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Evaluating the Virginia Department of Transportation's Potential Use of Electric Pickup Trucks Using Field Test Data

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Final Report VTRC 26-R24

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Field testing revealed that the electric truck performed consistently with manufacturer estimates under standard driving conditions but experienced significant range reductions during towing operations (50–70% decrease) and cold weather conditions (energy consumption of 4.1 miles per hour equivalent during winter idling). The vehicle demonstrated good suitability for local maintenance operations, with accurate range estimation and effective performance during low-speed work zone operations. Based on these findings, the study recommends that VDOT's Maintenance Division initiate a pilot electric vehicle deployment that prioritizes electric sport utility vehicles and sedans at selected facilities. The operational limitations observed in electric pickup trucks during towing and cold weather operations indicate that electric sport utility vehicles and sedans can provide similar fuel and maintenance cost benefits without these constraints because they are typically not required for heavy towing or 24-hour, around-the-clock emergency operations that characterize many pickup truck applications. The refined Electric Vehicle Decision Support Tool developed from field test data can guide optimal deployment decisions, with properly deployed electric trucks providing potential annual savings of $1,400 per vehicle compared with conventional pickup trucks through reduced fuel and maintenance costs.

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FINAL REPORT

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Virginia Transportation Research Council
(A partnership of the Virginia Dept. of Transportation
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INTRODUCTION

The Virginia Department of Transportation (VDOT) operates a fleet of light vehicles to support its duty in maintaining and operating roadways. In recent years, the interest in transitioning to electric vehicles (EVs) has been growing. This transition is expected to reduce carbon emissions and dependence on fossil fuels while minimizing operating costs.

The benefits of EVs include lower fuel and maintenance costs, as well as reduced emissions and noise pollution. However, transitioning to EVs also involves upfront costs, such as the purchase price of the vehicles and the installation of charging infrastructure. Furthermore, the performance characteristics of EVs are not precisely known because multiple factors can negatively influence EVs' posted range.

VDOT's vehicle fleet does not currently use electrification in the form of hybrid electric vehicles (HEVs), which charge a battery from the internal combustion engine; plug-in hybrid electric vehicles (PHEVs), which also charge batteries from the internal combustion engine but also allow the battery to be recharged from an external source; or battery electric vehicles (BEVs), which are entirely battery powered and do not have internal combustion engines. VDOT has begun introducing electric pickup trucks into the fleet on a pilot basis. Electric trucks have different performance characteristics than internal combustion engine trucks, such as shorter ranges and longer recharge times. Because electric trucks have only been available for purchase since 2022, many other aspects of their performance are not well understood, including towing, range reductions in extreme weather, and tire wear. In addition, electric trucks require charging infrastructure at VDOT offices, which introduces additional challenges.

In preparation for the introduction of EVs into the VDOT fleet, the Virginia Transportation Research Council (VTRC) completed a technical assistance report, *Potential for Electrification of the VDOT Vehicle Fleet*, in December 2022 (Goodall and Robartes, 2022). This work investigated the feasibility of EVs in the VDOT fleet by analyzing daily mileage from VDOT's internal combustion engine pickup trucks. Because the temperature impacts on EV batteries are known, models were developed using data from an American Automobile Association (AAA) report on the effects of climate control on EV range to approximate the kilowatt-hours (kWh) per minute an electric pickup truck uses while idling and while driving based on ambient air temperature (AAA, 2019). These models were applied to the dataset of trips taken by VDOT internal combustion engine pickup trucks to determine whether a standard range Ford F-150 Lightning pickup truck could complete the trips taken by VDOT pickup trucks.

Results found that an electric truck could accomplish most trips taken by VDOT pickup trucks during the 1-year timeframe. Across all trips in the 1-year dataset, an electric truck with standard range (98 kWh) could complete more than 97% of trips, and an electric truck with extended range (131 kWh) could complete more than 99%. The small percentage of trips exceeding electric truck capabilities was spread out across vehicles and VDOT districts. On analyzing individual truck data of the 403 pickup trucks reviewed, 126 vehicles (31%) never recorded a trip exceeding the range of the electric truck with a standard battery. In addition, 259 vehicles (64%) never recorded a trip exceeding the range of the electric truck with an extended range battery. These vehicles could be immediately replaced with an EV with no change to usage characteristics. The technical assistance report also includes a discussion of how designating conventional vehicles for longer trips could maximize the number of pickup trucks compatible with EV replacement.

Because VDOT has now received several electric trucks that are being introduced into the fleet on a pilot basis, the opportunity for a more robust analysis exists. Building on the previous technical assistance effort, this report evaluates the performance of an electric pickup truck for its suitability as part of the VDOT vehicle fleet.

A research advisory committee did not rate this project, but the VDOT Maintenance Division identified it as a priority need.

PURPOSE AND SCOPE

The purpose of this project was to assess the viability of using electric pickup trucks within VDOT and to identify appropriate use cases. This effort was accomplished through the following tasks:

- Evaluate the performance of the electric truck in field tests.
- Document any challenges and costs associated with installing and maintaining the necessary charging infrastructure.
- Capture maintenance costs where possible.
- Collect data on required charging time at different public charging stations throughout the Commonwealth.
- Refine VDOT's EV cost-benefit analysis tool using the data collected as part of this effort.
- Pilot the vehicle at select residencies and district offices to document user experiences.

The scope of the study is as follows:

- Performance evaluation is limited to a single 2023 Ford F-150 Lightning delivered to VTRC on June 7, 2024. The results may or may not be indicative of other Ford F-150 Lightnings, and results for other EV pickup trucks may differ.

- The evaluation does not consider any potential technology changes because EV technology is evolving rapidly.
- The evaluation period is 9 months to capture the effects of cold weather.
- The study will only capture short-term maintenance for the vehicle because of the length of the study. Long-term maintenance, including battery wear issues, will not be examined.

METHODS

To accomplish the study objectives, the following tasks were performed:

1. Completing a literature review.
2. Conducting field tests.
3. Refining the Electric Vehicle Decision Support Tool.
4. Performing VDOT user testing.
5. Writing the final report.

Literature Review

The literature review covered topics including electric truck capabilities, user surveys and focus groups, and public and private charging infrastructure. This review builds off the literature review conducted for the technical assistance project, *Potential for Electrification of the VDOT Vehicle Fleet* (Goodall and Robartes, 2022). Because electric trucks are new to the market, the literature review covered non-academic literature, such as consumer-oriented publications and media.

Conducting Field Tests

The performance characteristics of the electric truck were tested in a controlled environment as practicable. Data were collected to better understand vehicle performance in terms of range under a variety of conditions. Range and power were measured directly from the Lightning's dashboard via a dash-mounted GoPro camera programmed to take photographs of the dashboard at 1-minute intervals. The effect of variables on range and power was tested as well. Variables included towing, road grade, vehicle-mounted changeable message signs, ambient temperature, heating and air conditioning, and truck speed (freeway, low-speed, and idling). In addition to truck range and power, researchers tested other attributes, such as vehicle behavior at low battery levels, battery recharging times, and maintenance needs. In addition, battery level and estimated range data from the FordPass application were collected routinely during field tests.

Towing

To assess the effect of towing on the pickup truck's range and power, the pickup truck was fitted with a hitch and trailer, and the trailer was loaded with two mowers. The load was selected as a common use case for a VDOT pickup truck based on discussions with VDOT staff.

The trailer weighed approximately 1,500 pounds, and each mower weighed approximately 1,000 pounds, for a total weight of 3,500 pounds. The trailer was driven along Interstate 64 (I-64) from Exit 121 eastbound to Exit 175 and back (approximately 53 miles each way). This segment of I-64 was selected for its lack of hills and low traffic volume. Timestamps, miles traveled, percentage of charge, range, and temperature were collected throughout the tests using the FordPass application and the truck dashboard readings.

Grade

To study the effects of grade on the pickup truck's range and power, an out-and-back route on a mountainous freeway was driven three times (see highlighted route in Figure 1). The route began at mile marker 118 on I-64 West outside of Charlottesville, Virginia. The pickup truck was driven approximately 18 miles west on a predominantly uphill section of the interstate until Exit 99 (mile marker 99.9), where the freeway reaches 5% uphill grades (Dunn, 2022). The driver then exited the freeway, turned around, and re-entered I-64 East for another 18 miles on a net downhill section of the interstate. Timestamps, miles traveled, percentage of charge, range, and temperature were collected throughout the tests using the FordPass application and the truck dashboard readings.

Figure 1. Map of Grade Test Route

Ambient Temperature

Ambient temperature tests were conducted at freeway speeds and at a variety of temperatures to understand the effect of ambient temperature on battery range. Tests consisted of 2 hours of interstate driving. The climate control was on and set to approximately 70°F. Timestamps, miles traveled, percentage of charge, range, and outside temperature were collected throughout the tests using the FordPass application and the truck dashboard readings.

Climate Control and Idling

To discern the effects of heating and air conditioning on the pickup truck's battery, a series of tests were conducted while the truck was idling at various temperatures. Two tests were run in cold weather (12–38°F), two in temperate weather (47–63°F), and two in hot weather (73–93°F). For each pair of temperature tests, one was run with the climate control on and one with the climate control off. The truck was idled in the parking lot of the VTRC office. Timestamps, percentage of charge, range, and temperature were collected throughout the tests using the FordPass application and the truck dashboard readings.

Low Speed

Low-speed operation is a use case specific to a department of transportation for work such as a slow rolling work zone during the installation of pavement markings. To simulate these operations, an out-and-back route was chosen on a low-volume, dead-end residential road where the pickup truck could be driven at 10 to 15 miles per hour (mph) for 2 hours at a time with minimal effect on traffic. The truck was briefly pulled onto the shoulder to let traffic pass, which occurred approximately twice per hour and lasted less than 10 seconds each time. The test was run under cold (32–35°F), temperate (62–65°F), and hot weather (73–93°F) conditions with the climate control on and set to approximately 70°F. The test was repeated twice for each weather condition. Timestamps, miles traveled, percentage of charge, range, and temperature were collected throughout the tests using the FordPass application and the truck dashboard readings.

Low and No Battery

Additional tests involved running the truck's battery to low levels to determine how the truck warns the passengers, the accuracy of the truck's own battery level, and the behavior of the truck when approaching complete battery discharge.

Recharging

Battery charge times across VDOT-installed chargers and public charging stations were recorded. Timestamps, percentage of charge, range, charging rate, and energy added to the battery were recorded each minute during charging tests using the FordPass application.

Maintenance

Tire tread depth was measured as needed with a digital tire depth gauge, and any associated maintenance needs were recorded.

Safety Lighting and Message Boards

After an initial investigation into the feasibility of installing safety lighting or a message board on the electric truck, it was determined that it was not possible within the scope of the research effort. Because electric pickup trucks are new to the market, experience in the industry on installation procedures is lacking. As an alternative, the authors reviewed equipment specifications to approximate battery draw due to additional lighting.

Summary of Tests and Testing Plan

Table 1 shows the testing plan that includes metrics, variables, repetitions, and estimated time required.

Table 1. Testing Plan

Test	Factors						Notes
	Metric	**Climate Control**	**Weather**	**Details**	**Hours**	**Repeats**	
Towing	Range	On	Consistent	I-64 Afton Mountain	2	2	This test examined battery performance while towing a standard VDOT 6- x18-foot double-axle trailer loaded to 60–80% of truck's towing capacity.
Grade	Range/Power	On	Consistent	I-64 Afton Mountain	2	3	This test examined battery performance on a route with steep grades. VTRC to Afton Exit 99 and back, charge, repeated 3x.
Ambient Temperature	Range x Temp	On	Hot	Freeway speeds	2	2	This test isolated the effects of ambient temperature on range at freeway speeds.
			Temperate		2	2	
			Cold		2	2	
Climate Control and Idling	Battery remaining x Time	On	Hot	Stationary	8	1	This test isolated the effects of climate control on the battery while the vehicle is stationary.
		Off			8	1	
		On	Temperate		8	1	
		Off			8	1	
		On	Cold		8	1	
		Off			8	1	
Low Speed	Range x Time x Miles	On	Hot	10–15 mph	4	2	This test examined range at low speeds along a low-volume residential road.
			Temperate		4	2	
			Cold		4	2	
Low and No Battery	Observe			Closed parking lot	4	1	Low-battery notifications, low-mileage estimate accuracy, and performance loss at zero battery.
Recharging	Battery Level x Time	Off	Temperate	VTRC charger	2	2	Data from recharging events were studied by plotting recharge rate over time to determine linear vs. exponential vs. logarithmic recharge rate. Compared listed vs. actual kWh, cross checking against crowdsourced sources such as PlugShare.
		On			2	2	
		Off	Hot		2	2	
			Temperate	DC Fast Charger 1	2	2	
			Hot		2	2	
			Temperate	DC Fast Charger 2	2	2	
			Hot		2	2	
Maintenance	Tread Depth x Odometer	-	-	-	-	Weekly	Tire wear was studied by recording mileage and tread depth.
	Other Maintenance as Needed	-	-	-	-	As Needed	Collected from all VDOT Lightnings via the Maintenance Division.

DC = direct current; kWh = kilowatt-hours; mph = miles per hour; VTRC = Virginia Transportation Research Council.

Refining Electric Vehicle Decision Support Tool

VTRC developed an Electric Vehicle Decision Support Tool to assist VDOT in making decisions regarding when and how to transition fleet vehicles to electric. Some of the model inputs were based on manufacturer claims (e.g., range) or extrapolated from electric sedans (e.g., maintenance costs).

VDOT User Testing

This task involved loaning the vehicle to the Keene Area Headquarters, within the Charlottesville residency. The electric truck was assigned to a crew manager, with different staff members borrowing the truck at the staff's discretion. Researchers conducted a semi-structured interview with drivers to document their impressions of the vehicle and any issues encountered.

Writing the Final Report

Researchers prepared a final report documenting the methods and findings from previous tasks. This report includes all relevant findings regarding the viability of EV trucks in the various circumstances tested.

The report recommends preferred use cases for electric trucks. These recommendations are based on the measured performance characteristics from conducting field tests, the updated decision support tool, and perspectives from VDOT users while performing user testing.

RESULTS AND DISCUSSION

Literature Review

Many new vehicle models are powered entirely or partly by electricity. These vehicles include BEVs, PHEVs, and HEVs. Each type has unique characteristics.

BEVs are powered solely by electricity from a battery pack, which is charged by plugging the vehicle into an external electric power source. These vehicles do not have an internal combustion engine and do not use gasoline or other fossil fuels. Instead, they rely on the stored electricity in the battery pack to power the motor and drive the vehicle.

PHEVs are hybrid vehicles that can be charged by plugging them into an external electric power source, in addition to having an internal combustion engine that runs on gasoline or other fossil fuels. These vehicles can switch between using electricity from the battery pack and using the internal combustion engine, depending on the driving conditions and the state of charge of the battery pack.

HEVs are also hybrid vehicles that combine an internal combustion engine with an electric motor and a battery pack. However, unlike PHEVs, they cannot be plugged in to charge the battery pack and rely solely on the internal combustion engine and regenerative braking to charge the battery.

In the third quarter of 2024, BEVs represented 8.9% of new vehicle sales in the United States, a new record (Abboud, 2024). These vehicles, which rely only on battery power, without the addition of an internal combustion engine, are expected to significantly reduce emissions even when considering the additional power needed to support them. Converting 25% of the U.S. vehicle fleet to fully EVs is expected to produce 242 million fewer tons of carbon dioxide emissions, with 437 deaths avoided because of annual reductions of particulate matter with a diameter of 2.5 micrometers or less (Peters et al., 2020). Adopters may also benefit directly because BEVs are estimated to save an average of $4,500 in total ownership costs when considering vehicle price, maintenance, fueling, insurance, and depreciation (Booth et al., 2022a).

Fleets represent a unique opportunity for vehicle electrification. EVs can be phased in slowly over time, allowing employees to adapt to the new technology. Because vehicles are housed at a central location overnight, facilities are incentivized to invest in high-speed charging infrastructure. Employees exposed to EV technology at work may be more comfortable in purchasing vehicles for personal use. VDOT represents an especially attractive use case for electric trucks, given the high percentage of pickup trucks in VDOT's fleet.

A significant challenge for VDOT is EVs' shorter range and limited ability to charge remotely. For example, electric trucks on the market today have stated ranges of between 240 and 492 miles on a single charge (U.S. Department of Energy [DOE], n.d.), with significant range reductions in cold weather or when towing (O'Hare, 2022; Steinstraeter et al., 2021). High-speed public charging stations can fully recharge a battery in under an hour, but charging stations are generally clustered in coastal urban areas and may not be as readily available for departments of transportation covering large rural areas.

Another challenge is assessing the costs and benefits of EVs. Although many EVs have higher purchase prices, lower fuel and maintenance costs can offset the purchase price. Alternatively, some BEVs, by removing the internal combustion engine completely, have lower purchase prices but may require high-speed charging infrastructure.

Prior studies have investigated fleet adoption of HEVs, PHEVs, and BEVs. The city of Philadelphia found that it could electrify 44% of its vehicle fleet by 2030 while adhering to scheduled vehicle replacements (City of Philadelphia, 2021). The greatest benefits were found from introducing BEV sedans into the fleet, followed by BEV pickup trucks. A pair of National Renewable Energy Laboratory studies found that universities could replace 29% of their vehicle fleets with BEVs (Booth et al., 2022b), and 46% of state fleets were good candidates for replacement (Booth et al., 2022a). In both studies, battery electric pickup trucks were not yet on the market, and so pickup trucks were assumed to be replaceable with electric sport utility vehicles (SUVs). Similar studies were conducted on taxis in Columbus, Ohio (Moniot et al., 2019), Washington state fleet vehicles (Satterfield et al., 2020), and federal government fleet vehicles (U.S. Government Accountability Office, 2019).

Other studies have modeled EV fleet operations, with focuses on smart charging (Tuchnitz et al., 2021), pricing schemes in a hybrid rideshare and transit deployment (Chen and Kockelman, 2016), shared autonomous EV energy demand (Chen et al., 2016), and optimal routing strategies (Chen et al., 2018). The technical challenges of EVs that would apply to fleet management have also been investigated, including battery life cycle (Lai et al., 2022), ambient temperature's effect on range (Al-Wreikat et al., 2022; König et al., 2022), and charging infrastructure requirements for transit fleet operators (Alamatsaz et al., 2022).

Several organizations have developed tools that aim to compare costs associated with EV ownership with those of traditional internal combustion engine vehicles (ICEVs). A tool developed by the Virginia Tech Transportation Institute compares a single ICEV with a single EV based on purchase price, annual mileage, electricity costs, loan information, and returns a table showing the savings associated with either vehicle, depending on years of ownership and the price of gasoline. The tool is straightforward, with minimal input required (Virginia Tech Transportation Institute, 2022).

The U.S. Department of Energy developed a publicly available Vehicle Cost Calculator that can be used to compare the ownership cost of up to eight different vehicles (DOE, 2022). Vehicles may be selected from dropdown menus, or a custom vehicle may be input. Purchase price can be adjusted, and the tool requests information about daily and annual vehicle driving patterns, local fuel prices, and the U.S. state where the vehicle will be driven for calculating electricity costs and emissions. The tool produces a figure comparing yearly cumulative ownership costs for each vehicle input and annual fuel, electricity, and operating costs and emissions. Thorough documentation for the tool states assumptions and calculation methodologies.

The Electric Vehicle Transportation Center developed a life cycle assessment tool for EVs, PHEVs, HEVs, and ICEVs (Raustad and Fairey, 2014). The default inputs to the tool are based on values for the state of Florida. The tool requires inputs such as vehicle lifespan, utilities, financing, driving data (daily commute and other travel), fuel and energy cost, charging location, and vehicle data, allowing for a fair amount of user customization. Model results compare life cycle costs of the input vehicles for each year of their lifespan and detail daily and annual energy usage.

Atlas Public Policy developed the Dashboard for Rapid Vehicle Electrification, a tool that can assess an existing fleet of vehicles and compare the total cost of ownership with EV alternatives (Atlas Public Policy, 2022). The tool includes a lengthy user manual and requires the user to input an Excel file of vehicle identification numbers, lifespan, and annual vehicle miles traveled for the existing fleet. The tool processes the vehicle identification numbers, populating a list of vehicles in the fleet. The user can manually input vehicles if the tool cannot decode the vehicle identification number. The tool then provides a default EV replacement vehicle for each vehicle in the fleet, which the user can modify. Assumptions of the tool can be modified, including variables such as charging infrastructure costs, maintenance costs, where the EV would be charged (home versus public charger) and purchase terms (e.g., cash or lease). The results of the analysis provide figures and data about total cost of ownership of the original fleet, alternative fleet, or both. This tool is less intuitive but more customizable than some others available.

Consumer Publications on Range of Electric Pickup Trucks

Electric pickup trucks launched in the U.S. market in 2022 with the releases of the Rivian R1T, GMC Hummer EV Pickup Truck, and Ford F-150 Lightning. In 2024, the Chevrolet Silverado EV, GMC Sierra EV Denali, and Tesla Cybertruck were all released. Numerous other models have been announced but not yet brought to market (Threewitt, 2025). Electric pickup trucks boast some of the highest ranges among all EVs on the market, carrying large batteries. Because of the weight of these vehicles and the batteries, electric pickup trucks tend to have relatively higher ranges but lower fuel economies compared with the rest of the EV market. However, they still perform better than their gas-powered counterparts when comparing miles per gallon gasoline equivalent and miles per gallon.

The U.S. Environmental Protection Agency (EPA) estimated that ranges for the six trucks on the market vary considerably, according to EPA estimates of total range (DOE, n.d.). Table 2 displays electric truck models with the lowest and highest estimated ranges for each vehicle make.

Table 2. EPA Combined City and Highway Estimates of Total Range, Fuel Economy, and Fuel Consumption Rate for Selected Electric Pickup Trucks on the Market in 2025

Vehicle Make	Year	Vehicle Model	Range (miles)	Combined City and Highway Fuel Economy (MPGe)	Fuel Consumption Rate (kWh/100 miles)
Rivian	2025	R1T Dual Standard	258	79	43
		R1T Dual Max	420	87	39
GMC	2025	Hummer EV MT Tires 2X	282	47	72
		Hummer EV 2X	318	53	64
		Sierra EV	390	64	52
Chevrolet	2025	Silverado EV	390	64	52
		Silverado EV 8 Work Truck	492	68	50
Tesla	2025	Cybertruck	325	79	43
Ford	2025	F-150 Lightning Standard Range XLT	240	68	49
		F-150 Lightning Platinum Extended Range	300	66	51
		F-150 Lightning Lariat Extended Range	320	70	48

EPA = U.S. Environmental Protection Agency; EV = electric vehicle; kWh = kilowatt-hours; MPGe = miles per gallon gasoline equivalent.

The EPA estimated range of a vehicle is calculated from laboratory testing in a controlled environment. Repeatable tests in a controlled laboratory allow for comparisons across vehicle models but cannot be fully representative of how the vehicle will perform in the real world.

Some consumer publications have performed tests for practical driving ranges, and others have recreated test scenarios intended to model the EPA total range laboratory test in the real world. *MotorTrend* magazine evaluated the 2023 F-150 Lightning Platinum range using a 70-

mph range test, which depleted 95% of the battery and determined a range of 222 miles (74% of EPA) (Markus, 2024). Because the *MotorTrend* test is performed at highway speeds, and the EPA range estimate is based on a mix of city and highway driving, the lower value from the *MotorTrend* test is expected. EVs are generally less efficient at highway speeds. *MotorTrend* also estimated that, after a year of use, a reasonable expectation for the F-150 Lightning XLT extended range when using for a road trip (highway usage, starting with a full charge) is about 240 miles (75% of EPA). *MotorTrend* estimated that during the course of a 1,000-mile road trip, traveling 80 mph on average will result in a trip length nearly as long as if the driver had been averaging 65 mph because of an increased number of charging stops (Markus, 2023).

Edmunds, a car-shopping website, uses a test procedure designed to be a real-world complement to the laboratory-based EPA estimated range by taking an EV with a full battery on a 60% city, 40% highway mix of streets until the battery has about 10 miles of range remaining (Elfalan and Rogers, 2025). Miles traveled plus remaining range are added together for the total range test. Using this procedure, Edmunds found a 345-mile range for the 2023 F-150 Lightning Lariat (108% of EPA), 332 miles for the 2022 F-150 Lightning Platinum Extended Range (104% of EPA), and 265 miles for the 2022 F-150 Lightning Pro (115% of EPA) (Weaver and Clonts, 2025).

Consumer Publications on Charging

EV manufacturers caution against charging to 100% routinely to avoid premature battery degradation, and the risk of being stranded would keep the driver from running the EV to 0%. Thus, the range that is practical to drive in will always be smaller than the maximum range. Ford recommends charging the electric truck to 90% for daily driving and 100% when the full range is needed for longer trips (Ford Motor Company, n.d.).

Ford F-150 Lightning Frequently Asked Questions state that the 2024 and 2025 F-150 Lightning with a standard range battery charges from 15 to 80% in approximately 32 minutes using a direct current fast charger. The same Lightning models with an extended range battery charge from 15 to 80% in about 38 minutes using a direct current fast charger. With an alternating current charger, the expectation is about 10 hours to charge from 15 to 100%. These values are based on computer simulations and analytical projections (Ford Motor Company, n.d.). Real-world charging times are subject to environmental conditions and the vehicle's battery health.

Various consumer publications have studied charging times and rates because charging rates are known to taper off as the battery approaches a full charge. An article by EV Charging Stations found that a 2022 Ford F-150 Lightning Lariat Extended Range with updated software charged from 10 to 80% in 39.5 minutes on a direct current fast charger (Kane, 2025). This finding is similar to the expected value documented by Ford. A *MotorTrend* article described charging a 2022 Ford F-150 Lightning Lariat from 5 to 100% in about 2 hours (Lau, 2022). The authors noted that increasing the charge from 90 to 100% took 50 minutes. The driver would be better served to charge from 5 to 80%, which took 50 minutes, rather than waiting for a full charge, particularly if the station charges by time. Real-world charging reports support Ford's charging time estimates. Furthermore, charging the battery fully is not efficient in terms of time, nor is it recommended for battery health.

Consumer Publications on Towing

Because electric pickup trucks are very new to the market, limited academic literature has been published regarding their performance capabilities. However, several consumer-oriented publications have released findings on electric pickup truck towing. *Consumer Reports* tested the Ford F-150 Lightning Lariat (extended-range battery) and Rivian R1T Launch Edition (large battery pack) on a 74-mile flat loop in Connecticut while towing a 5-ton box trailer (Knizek, 2023). The F-150 and the Rivian have respective EPA estimated ranges of 320 and 314 miles. The trailer, at just under 10,000 pounds, was approaching the stated maximum towing capacity of the F-150 and was about 1,000 pounds under that of the Rivian. The same driver drove the trucks at approximately 65 mph, with the climate control set to 70°F, and the external temperature was 48 to 52°F. Both trucks had a towing drive mode, with the F-150 also being set up with a trailer profile. The F-150, with an EPA range of 320 miles, displayed an estimated 161 miles when towing was engaged on a full battery, and the actual range with the 10,000-pound trailer was about 91 miles. The Rivian, with an expected EPA range of 314 miles, showed an expected range of 150 miles when the trailer was hooked up, and the actual range was about 85 miles. Although range was severely compromised, the authors reported that the drivetrains handled the weight easily, but the Rivian suspension was observed to handle the trailer more smoothly.

Similarly, *Car and Driver* magazine tested a Rivian R1T's towing capabilities (Colwell, 2022). The R1T was studied while pulling a 5,650-pound trailer loaded with another vehicle. *Car and Driver* had previously tested the Rivian's estimated highway range when unloaded and found it to be approximately 220 miles at 75 mph. When hooked up to the trailer, the R1T's estimated range dropped by approximately one-half to 103 miles. Like the *Consumer Reports* study, the *Car and Driver* article noted that the R1T handled the trailer very smoothly. Both studies noted that for short distances, all the pickup trucks were very capable of towing near their maximum load, but the logistics of charging may become challenging for long distances. Many EV charging stations are not set up for a vehicle with a trailer; they are often parking spots rather than a pull-through like a gas pump.

In 2022, *Car and Driver* compared three different EV pickup trucks and tested their towing ranges: the GMC Hummer EV, Ford F-150 Lightning, and Rivian R1T, which had 7,500-, 10,000-, and 11,000-pound towing capacities, respectively (VanderWerp, 2022). The test involved towing a 29-foot, 6,100-pound camper on a flat loop at approximately 70 mph, starting with a full battery and running the battery nearly to empty. The GMC Hummer EV, F-150 Lightning, and R1T were able to tow the camper for approximately 140, 100, and 110 miles, respectively.

Another study from *MotorTrend* in 2024 compared the towing capabilities of the 2024 Rivian R1T Dual Motor Performance Max Pack, the 2024 Tesla Cybertruck Dual Motor Foundation Series, and the 2023 Ford F-150 Lightning Platinum (Markus, 2024). The Rivian and Tesla in this test were rated to tow 11,000 pounds and the Ford rated for 8,500 pounds. To conduct a real-world test, each vehicle was hitched to a Bowlus Volterra camping trailer weighing 3,170 pounds and taken on a 110-mile loop (65% highway, 35% rural) at an average speed of 50 mph. The Rivian, Tesla, and Ford had respective towing ranges of 200, 160, and 158 miles. Like other previously described tests, the drivers in this test found the Rivian to be the most stable under towing conditions. Bowlus, the company that manufactures the Bowlus Volterra, ran its own towing tests of a Tesla Cybertruck (EPA range of 340 miles) and a Tesla Model X (range of 330 miles) (Nedelea, 2024). The company's methods (roughly 65% highway and 35% rural driving) found that the Cybertruck and the Model X managed 160 and 235 miles, respectively, while towing the Bowlus Volterra. Limited details of the study methodology were provided, but the results provide insight into the inefficiencies of EV towing.

Edmunds tested a 2022 Ford Lightning with the extended-range battery (131 kWh) and a 2022 Rivian R1T (135 kWh) while towing an SUV in an enclosed trailer weighing 7,420 pounds, nearing this F-150's towing maximum of 7,700 pounds but well under the R1T's maximum of 11,000 pounds. After more than 200 test-miles, the Lightning averaged 1 mile per kWh, and the R1T averaged 0.9 miles per kWh (Hall, 2023).

AAA conducted a related type of test by loading the F-150 Lightning's truck bed with 1,400 pounds of sandbags as compared with the previous tests, which loaded a trailer attached to the pickup by a hitch. The AAA (2023) test found that the pickup truck range decreased from 278 miles to 210 miles.

As evidenced by towing tests completed by various consumer-oriented publications, EVs are capable of towing heavy loads. Drivers report that EV pickup trucks are stable and highly responsive under towing conditions, even with very heavy loads. However, significantly reduced ranges and recharging logistics make them inconvenient for frequent long-distance towing.

Maintenance

Long-term maintenance costs of battery electric pickup trucks are unknown because the earliest models have only been on the road for 3 years. Generally, however, BEVs are expected to have lower lifetime maintenance costs compared with an ICEV. An analysis of survey data by *Consumer Reports* found that the approximate lifetime repair and maintenance costs were $0.061 per mile for ICEVs and $0.031 per mile for BEVs (Harto, 2020). A study by Argonne National Laboratory determined the maintenance costs by reviewing the prescribed service schedule in the owner's manual for a selection of vehicles (Burnham et al., 2021). Results found that BEVs' maintenance costs were $0.061 per mile, and ICEVs' maintenance costs were $0.101 per mile. Similarly, another study based on costs in Germany found ICEVs to have higher maintenance and repair costs than BEVs, at €2,892 and €2,348, respectively, over 4 years, assuming 10,000 km annually (Propfe et al., 2012). This sum corresponds to approximately $0.129 per mile for ICEVs and $0.105 per mile for BEVs based on Euro-to-USD conversion rates (MSN Money, n.d.).

Field Tests

Towing Field Tests

Two towing tests were conducted on June 16, 2025. For the test, a ball hitch and 6- x 18-foot flatbed trailer were borrowed from the VDOT Keene Area Headquarters and loaded with two riding lawnmowers. This load was selected based on availability, its similarity to the requirements performance of a VDOT mowing crew, and its weight limit within 60 to 80% of the truck's towing capacity of 5,000 pounds. The temperature was approximately 73°F for both tests, and the vehicle was charged to 90% between tests.

The electric truck required the user to select towing mode and to input the trailer's size, height, and weight. The towing menu also instructed the driver to drive the vehicle for a few miles to generate an accurate range estimate. Accordingly, the initial run involved a 12-mile drive from the Keene Area Headquarters to the start of the test run.

In nontowing operations, the truck estimates between 2 and 2.2 miles per percentage point of battery charge (equivalent to 200–220 miles of range), slightly less than its listed maximum range of 240 miles. The estimated range in the towing test was significantly lower after the initial calibration period, measured as 97 miles at 85% (114-mile maximum) and 105 miles at 88% (119-mile maximum).

The range prediction was accurate throughout both tests. Figure 2 shows the accuracy of the range estimation by plotting the sum of distance traveled and remaining range, normalized to zero miles at the starting point. Negative values indicate the estimated range is decreasing faster than actual distance covered, suggesting potential power loss before reaching the destination. Positive values indicate the estimated range is decreasing more slowly than the distance traveled, providing a safety buffer. A horizontal line, y = 0, indicates that the range estimation is accurate throughout the trip. In this case, the miles traveled and estimated remaining range would sum to the same value at any point on the trip. Run 1 experienced a temporary reduction in range estimation between miles 15 and 30. The cause of the reduction was not clear, although a sudden thunderstorm and 10-degree temperature reduction did occur during the run, which may have been related.

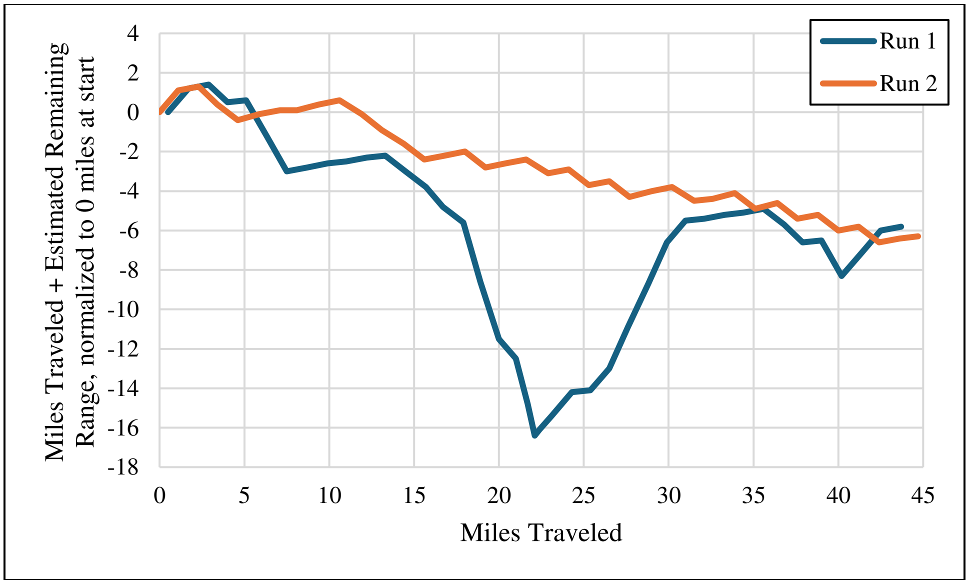


Figure 2. Sum of Estimated Remaining Range and Miles Traveled versus Miles Traveled for Towing Tests

Grade Field Tests

To determine the vehicle's performance in mountain regions, it was driven from Charlottesville on I-64 West to Afton Mountain, for an elevation gain of 1,240 feet occurring over 17 miles (1.38%), with the final 991 feet of elevation occurring over just 4.6 miles (4.1%). The vehicle was turned around at Exit 99 at the top of the mountain and driven back down to measure any regeneration during the descent.

Performance was measured as the change in the estimated range remaining over the distance driven (Figure 3). The vehicle lost a maximum of 12.0, 16.8, and 20.6 miles of range on the uphill portion, with an average of 16.5 miles lost. The vehicle was able to regenerate range on the downhill portion, recapturing 7.4, 12.0, and 9.9 miles of range respectively. The overall loss of range for the full out and back route was 22% of miles traveled, or 22 miles per 100 miles traveled.

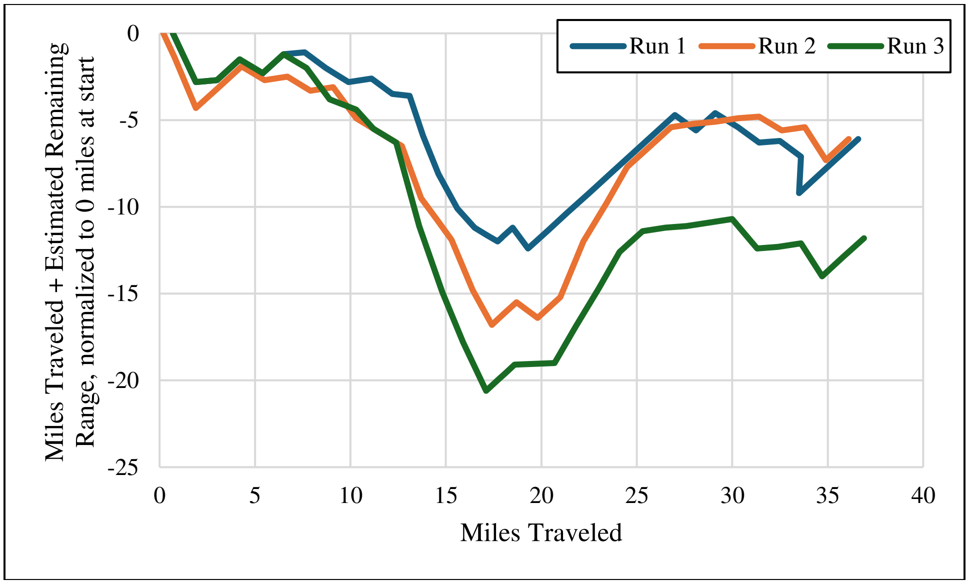


Figure 3. Sum of Estimated Remaining Range and Miles Traveled versus Miles Traveled for Grade Tests

Ambient Temperature Field Tests

To test the effect of ambient temperature on range, the vehicle was driven at 70 mph along a relatively flat out-and-back section of I-64 between Charlottesville and Richmond, Virginia. Most tests were run for approximately 2 hours, with the exception of the second temperate run, which ended early upon encountering congestion. The temperature in the hot runs was 88°F in both instances and between 73 and 78°F in the temperate runs. In all tests, climate control was set to 70°F in the truck using air conditioning.

Figure 4 shows the results of the ambient temperature tests. In most tests, the miles of range lost were between 8 and 15 across tests. The rate of range lost was approximately 15 miles across 120 miles traveled, for a loss rate of 7 to 12%, or 7 to 12 miles per 100 miles driven. There was no discernable difference between hot and temperate runs, and the differences between runs do not have observable causes.

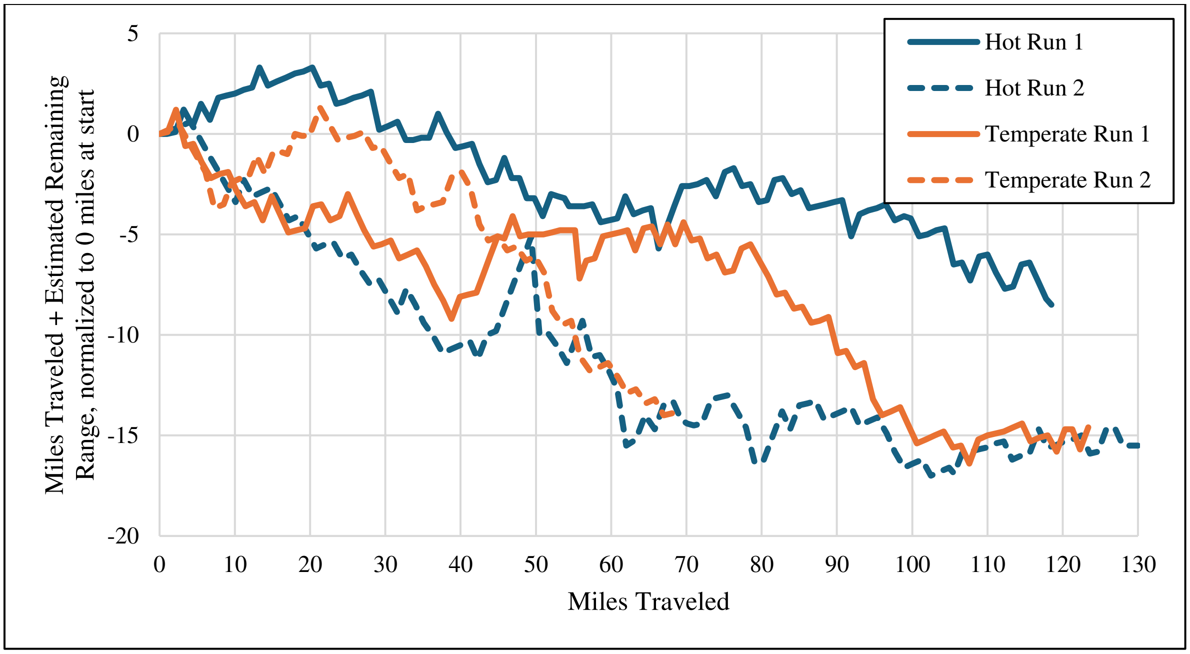


Figure 4. Sum of Estimated Remaining Range and Miles Traveled versus Miles Traveled for Ambient Temperature Tests

Climate Control and Idling Field Tests

Some VDOT operations require extended periods of idling along the roadside and in work zones. To test the effect of idling in different weather conditions on the vehicle's range, the vehicle was turned on, and battery and range estimates were recorded at 1-minute intervals during 8 hours in hot, temperate, and cold conditions, both with climate control (air conditioning or heat) on and off. When climate control was activated, the cabin thermostat was set to 70°F.

Table 3 shows the results of the idling tests. The energy expended is expressed in three ways: kWh per hour of operation, estimated maximum runtime assuming a 100% charge of the vehicle's 92 kWh capacity, and the equivalent miles of range lost per hour of idling as measured from the vehicle's own real-time range estimates.

Table 3. Results of Idling Tests

Weather conditions	**Hot**		**Temperate**		**Cold**	
Climate control status	**On**	**Off**	**On**	**Off**	**On**	**Off**
Temperature (°F)	73–83	90–93	50–63	47–61	27–38	12–34
kWh per hour	0.92	0.23	1.07	0.32	1.97	1.63
Estimated maximum runtime (hours)	100	396	86	291	47	57
Equivalent miles per hour	2.2	0.6	2.3	0.5	4.1	3.5

kWh = kilowatt-hours.

Climate control represented a significant portion of energy consumption, particularly during hot and temperate conditions. With climate control on, the vehicle consumed energy equivalent to 2.2 mph in hot conditions compared with 0.6 mph without climate control, and 2.3 mph in temperate conditions compared with 0.5 mph without. Energy usage with climate control in this test was slightly higher in temperate conditions than in hot conditions because the thermostat setting of 70°F required a greater adjustment from the ambient temperature during the temperate test runs (50–63°F) compared with the hot test (73–83°F).

As expected, energy consumption was highest in cold conditions, reaching 4.1 mph with climate control on and 3.5 mph with climate control off. The cold weather test without climate control was conducted under particularly severe conditions, with temperatures ranging from 12 to 34°F. Even with climate control off, energy consumption remained relatively high because of the battery's thermal management system, which must maintain optimal operating temperatures for proper battery function. Even with the battery management system, the vehicle has an expected run time of 57 hours without climate control.

Low-Speed Field Tests

To simulate a rolling work zone, the vehicle was tested during 2-hour periods along a low-speed residential road at approximately 10 mph under hot (73–91°F), temperate (62–65°F), and cold (32–35°F) conditions.

Figure 5 shows the accuracy of the range estimates versus miles traveled. The periodic dips in range accuracy are due to a hill on the course, with the vehicle revising its range estimate downward while traveling uphill and revising it upward while traveling downhill because of regenerative braking.

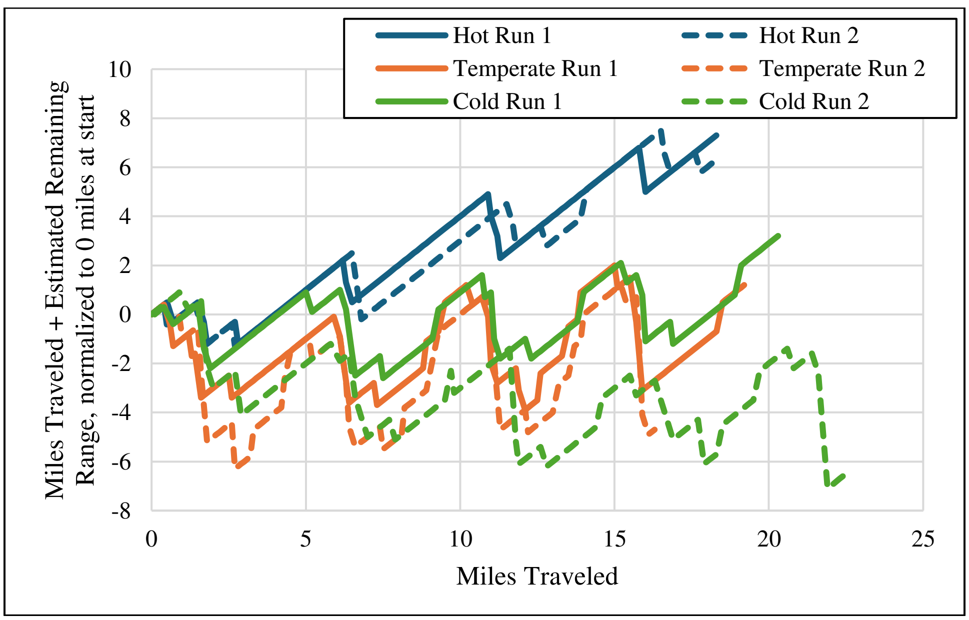


Figure 5. Sum of Estimated Remaining Range and Miles Traveled versus Miles Traveled for Ambient Low-Speed Tests

Range estimates were fairly accurate, staying within plus or minus 6 miles during the 2-hour period. This outcome suggests that the vehicle does not experience significant changes in fuel efficiency at low speeds and could theoretically maintain 10 mph for at least 15 hours.

Low and No Battery Field Tests

The vehicle was run to within 3 miles of remaining range to determine warnings. At 30 miles remaining, the vehicle issued a low-mileage warning on the main dash accompanied by an audible tone. A second warning was issued at 15 miles remaining. The test was ended at 3 miles remaining to avoid damaging the battery, although videos of total depletion posted to YouTube show a warning issued at 1 mile remaining: "Depleted battery; Stop safely now." Based on user videos, climate control will then shut off, and the vehicle will transition to a small amount of reserve power. At total depletion, the vehicle will begin to coast to a stop, and the vehicle will slow to a stop and display the message "Vehicle shut off; Depleted battery."

Recharging Field Tests

Recharge times were tested across a range of charging stations and weather conditions. Recharge times were recorded via automated screenshots of the FordPass application or through manually recording range and battery levels from the vehicle's dashboard. Performance was evaluated based on the miles of range added per mile, as well as the calculated time required to charge the vehicle from 20 to 80%, adjusted based on the actual beginning and end battery levels observed in tests.

In all tests of high-speed chargers, the charging rate slowed as the battery reached a full charge. The charging rate decreased after the battery level reached 80%, decreased again after the battery level reached 90%, and continued to decrease between 95 and 100%. The battery was charged only once above 90% at a high-speed charger because Ford recommends keeping battery levels at 90% or below unless additional range is specifically needed for a long trip. In all tests, the charge rate did not exceed 40 kW above 80% of the battery level and 25 kW above 90% of the battery level.

Table 4 shows the results of the charging tests. Ambient temperature did not appear to alter the time required to charge from 20 to 80%, although vehicles did add more range when charging at hotter temperatures than at moderate temperatures. This result may be due to a difference in range estimates in hot weather, in which the vehicle may assume additional miles per kWh in hotter temperatures, potentially resulting in miles increasing at a faster rate than battery level for a given kWh charge.

It is possible to leave the vehicle running while charging. The effect on charge rates is fairly small, with 4 fewer miles per hour added when climate control is running during moderate temperatures. For low-speed charging, leaving climate control on results in an increase of 20 to 80% charging time from 10.7 to 13.7 hours. When using high-speed charging, climate control may only reduce charge times by 2 to 3%, adding a mere minute or 2 to total charging time.

Table 4. Results of Charging Tests

Location	Capacity	Conditions	Climate Control Status	Miles of Range Added per Hour	20–80% Charge Time (hours, calculated)
VTRC	5.5 kW	Temperate	On	11	13.7
VTRC	5.5 kW	Temperate	Off	15	10.7
VTRC	5.5 kW	Hot	Off	11	10.6
Ford Dealership	50 kW	Temperate	Off	127	1.2
Albemarle County Office Building	50 kW	Temperate	Off	121	1.1
Mill Creek	75 kW	Temperate	Off	166	0.9
Mill Creek	75 kW	Hot	Off	177	0.9
Ford Dealership	100 kW	Hot	Off	220	0.6

kW = kilowatt; VTRC = Virginia Transportation Research Council.

Maintenance

Tire tread depth was measured periodically using a digital depth gauge because the heavier weight of BEVs has been associated with increased tire wear. Table 5 shows the results of tread depth measurements. No measurable change in tread depth was observed, although the tires were driven less than 2,000 miles. By comparison, Ford recommends checking tread depth every 10,000 miles and estimates tire replacements at between 30,000 and 40,000 miles for EVs. Measurable changes in tread depth may only become observable at greater distances than those tested.

Table 5. Tire Tread Depth Measurements

Date	Odometer (miles)	Tread Depth (mm)			
		Front Driver	Rear Driver	Rear Passenger	Front Passenger
11/4/2024	245.7	7.84	7.9	7.84	8.03
11/4/2024	287.9	7.57	7.56	7.73	7.48
11/8/2024	330	7.43	7.53	7.47	7.44
11/12/2024	377.6	7.72	7.85	7.69	7.71
11/15/2024	498.8	7.47	7.43	7.69	7.71
11/22/2024	614	7.36	7.57	7.43	7.26
7/21/2025	1,948	7.5	7.8	7.66	7.47

The truck did not require any maintenance during testing.

External Emergency Lighting Draw

The study's initial scope included tests related to safety lighting and message boards. The tests would have determined the battery draw of the safety lighting and message boards while the vehicle was stationary and while the vehicle was moving. However, at the time of the study, VDOT's preferred provider of special light installation packages had never installed such equipment on an electric pickup truck. As such, the field tests related to safety lighting and message boards were not conducted. Using the specifications for VDOT's typical emergency lighting products, approximate calculations of the lighting battery draw were determined. These estimates of energy draw were compared with the battery capacity of the electric truck for context.

The message sign used by VDOT has a typical load of 8.4 amps at 13.6 volts direct current and a maximum load of 24.6 amps at 13.6 volts direct current (Wanco, 2023). For 1 hour of typical use of the message sign, it translates to 0.114 kWh, which is 0.12% of the truck's standard battery (98 kWh). For 8 hours of typical and maximum use, the message sign would consume 0.93% and 2.7% of the truck's standard battery, respectively. In the case that the message sign is being used while the vehicle is moving, the additional weight (220 pounds) and aerodynamics of the message sign will also affect the expected range of the vehicle. This study was unable to capture those effects because of the sign not being installed on the vehicle.

Refine Electric Vehicle Decision Support Tool

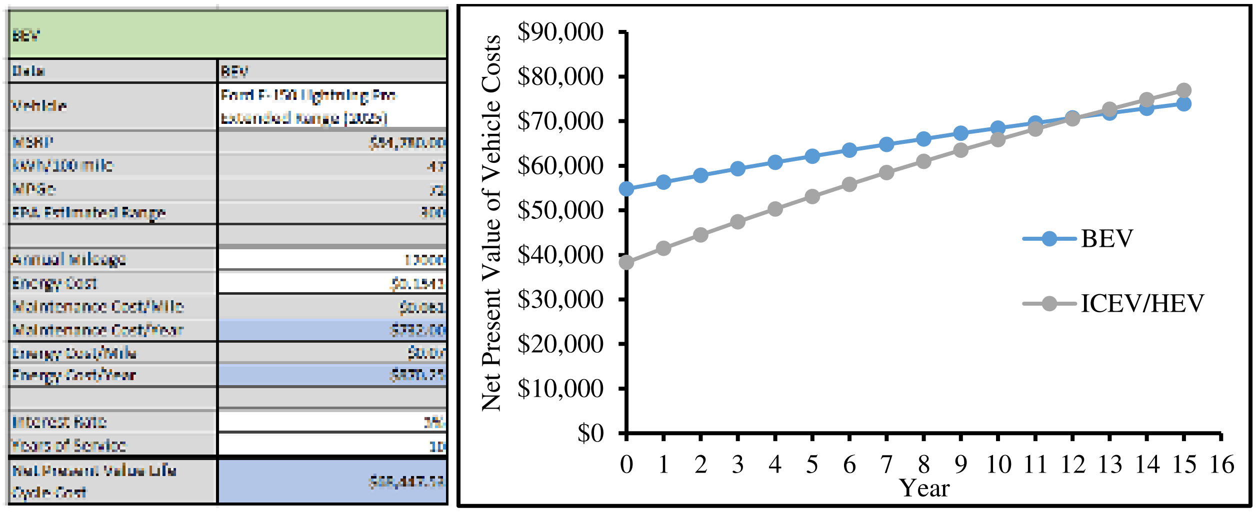
Sources for EV, HEV, and ICEV data in the model are as follows:

- Manufacturer suggested retail price. Values are from the vehicle manufacturer's website (data retrieved June and July 2025).
- Miles per gallon gasoline equivalent, kWh per 100 miles, and EV range values were retrieved from fueleconomy.gov.
- Maintenance costs per mile for EVs, HEVs, and ICEVs are based on research from Argonne National Laboratory (Burnham et al., 2021). The maintenance costs may not fully reflect electric pickup trucks because the study was completed before these vehicles came to the market in the United States. As of now, long-term maintenance data for electric pickup trucks are still not available.

The decision support tool was developed to provide an approximate life cycle cost analysis for select EV and ICEV models or for a custom EV or ICEV input by the user. The tool calculates the net present value of life cycle costs based on the service life of the vehicle, expected interest rate, vehicle's purchase price, yearly maintenance costs (based on estimated maintenance costs per mile and annual mileage), and yearly energy costs (based on local energy or fuel cost, annual mileage, and energy usage of the vehicle).

The user may adjust any of the inputs, although some recommendations are made. The suggested annual mileage is 12,000 miles based on the average mileage of CalAmp-equipped, VDOT-owned pickup trucks for which a year of data was reviewed for the technical assistance report, *Potential for Electrification of the VDOT Vehicle Fleet* (Goodall and Robartes, 2022). The recommended cost of electricity is $0.1543 per kWh based on the average residential price of Virginia electricity in 2025 (U.S. Energy Information Administration, 2025). The recommended service life of the vehicle is 10 years, the standard for VDOT vehicles.

The tool exists as a Microsoft Excel spreadsheet that calculates costs and benefits based on user-adjusted inputs and publicly available vehicle cost-of-ownership models. The tool was submitted as part of this report. Figure 6, a screen shot of the tool, shows some of the tool's inputs (Figure 6a) and one of the tool's outputs, with which the life cycle costs of multiple vehicles can be compared (Figure 6b). The user manual for the tool is in the Appendix.



(a) (b)

Figure 6. Screenshots of Some of the Electric Vehicle Decision Support Tool's (a) Inputs and (b) Outputs. BEV = battery electric vehicle; EPA = U.S. Environmental Protection Agency; HEV = hybrid electric vehicle; ICEV = internal combustion engine vehicle; kWh = kilowatt-hours; MPGe = miles per gallon gasoline equivalent; MSRP = manufacturer suggested retail price.

VDOT User Testing

The vehicle was loaned to the Keene Area Headquarters in Scottsville, Virginia, part of the Charlottesville Residency in the Culpeper District. Staff used the vehicle for 3 weeks in July 2025 to assess its ease of operation, charging, and suitability for VDOT operations. Debriefs with staff indicated that the vehicle was very intuitive to operate because of its similarities to similar truck models in VDOT's fleet. Staff noted that the range limited some uses of the vehicle because staff occasionally had to travel 200 or more miles during a shift in areas without access to high-speed charging stations. They recommended considering long-range variants to allow more use cases. They were unable to test the vehicle during mowing operations because of its lack of flashing amber lights but were able to test it adequately during administrative tasks.

CONCLUSIONS

- *Range performance under real-world conditions is generally consistent with manufacturer estimates although significantly affected by specific operational factors.* Field testing revealed that the electric truck's range estimates proved accurate during most standard driving conditions, with the vehicle's onboard range predictions staying within plus or minus 6 miles during extended test periods. However, towing operations reduced practical range by approximately 50 to 70%, with actual towing ranges of 91 to 105 miles compared with nontowing ranges of 240 to 320 miles, depending on battery configuration.

- *Temperature significantly affects battery performance, particularly during extended idling operations common to VDOT work.* Cold weather testing showed energy consumption rates of 4.1 mph equivalent during idling with climate control compared with 2.2 to 2.3 mph in hot and temperate conditions. Even without climate control, cold conditions consumed 3.5 mph equivalent because of battery thermal management requirements, indicating potential operational limitations during Virginia's winter months.

- *Mountainous terrain presents manageable challenges with regenerative benefits on descent.* Testing on I-64's Afton Mountain route showed range losses of 12.0 to 20.6 miles during uphill sections, but the vehicle recovered 7.4 to 12.0 miles through regenerative braking on descent. The net range loss of 22% over the full mountainous route demonstrates that electric trucks can operate effectively in Virginia's varied topography, although with reduced overall efficiency.

- *Low-speed operations typical of maintenance work zones are well suited to electric truck capabilities.* Testing at 10 to 15 mph showed consistent range performance, with the vehicle capable of maintaining slow speeds for approximately 15 hours on a full charge. The range estimation system remained accurate during low-speed operations, indicating good suitability for rolling work zones and maintenance activities.

- *Short-term maintenance requirements are minimal, although long-term battery degradation could not be assessed.* During the 9-month evaluation period, the vehicle required only routine maintenance similar to conventional vehicles, with no electric-specific issues identified. Tire wear patterns were not observable because of the low overall mileage driven. More mileage is required to draw definitive conclusions about long-term maintenance costs.

- *Charging infrastructure requirements are manageable but require strategic planning for optimal deployment.* Field testing demonstrated that direct current fast charging can restore the vehicle from 20 to 80% battery capacity in approximately 0.6 to 1.2 hours, depending on charger capacity, consistent with manufacturer specifications. However, 240-volt charging at VDOT facilities required 10.7 to 13.7 hours for a similar charge cycle, indicating that overnight charging infrastructure at facilities will be essential for daily operations. The study's findings suggest that successful electric truck deployment depends on reliable access to 240-volt charging infrastructure at base facilities.

- *User acceptance among VDOT staff is generally positive, with operational limitations clearly understood.* Field testing with VDOT personnel revealed that drivers adapt well to electric truck operation and its similarities with conventional internal combustion engine models. Personnel expressed a preference for extended-range models to improve operational versatility.

- *The refined Electric Vehicle Decision Support Tool provides improved accuracy for fleet planning decisions.* These improvements enable more informed decision-making regarding which vehicle applications are most suitable for electric truck deployment.

RECOMMENDATIONS

1. *VDOT's Maintenance Division should implement a pilot EV deployment, prioritizing electric SUVs and sedans, at selected facilities.* Field testing revealed that electric pickup trucks experience significant operational limitations during towing operations and cold weather conditions that make them less suitable for VDOT's diverse operational needs. Electric SUVs and sedans can provide similar fuel and maintenance cost benefits without these operational constraints because they are typically not required for heavy towing or for 24-hour, around-the-clock emergency operations that characterize many pickup truck applications. EVs should be deployed in applications that support routine overnight charging and avoid heavy towing operations and emergency roles in which charging infrastructure may be compromised. This gradual approach allows VDOT to develop charging infrastructure incrementally and identify optimal deployment strategies while maintaining conventional vehicles for essential operations. The refined Electric Vehicle Decision Support Tool developed in this study may be utilized during the selection process to identify facilities and vehicle applications most suitable for EV deployment.

2. *VDOT's Fleet Management should continue collecting long-term maintenance and battery degradation data from existing and any future electric truck deployments to inform procurement decisions.* This study's 9-month duration was insufficient to assess long-term battery performance and maintenance costs. Continued monitoring of deployed vehicles will provide crucial data for refining cost-benefit analyses and validating manufacturer claims regarding battery longevity and total cost of ownership.

IMPLEMENTATION AND BENEFITS

Researchers and the technical review panel (listed in the Acknowledgments) for the project collaborate to craft a plan to implement the study recommendations and to determine the benefits of doing so. This process is to ensure that the implementation plan is developed and approved with the participation and support of those involved with VDOT operations. The implementation plan and the accompanying benefits are provided here.

Implementation

Regarding Recommendation 1, VDOT's Maintenance Division will initiate a pilot EV deployment within 1 year of this report's publication at selected facilities that represent diverse operational patterns and geographic conditions across Virginia. The pilot program will focus on electric SUVs and sedans deployed in applications supporting routine overnight charging while avoiding heavy towing and 24-hour, around-the-clock emergency operations. VTRC will provide technical assistance in facility selection, performance monitoring, and charging infrastructure planning on request. The refined Electric Vehicle Decision Support Tool may be utilized during the selection process to identify facilities and vehicle applications most suitable for EV deployment, with pilot results informing broader fleet expansion decisions.

Regarding Recommendation 2, VDOT's Fleet Management will continue collecting long-term maintenance and battery degradation data from existing and future electric truck deployments through the vehicles' operational lifespans. VTRC will assist with data analysis and reporting on request to inform future procurement and deployment decisions.

Benefits

The benefit of implementing Recommendation 1 is informed decision-making through pilot testing that builds operational knowledge while managing risks and maximizing cost savings across vehicle types. Pilot deployments allow VDOT to evaluate EV performance in real-world conditions, develop charging infrastructure at selected facilities, and train staff on EV operations before making broader procurement decisions. Based on the refined Electric Vehicle Decision Support Tool and current energy costs, replacing conventional vehicles with EVs in suitable applications can save approximately $1,400 annually per vehicle in fuel and maintenance costs, assuming 12,000 miles of annual operation. Electric sedans and SUVs typically offer additional savings compared with electric trucks because of lower purchase prices and higher energy efficiency, while avoiding the operational limitations observed in electric trucks. This approach minimizes the risk of operational disruptions while providing data to refine future deployment decisions and demonstrates feasibility across multiple vehicle classes. Early pilot deployments can build organizational confidence in EV technology while maintaining operational readiness during emergency situations when conventional vehicles remain essential.

The benefit of implementing Recommendation 2 is continued improvement in cost-benefit analyses and deployment strategies based on real-world Virginia operating conditions. Long-term data collection will validate manufacturer claims regarding battery longevity and total cost of ownership, potentially identifying additional cost savings or operational adjustments. These data will also inform VDOT's broader vehicle electrification strategy and provide valuable information for other state transportation agencies considering similar transitions.

ACKNOWLEDGMENTS

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APPENDIX

User Manual

The life cycle cost analysis tool allows for a life cycle cost analysis comparison of multiple vehicles, including battery electric vehicles (BEVs), hybrid electric vehicles (HEVs), and internal combustion engine vehicles (ICEVs). The following sections constitute the user manual.

The tool requires input about how the vehicle will be used (i.e., how long the vehicle will be in service and annual mileage). In addition, the tool requests user inputs about current and local energy costs (for BEVs) and fuel costs (for HEVs and ICEVs). The tool's current setup allows for a comparison of a BEV (column C), a custom electric vehicle (column D), an HEV/ICEV (column G), or a custom HEV/ICEV (custom H).

Required Inputs

- **Vehicle.** The vehicle cell in columns C (BEV) and G (HEV/ICEV) are prefilled with a dropdown menu of motor vehicles that can be selected for analysis. If the vehicle of interest is not contained in the dropdown list, column D (BEV) or H (HEV/ICEV) may be used to fill in a custom vehicle. Custom vehicle columns will require additional information to be input into the sheet, including the manufacturer suggested retail price, kWh-per-mile data (BEV), and miles per gallon (HEV/ICEV). Fueleconomy.gov may be used as a source for each of these data elements. For the purposes of this tool, combined city and highway miles per gallon are used in all prefilled data.
- **Annual Mileage.** This variable is used in calculations of yearly maintenance and energy costs. In estimating this variable, some Virginia vehicle data may be referenced. Some VDOT-owned pickup trucks are equipped with CalAmp Vehicle Trackers, which capture vehicle travel data. Of those vehicles with data trackers, trucks with 12 months of data available (June 2021–May 2022) averaged an annual mileage of about 11,790 miles.
- **Energy and Fuel Cost.** Energy and fuel costs are user-required inputs into the model because these variables may fluctuate based on local and economic conditions. The U.S. Energy Information Administration provides electricity costs (Electricity - U.S. Energy Information Administration (EIA)). The American Automobile Association may be used for Virginia gas prices (https://gasprices.aaa.com/?state=VA).
- **Interest Rate.** Estimating the expected rate of inflation during the vehicle's lifetime is necessary for the net present value cost estimations. The default is 3%.
- **Years of Service.** Expected lifetime of the vehicle. The default is 10 years.
- **Maintenance Cost per Mile.** Table A1 lists the recommended maintenance costs per mile by type of vehicle (Burnham et al., 2021). These data come from research carried out at the Argonne National Laboratory, sponsored by the U.S. Department of Energy. Custom values may be used if more precise data are available.

Table A1. Vehicle Maintenance Costs per Mile

ICEV	$0.101
HEV	$0.094
PHEV	$0.090
BEV	$0.061

BEV = battery electric vehicle; HEV = hybrid electric vehicle; ICEV = internal combustion engine vehicle; PHEV = plug-in hybrid electric vehicle.