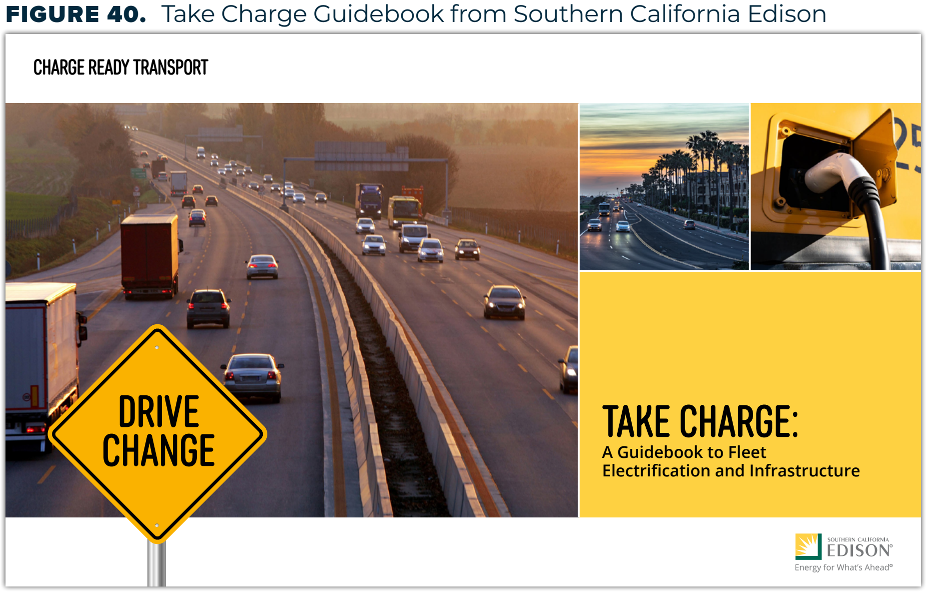
EV Charging Friendly Tariffs

Electricity costs, especially demand charges, are expected to be significant operational costs for ZEV fleet operators. Utilities could consider EV-specific rate designs to help encourage the adoption of MHD BEVs, such as time-of-use programs.

Develop Guidance Documents

By providing guidance, utilities can help potential MHD operators understand and navigate the various processes and considerations associated with MHD charging (example shown on **Figure 40**). Guidance could help inform the planning, implementation, maintenance and operations of charging infrastructure. It can also help MHD operators understand the limitations of the electricity

FIGURE 40. Take Charge Guidebook from Southern California Edison



distribution system and considerations of time and cost in deploying infrastructure upgrades. Managing expectations of MHD operators can also be achieved by the publication of guidance documents. Examples of such documents can be found at the Southern California Edison Website.[38]

Make Ready Programs

Utility make-ready programs can assist users with the up-front cost of bringing sufficient electricity to a location for vehicle charging. Duke Energy has deployed an EV make ready program in North Carolina following approval from NCUC. As the scale of MHD ZEV adoption is expected to grow, so will the investments necessary to support grid infrastructure. The suitability of existing make ready programs needs to be continually reassessed to ensure they can incentivize and support fleets in the transition to electric vehicles.

Proactive Approach to Engaging MHD Fleets and Strategic Planning

While utilities have typically taken a reactive approach to increasing electricity distribution system capacity, the improvements necessary for large-scale fleet electrification of medium and heavy-duty fleets will require strategic, long-term and proactive planning. It can take years to develop high-voltage infrastructure; if upgrades are not planned properly with a long-term view in mind, fleet transitions may be delayed, and the overall cost of grid improvements will likely be more expensive. Utilities could identify locations where potential MHD ZEV operators may be based, and local electricity distribution system capacity exists with minimal or no requirement for grid upgrades, potentially using the location analysis identified in this project. Priority could also be placed on those fleets co-located with electricity distribution system capacity and in environmental justice areas.

Strategic Power Network and Generation Assessment

Further work will be required to assess the impacts of transportation electrification on all components of the grid. This includes power generation and transmission that considers the volume of overnight charging and daytime rapid charging that is likely to occur in both the light and MHD sectors and how this will be sourced, given the State's commitments to reducing greenhouse gases in the electricity sector by a 70 percent reduction from 2005 levels by 2030, and achieving net-zero greenhouse gas emissions no later than 2050.

FUNDING

Stretching Available Funds

It is recognized that many grant funding opportunities are oversubscribed. The EPA's Clean School Bus program is a good example. Out of 185 electric buses requested by NC school districts in the 2022 round, only 31 were eventually funded. Costs for electric school bus acquisitions could be lowered two ways. First, prioritizing lower cost solutions, such as Level 2 charging investments, rather than DCFC which may require more expensive electricity distribution system upgrades, could assist with deploying more ZEVs. Second, collective procurement or group purchasing can also be used to stretch available funding by lowering vehicle and charging unit costs compared to individual procurement.

Maximize Existing Programs

Consideration of funding for EV charging infrastructure in existing economic development programs, such as the NCDOT and NCDOC Joint Economic Development Program (it should be noted for these programs that funding eligibility is tied to job creation). Integrating EV infrastructure into this program not only supports industrial growth, but helps potential users receive value for money by integrating EV infrastructure into a planned construction program, rather than retrospectively adding the infrastructure later. Going further, these programs could be amended to tie new economic development investments to MDH charging infrastructure. Again, investments could be limited to, or prioritized, for fleets located and charging in environmental justice areas. Other programs include the NC Job Ready workforce development initiative and the North Carolina Agricultural and Technical State University STEPs4GROWTH, clean energy workforce training

38 Charge Ready Transport (https://www.sce.com/sites/default/files/2020-07/Electrification%20%26%20Infrastructure%2 Guidebook-Final_06.29.20.pdf)

program. These could help prepare the North Carolinian workforce to install and maintain EV infrastructure and service ZEVs.

Federal programs such as transportation grants (such as RAISE), the National Electric Vehicle Infrastructure (NEVI) Program, and the Carbon Reduction Program (CRP) are all potential Federal funding programs (among many) that can be pursued for funding to support MHD infrastructure.

Adoption Incentives

The proposed ACT rule spurs OEMs to sell ZEVs in North Carolina. From the demand side, even though the total cost of ownership for ZEVs is gradually moving into line with diesel-fueled vehicles, the higher capital costs of both ZEVs and charging infrastructure will remain challenging. For example, a diesel-fueled school bus costs approximately $100,000, but its battery equivalent with charging infrastructure is about $420,000. Users across the MHD spectrum are likely to need financial support to help bridge the cost differential gap, especially over the next five or so years. Recommendations include:

- Allow the state's utilities to invest in all elements associated with charging – both before and after the meter, and they have appropriate financial instruments to receive a return on their investment. This could include tariffed on-bill financing programs, where additional electricity distribution system upgrade costs or customer infrastructure including chargers, not covered by make ready programs, are paid for through a surcharge on the customer's bill. This may be very specific to certain users and consider issues such as credit scoring and risk.
- In addition to grants, vehicle rebate and voucher schemes, other financing arrangements including loans, that provide access to capital funding for MHD users should be explored, including schemes associated with North Carolina Clean Energy Fund.[39] Other schemes similar to the Property Assessed Clean Energy (PACE) program[40] which offer low-interest loans to property owners investing in energy efficiency improvements and the loan is repaid through an increase in property tax assessment payment semi-annually, over a period of 15 years to 30 years depending on the county PACE guidelines. Consideration could be given to including charging infrastructure into a NC PACE program.
- Consider adding charging infrastructure to the School Bus Replacement Fund as an eligible expense.

OTHER SOLUTIONS

Work With Industry and Align State Resources to Develop/Support a Charge as a Service Facility

In the early stage of EV adoption, not all MHD fleet operators will be willing to invest in charging infrastructure as they go through a process of testing and evaluating their new equipment. A CaaS solution enables operators to test and grow their ZEV fleets, while having certainty of charging their vehicles, without upfront investment in charging infrastructure. Currently most CaaS activity is focused on California where the ACT rule has been adopted. Engagement and incentives are needed to get CaaS providers interested in North Carolina. Recognizing there is federal funding available for EV charging , through programs such as Rebuilding American Infrastructure with Sustainability and Equity (RAISE) and the Charging and Fueling Infrastructure Discretionary Grant Program, securing federal funding represents a potential path forward to establish as CaaS operator in North Carolina.

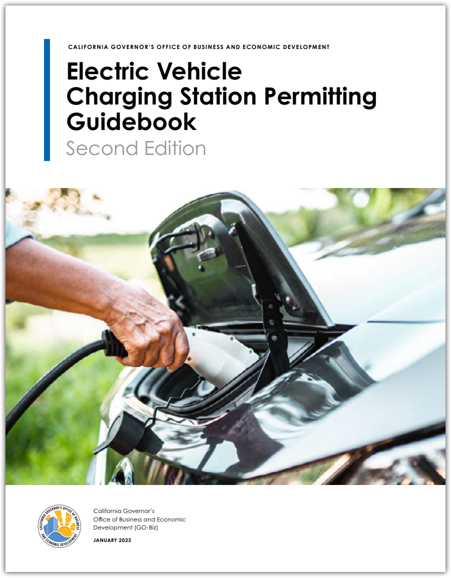
To move this forward, it is recommended NCDOT issues a Request for Information (RFI) to potential CaaS operators to assess the viability and market potential for CaaS sites in North Carolina. Depending on the feedback, NCDOT could then assess ways of working with potential CaaS operators to compete for discretionary grant funding.

39 https://www.nccleanenergyfund.com/
40 https://www.energy.gov/scep/slsc/property-assessed-clean-energy-programs

Streamline Permitting

The average time to complete the permitting process for a DCFC location is 65 days across the US.[41] Clearly the local permitting process has a key role to play in ensuring charging infrastructure is deployed safely, but consideration could be given to adopting local processes that streamline and expedite permitting associated with charging infrastructure. North Carolina could consider developing a permitting guide, such as the Californian guide[42] (see **Figure 41**) to help authorities streamline their permitting processes and ensuring charging infrastructure is planned for and installed where necessary, as part of a development's construction process.

FIGURE 41. California EV Permitting Guidebook



Pair Charging with On-Site Generation and Storage

MHD charging facilities which also support on- site generation and storage can improve not only site reliability and power, but may increase the cost-effectiveness of charging. Many fleet locations will be operating from locations with warehouses and distribution centers, whose roofs have high potential for supporting solar generation. A report from the Electric Power Research Institute (EPRI) analyzing a DCFC paired with stationary energy storage in Hawaii found that over a two-month period, the presence of stationary storage allowed for power delivery to EV customers at a rate higher than would typically be allowed by the available distribution infrastructure, which in turn reduced customer charging time.[43] Demand charges over the same-month period were also nearly half of what they would have been without stationary storage. However, while costs of solar and storage systems are decreasing, the cost effectiveness of such systems to offset electricity utility costs are highly site and use dependent. Note that fleet operators could contract with energy service companies to provide site generation and storage-as-a-service.[44]

Annual/Biennial Survey

A key issue facing utilities and other agencies with an interest in electric vehicles is understanding where BEVs might be deployed and charged, as well as when companies might start adopting BEVs. To help utilities and agencies plan, an annual or biennial survey led by an agency such as NCDOT, NC Division of Air Quality (DAQ) or NC Commerce and supported by utilities. The survey would assess interest in MHD BEV vehicles by contacting potential users who might be identified from several sources such as DMV, FMCSA and utility records. This could be targeted to areas of high potential for fleet electrification, such as those zip codes identified in this report's location analysis.

41 https://theicct.org/wp-content/uploads/2023/05/infrastructure-deployment-mhdv-may23.pdf
42 https://business.ca.gov/wp-content/uploads/2019/12/GoBIZ-EVCharging-Guidebook.pdf
43 Energy Storage Paired with Electric Vehicle DC Fast Charging: Demonstration and Analysis in Hawaii (https://www.epri.com/research/products/000000003002012710)
44 https://www.energy.gov/femp/energy-service-companies