Fleet Electrification Analysis: Fredericksburg City Public Schools
EXECUTIVE SUMMARY

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Executive Summary:

Virginia Clean Cities (VCC) conducted an alternative fuel fleet analysis with the Fredericksburg City Public Schools (FCPS) focused on the feasibility and implementation of alternative fuel vehicle adoption (encompassing full battery electric vehicles (EV), plugin hybrid electric vehicles (PHEV), and hybrid electric vehicles (HEV)). The goals of the study are designed to align with City Council's wider sustainability vision and goals to achieve powering municipal operations with 100% renewable energy by 2035. The following report covers the analysis of the FCPS fleet.

After gathering fleet data from FCPS, VCC performed an analysis to create a baseline of current FCPS fleet and vehicle performance indicators, chart out available alternative fuel options and create cost/benefit performance profiles showing the operational cost comparisons, the total cost of ownership (TCO), and total investment/return on investment needed for the city around each vehicle use case. We also provided recommendations on the number and type of electric vehicle supply equipment (EVSE) needed to support EVs within the different segments of the fleet. Fredericksburg City Public Schools has a diverse fleet of vehicles covering many use cases and vehicle types. For this report, we will focus on the vehicles and use cases that would make the most sense for the replacement of alternative fuel vehicles in the short-term while providing guidance for long-term fleet planning. For example, while data for a handful of medium-duty (MD) trucks were provided by the FCPS team, there are few viable EV and HEV alternatives on the market at this time.

The vehicle use case feasibility profiles were subdivided into two categories: those light-duty use cases eligible for EV and HEV replacement, those medium-to-heavy-duty use cases to consider on a longer-term (4+ years) replacement schedule based on model availability and market factors, and school bus replacements. Figure 1 shows the 84-vehicle on-road fleet broken down by use case category.

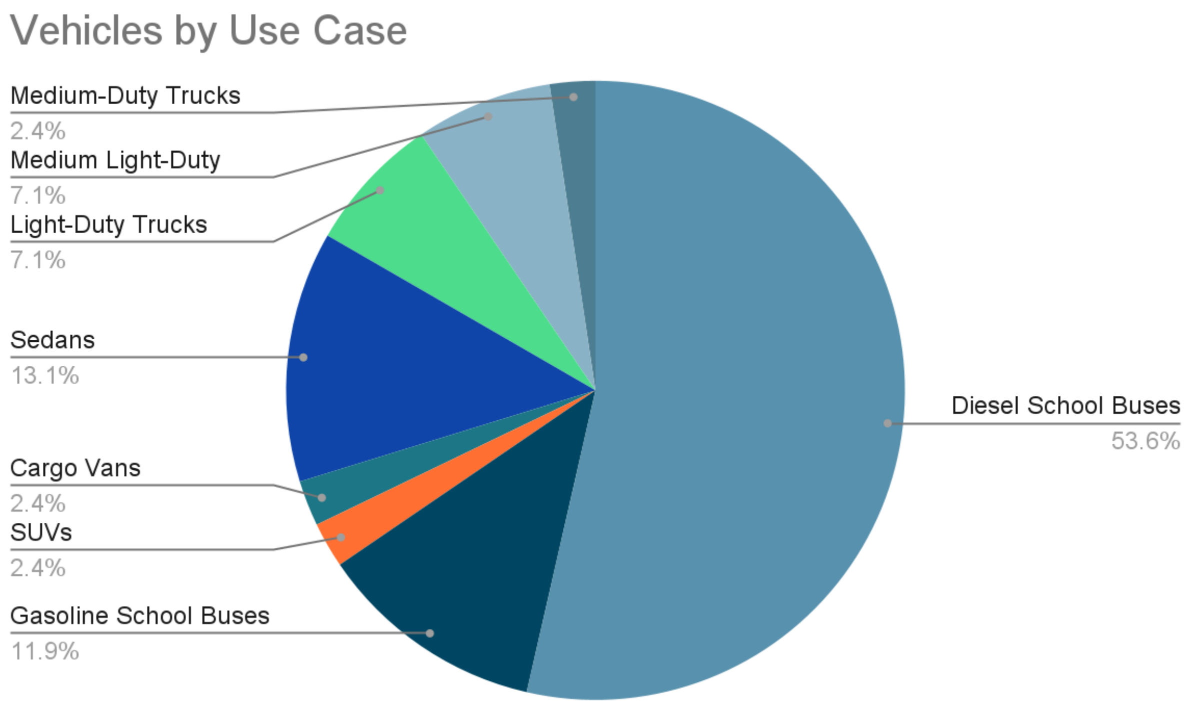

Figure 1: Fredericksburg City Public Schools Fleet Vehicles by Class

While we enthusiastically support the increased use of alternative fuel vehicles, it is unlikely that the Fredericksburg City Public School's fleet will find it cost-effective to fully eliminate gasoline and diesel fuels from operations in the near term. In the past, fleets have also been at a disadvantage when it comes to purchasing EVs, as they have been ineligible for the Federal EV Tax Credit. However, this analysis was conducted as a new tax credit was being developed. The Commercial Clean Vehicle Tax Credit could significantly reduce the cost of these electric vehicles. The Treasury Department has issued guidance that tax-exempt organizations qualify for between $7,500 and $40,000 per vehicle, depending on vehicle weight. More guidance is forthcoming from the Treasury and FCPS would need to work with their vehicle vendor to develop a process for utilizing this tax credit. Since this process has not been finalized for public fleets, this incentive was not included in our analysis. Further, many fleets, particularly public fleets, have several advantages when purchasing non-electric fuels. These include exemptions from state fuel taxes and the ability to negotiate attractive pricing based on the large annual fuel volumes purchased. An additional factor that reduces the financial benefit of electric and hybrid vehicles is the low annual mileage of some of the city's vehicles. Vehicles with high annual mileage recognize the benefits of Virginia's stable and low-cost electricity faster than those with low annual mileage. Finally, existing supply chain disruptions are reducing the available supply of EVs and HEVs. However, we believe there are significant benefits to transitioning select areas of fleet operations to EVs in both the near- and long-term.

Baseline vehicle analysis

Using the EPA ratings for miles per gallon (MPG) and the total annual miles driven per year we can calculate the estimated baseline for fuel consumption (use and cost) and mileage for the FCPS non-bus fleet vehicles we can then sort by class/use case allowed for comparisons to be made, showing the potential effects and outcomes when using EVs, PHEVs, HEVs as replacements to internal combustion engine (ICE) vehicles currently operating in the fleet.

EV and HEV KPI Averages Across Fleet Vehicle Classes- City Departments								
Conventional Vehicle	Alternative Fuel Vehicle	Conventional Vehicle MPG	Alternative EPA MPGGE	Efficiency	EPA kWH/100 miles	Battery Size (kW)	Range (miles)	Annual miles needed to produce payback in ≤10 years
Sedan	Chevrolet Bolt EV	33	120	0.28	28	65	259	15,000
Sedan	Nissan LEAF (40kw)	33	111	0.30	30	40	149	11,000
SUV	Ford Explorer HEV	23	27	0.85	-	-	486	No Payback
SUV	Chevrolet Bolt EUV	23	120	0.19	28	65	259	4,500
SUV	Ford Mach-E	23	103	0.22	33	70	247	14,000
LD Truck	Ford F-150 Lightning	21	68	0.31	48	98	230	15,000
LD Truck	Ford F-150 Hybrid	21	25	0.84	-	-	613	12,700
LD Truck	Ford Maverick Hybrid	21	37	0.57	-	-	511	Immediate
LD-MD Truck	Ford F-150 Lightning	15	68	0.22	48	98	230	5,000
Cargo Van	Ford E-Transit	16	63	0.25	50	68	126	6,000

Table 1: EV and HEV Key Performance Indicator (KPI) Averages Across Fleet Vehicle Classes

Based on our analysis of the use case for each vehicle type and available electric and hybrid vehicles on the Virginia Sheriff's Contract, we have identified several vehicle types that present strong cases for EV and Hybrid replacement. These cases are based on Total Cost of Ownership (TCO) savings potential. For all vehicles, we recommend prioritizing the replacement of the oldest vehicles and those with the greatest annual miles.

Based on the existing truck, sedan, SUV, cargo van, and school bus model availability, our recommendations for replacements are as follows:

1) Priority/near-term - The oldest diesel school buses with electric school buses, focus efforts around funding opportunities that cover the full incremental cost of the bus and infrastructure funding to achieve payback

2) Priority/ near-term- The oldest and highest mileage sedans with Nissan LEAFs or Chevy Bolt EVs

3) Priority/ near-term- Light-duty pickup trucks that can be sized down with Ford Maverick Hybrids

4) Replace cargo vans that achieve greater than 6,000 annual miles with E-Transit Vans

5) Downsize and replace the fleet daily use SUV with a Chevy Bolt EUV

For sedan and light-duty truck replacements, we recommend that the oldest and highest mileage vehicles be replaced first. In some cases, this may require some fleet vehicles to be reassigned to different use cases. For example, the school district currently has a 2003 Nissan Sentra that logged 6,278 miles last year. The schools also have a 2018 Ford Taurus that drove 12,221 miles in the last year. The fleet could maximize the benefits of their vehicle replacements with EVs in the short-term by removing the 2003 Sentra from the fleet, using the 2018 Taurus in its place, and replacing the Taurus with an EV, since EVs make the most efficient return on investment with higher annual miles. This also ensures that the newer (and likely higher mpg) Taurus remains in the fleet while the older (likely lower MPG) vehicle is removed from use.

Other vehicles that FCPS should plan to replace in the medium and long term would be replacing fleet Medium Light-Duty trucks (such as F-250s) with F-150 Hybrids or F-150 Lightnings where use case allows, and Medium-Duty trucks with electric alternatives that are expected to come to market or come down in price over the next decade. The School District should also consider replacing the remaining light-duty trucks whose use cases could not be served by Maverick Hybrids with F-150 Lightning battery electric trucks. Once all diesel buses have been replaced, FCPS should begin replacing their remaining gasoline school buses with electric.

Figures 2-7 show the TCO comparisons over a 10 to 15-year lifecycle for replacing the average fleet vehicle with EVs/HEVs versus ICE vehicles. Figures 2-8 also include a TCO scenario in which the cost of procuring and installing one Level 2 charging station for every two EVs is included in the upfront capital cost since they are the closest to seeing TCO savings even with that additional purchase. Figures 8-11 show the TCO comparisons over a 10 to 15-year lifecycle for replacing the average fleet school bus with electric alternatives. Figures 8-11 assume one charger per school bus and also compare the TCO differences between the use of high-powered Level 2 chargers and low-powered DC chargers.

Total cost of ownership analysis

This Total Cost of Ownership section will be broken into three parts: transportation, maintenance, and school buses. For this analysis, all white fleet vehicle comparisons utilize the base contract price provided on the Virginia Sheriff's contract unless otherwise specified. School bus prices were drawn from the Virginia State Contract. These rideable contracts allow public entities such as local and state governments to purchase vehicles without requiring a procurement process. Fredericksburg would be considered in the "Heritage" region for procurement purposes. These analyses were performed using the AFLEET tool. The Afleet tool was designed by Argonne National Laboratory to examine both the environmental and economic costs and benefits of alternative fuel. This tool also provides default data that can be used to supplement fleet data. In these analyses, default maintenance and infrastructure cost data were utilized for each vehicle type. Explanation and data sources are provided in the "background data" tab of the AFLEET tool. For EV planning, 1 charger was estimated for every 2 vehicles for white fleet vehicles and 1 charger per electric school bus.

Transportation

For the analysis of the school's fleets, the following fuel prices were used as provided: $2.78/ gallon gas and $3.71/ gallon diesel. Since no price was provided for electricity, we utilized the $0.10/ kWh electricity price provided by the City of Fredericksburg for their fleets.

Fredericksburg City Public Schools provided data for 6 different types of sedans. For the purposes of this report, we have selected the 2022 Nissan Sentra for comparison, as it is one of the most fuel-efficient sedans available on the VA Sheriff's contract at this time. FCPS's average gasoline price of $2.78/ gallon is a relatively low price per gallon, especially when considering the fuel price spikes that took place in 2022. Since the lower fuel price of electricity is of the biggest cost-saving factors for EVs, fleets that already pay lower fuel prices are less likely to achieve as many cost-saving benefits as fleets that pay higher prices for their petroleum-based fuels. Due to FCPS's low gasoline costs, vehicles would need to reach at least **15,000** (Chevrolet Bolt EV) or **11,000** (Nissan LEAF (40kW)) annual miles for EV replacement to reach payback in ten years or less. FCPS's current average annual mileage for sedans is 8,891 annual miles. It is important to note that the Nissan LEAF (40kW) has a shorter range than some of its EV counterparts at 149 miles per full charge. This would not make LEAFs an ideal replacement for vehicles used for long-distance trips but can easily serve in-town daily travel needs. Nissan also makes a 62kW option for LEAFs, but it is not currently available on a rideable contract. With FCPS's low gasoline prices, it is also unlikely that hybrid replacements would reach payback within a ten-year timeframe. Hybrid vehicles typically have higher purchase prices than conventional internal combustion engine vehicles and have better gas mileage. However, their fuel efficiency is still much lower than EV alternatives. Due to FCPS's relatively low annual miles and low gas prices, EVs would be more likely to make a return on investment than hybrid vehicles. We recommend the district prioritize replacing older and high-mileage vehicles. If Hybrid vehicles are still of interest, rideable contracts can be found in the National Auto Fleet Group.

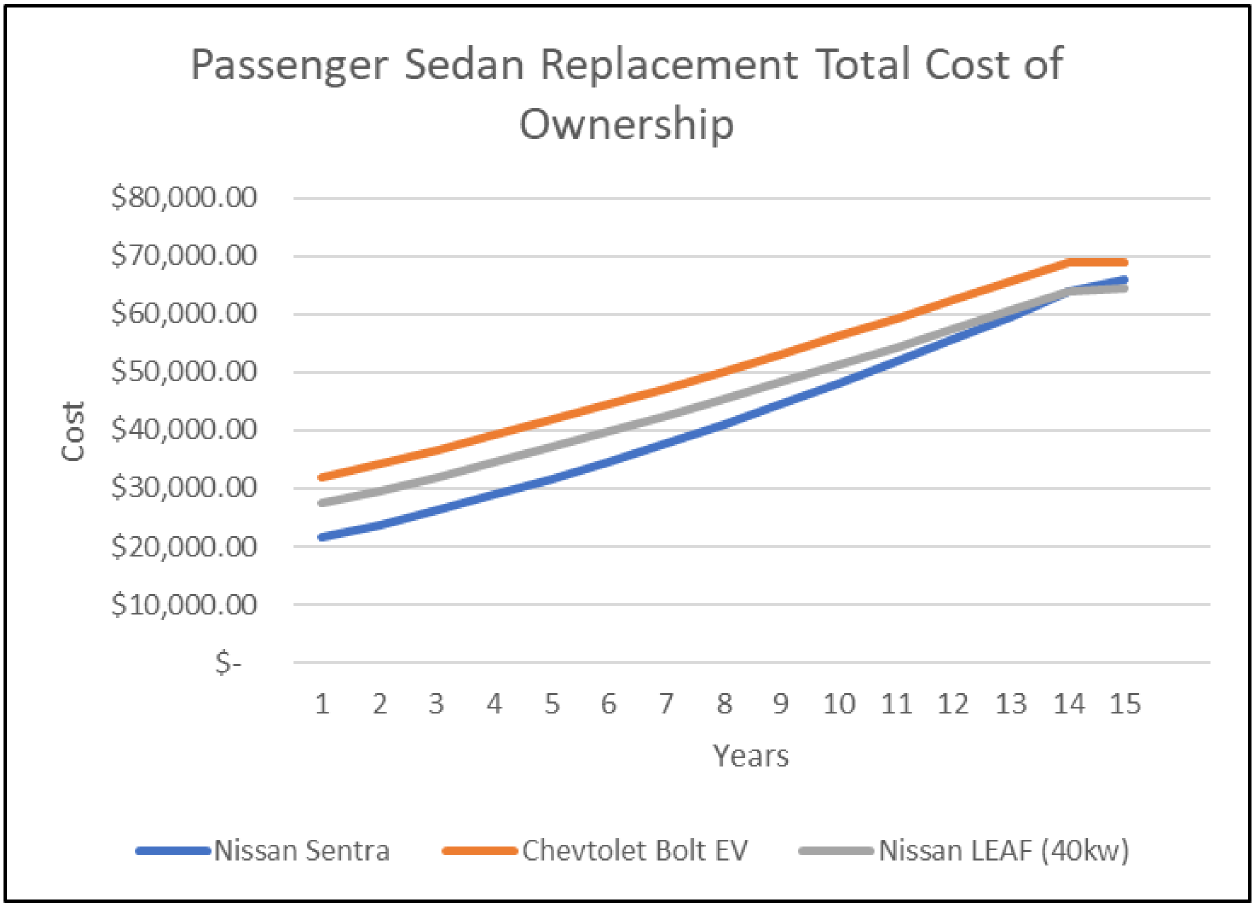

Figure 2: 2022 Passenger Sedan TCO Replacement Comparison, Average FCPS Utilization of 8,891 annual miles, 15-year Lifecycle

FCPS's fleet currently only lists one light-duty truck under transportation, a Ford F-150 that drove 1,649 miles in the previous year. Since this vehicle achieves so few annual miles, replacement with an EV truck would not result in payback in the lifetime of the vehicle. Similarly, replacement with a Ford F-150 Hybrid would not reach payback due to its higher purchase price. However, if the current F-150's use case could be served by a smaller truck then the school district would replace it with a Ford Maverick Hybrid that would reduce emissions and reach payback immediately even with low utilization. The Ford Maverick Hybrid, while smaller than a Ford F-150, would create an **immediate payback at any annual mileage** due to its higher gas mileage and lower purchase price, as seen in figure 2. While Ford Maverick Hybrid will not be able to replace every use case for light-duty trucks, it can still serve many use cases and in AWD Configurations can tow up to 4,000 lbs.

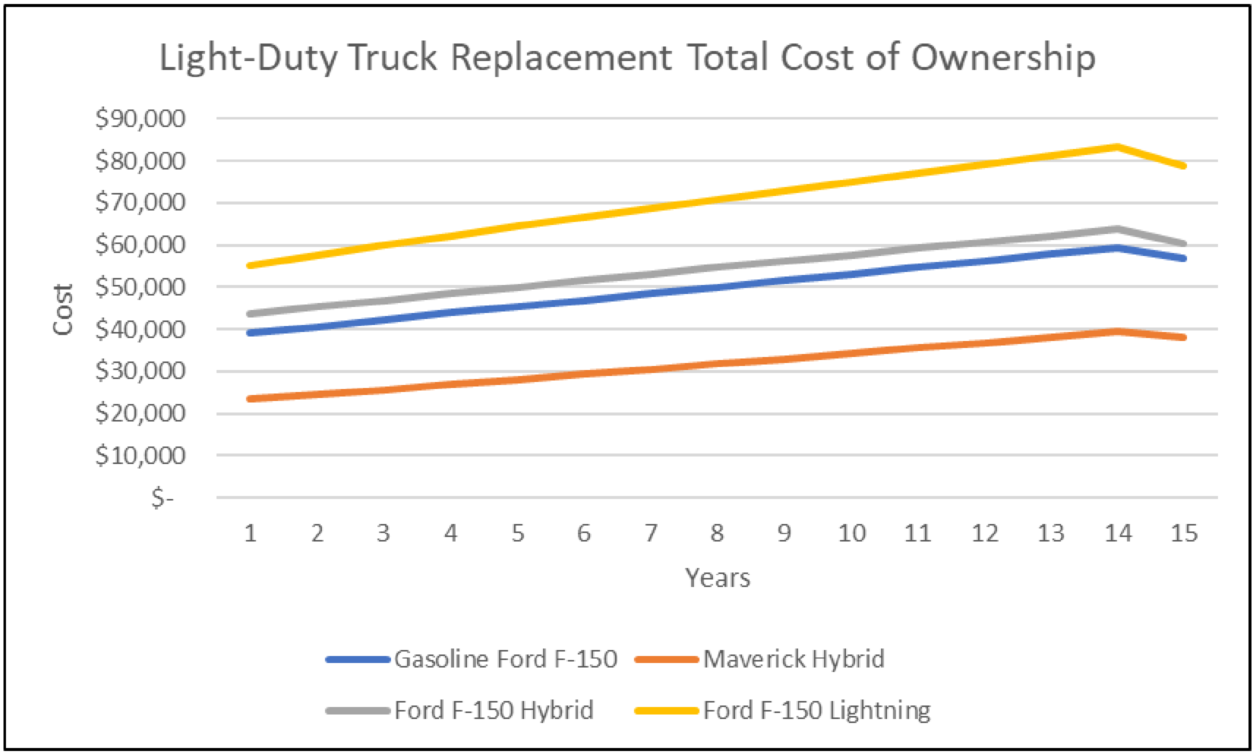

Figure 3: 2022 Light-Duty Transportation Truck, TCO Replacement Comparison, FCPS Utilization of 1,649 annual miles, 15-year Lifecycle

Fredericksburg City Public Schools provided data for two SUVs, a daily Ford Explorer with 8,106 annual miles and a supervisor vehicle with 854 annual miles. Since the supervisor vehicle has so few annual miles there would be no expected payback when replaced with an alternative fuel vehicle. As a result, we focus our analysis on the daily use SUV. Full-sized SUVs, such as Ford Explorers, traveling at least **4,500** annual miles would expect to reach immediate payback if replaced with a Chevrolet Bolt EUV. Bolt EUVs may not be a one-to-one replacement for every SUV due to their smaller size and limit of only 5 seats. Ford Mach-Es have a larger cargo capacity (24 ft3) compared to the Bolt EUVs (16 ft^3) but will not achieve payback as quickly as the Bolt EUV due to their higher purchase price and lower MPGGE. However, with Mach-E's higher purchase price and lower MPGGE, it is unlikely to reach payback in less than 10 years unless the vehicle is traveling at least **14,000** annual miles. In cases where a larger SUV-type vehicle is required, we recommend the Hybrid Ford Explorer for lower GHG emissions. However, at the current purchase price and MPG, the Hybrid Ford explorer is not expected to reach payback during the vehicle's life cycle.

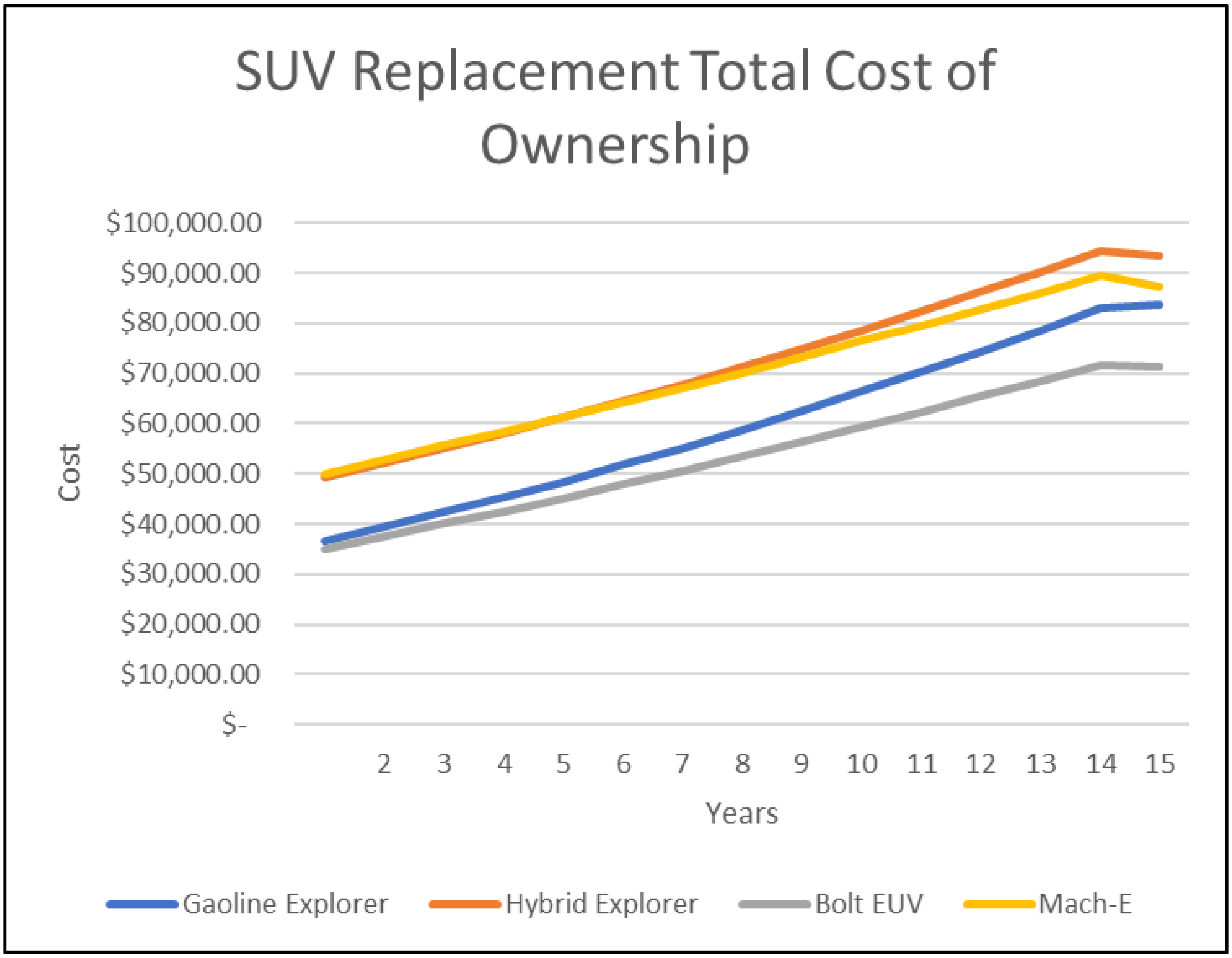

Figure 4: 2022 Ford Explorer TCO Replacement Comparison, Utilization of 8,106 annual miles, 15-year Lifecycle

Maintenance

For Maintenance light-duty trucks we recommend prioritizing near-term replacements with Ford Maverick Hybrids. The Ford Maverick Hybrid, while smaller than a Ford F-150, would create an **immediate payback at any annual mileage** due to its higher gas mileage and lower purchase price, as seen in figure 2. While Ford Maverick Hybrid will not be able to replace every use case for light-duty trucks, it can still serve many use cases and in AWD Configurations can tow up to 4,000 lbs. The Maverick Hybrid would also make ideal replacements for smaller trucks like Ford Rangers. The Ford F-150 Lightning or Ford F-150 Hybrid would be the closest one-to-one replacements available to the fleet, however, with high purchase prices and high demand on vehicle stock they should be prioritized for longer-term replacement (3 to 4 years down the road). Additionally, for some of the School's vehicles with lower average annual mileage, the larger F-150 EV and HEV replacements are unlikely to reach payback within the ten or fifteen-year expected lifetime of the vehicle. In order to reach payback for the fleet, a Ford F-150 Lightning would need to be driven at least **15,000** annual miles and a Ford F-150 Hybrid would need to drive at least **12,700** annual miles. With fleet downsizing and redistribution of mileage across remaining vehicles, these annual mileages may be achievable for some vehicles. It is also important to consider that any LD truck replaced with a Ford Maverick Hybrid will reach payback immediately, these savings could be used to offset the costs of the more expensive F-150 Lightnings or F-150 Hybrids for fleet trucks that need a larger vehicle to serve their use cases.

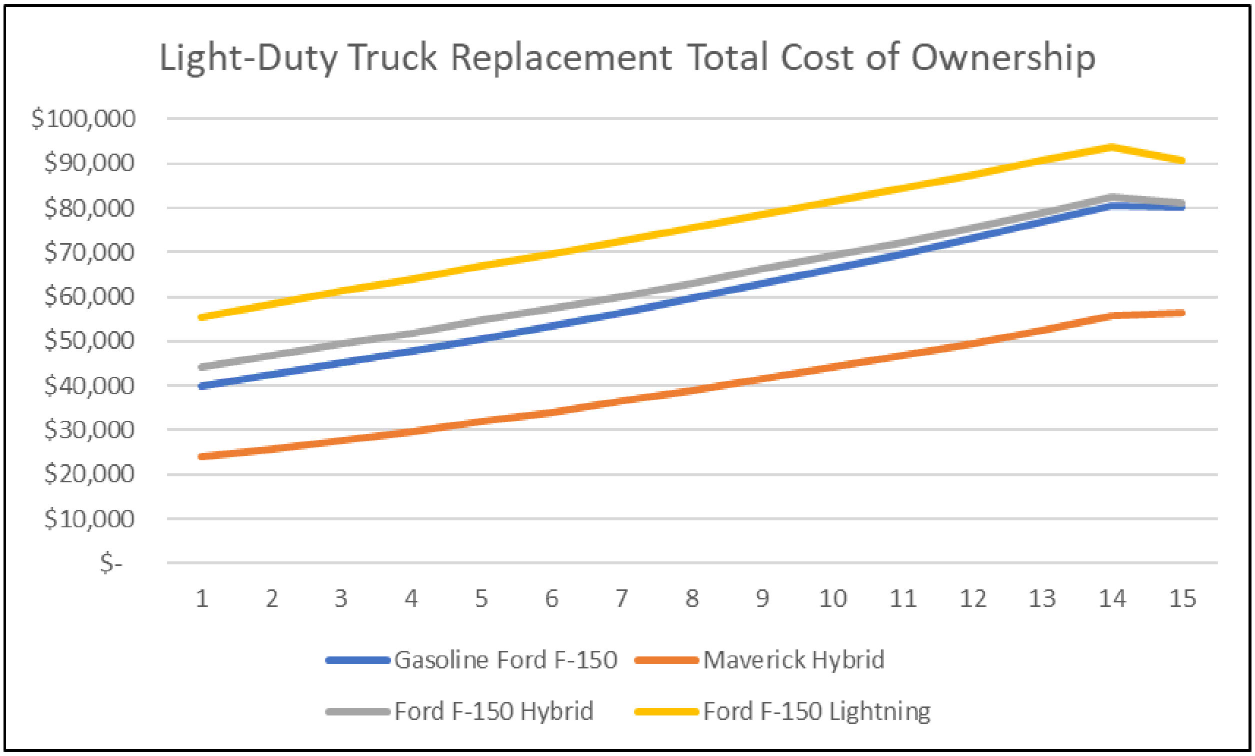

Figure 5: 2022 Light-Duty Maintenance Truck, TCO Replacement Comparison, Average FCPS Utilization of 5,775 annual miles, 15-year Lifecycle

The Ford F-150 Lightning and the Ford F-150 Hybrid do make sense in the short-term for replacing slightly larger trucks such as the Ford F-250 and F-350. If the use case allows and the vehicle travels at least **5,000** miles a year the Ford F-150 Lightning would reach payback in less than 10 years. The Ford F-150 Lightning can tow up to 7,700 lbs in its conventional configuration and up to 10,000 with extended battery and max tow package equipped. If the use case allows, replacement of an F-250 or similar truck would reach **immediate payback** if replaced with a Ford F-150 Hybrid.

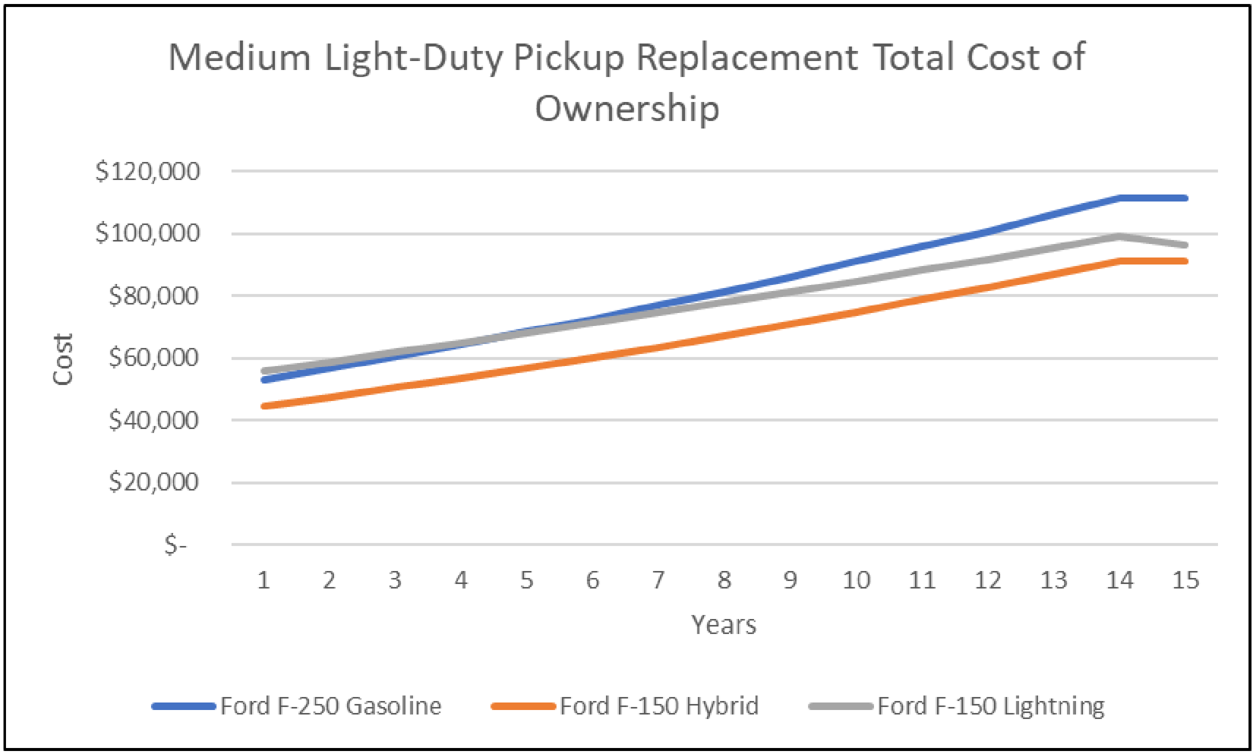

Figure 6: 2022 Medium Light-Duty Pickup, TCO Replacement Comparison, Average FCPS Utilization of 7,764 annual miles, 15-year Lifecycle

Heavy and medium-duty trucks or any truck that has a use case that cannot be served by an F-250 or smaller, do not have cost-effective EV or HEV technology available on the market at this time. However, propane autogas conversions or replacements may offer the city GHG reductions and lower TCO. Propane conversions can be completed in most vehicle types and top out at class 7 heavy-duty vehicles with a GVWR of 33,000. Anything larger than 33,000 GVWR does not have a cost-efficient alternative fuel replacement at this time. The City of Fredericksburg is located in an ozone attainment and maintenance area which makes the city eligible for Congestion Mitigation and Air Quality Improvement (CMAQ) funding. The Program provides a reimbursement of up to an average of $10,000 for the incremental cost of a new vehicle or aftermarket conversion to propane autogas. This would only be recommended if the FCPS was able to utilize another entity's fueling station (such as one owned by the City of Fredericksburg) or if the school district were to convert or replace 10 vehicles with propane, this is due to the high cost of building and maintaining a propane fueling station for a small number of vehicles.

For fleet cargo vans, we recommend replacement with E-Transit T-350 130" WB Low Roof Cargo Vans on vehicles with higher annual mileage. Since specific van configurations were not provided, the standard 130" wheelbase, low roof configuration was used for this comparison (figure 6). In order for these vehicle replacements to reach payback in 10 years or less, vehicle miles will need to exceed **6,000** miles annually. Replacing gasoline cargo vans that travel at least 9,000 miles annually with EVs would result in payback in less than 5 years.

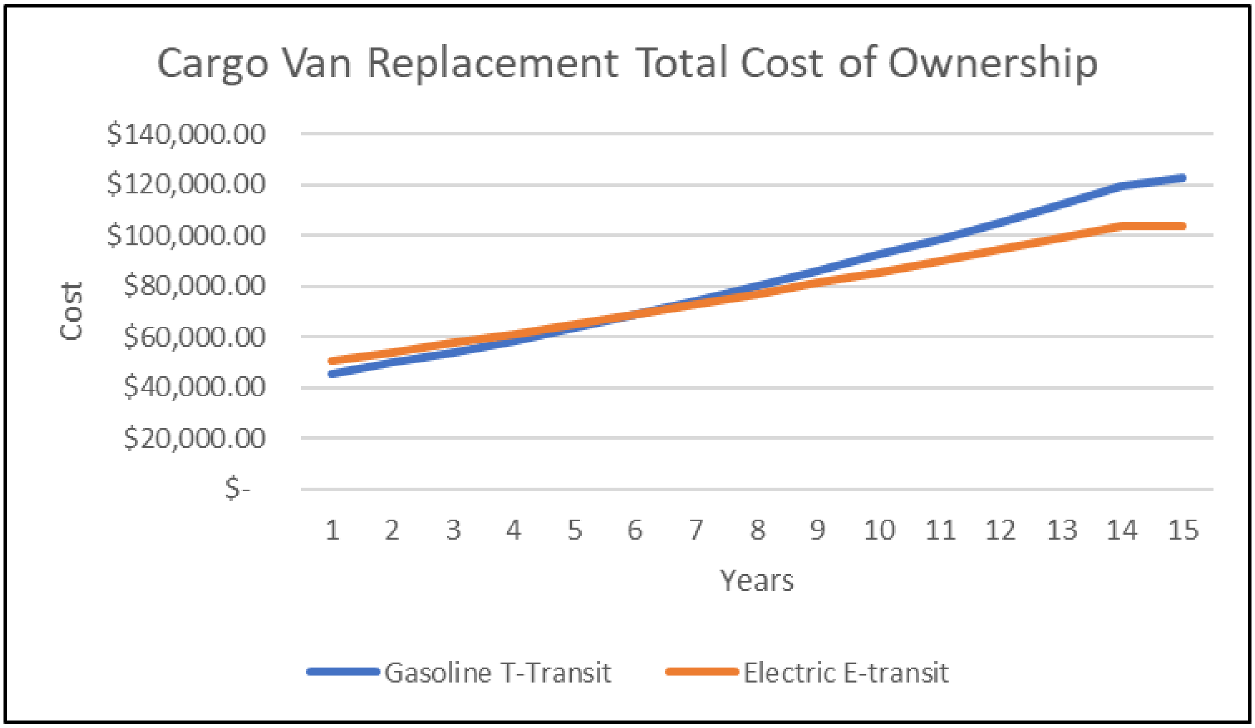

Figure 7: 2022 Cargo Van TCO Replacement Comparison, Average FCPS Utilization of 9,185 annual miles, 15-year Lifecycle

If the school district is interested in passenger vans, we do not recommend the electric options at this time due to the high cost of the vehicles. While EV passenger vans are available on the market, their configurations often exceed $100,000, making payback unachievable at this time. As the cost of EV passenger vans decreases, this replacement may become a possibility for school fleets. Until that time we recommend the fleet consider if any passenger vans could be replaced by minivans or SUVs that do have viable EV and hybrid alternatives.

School Buses

For this analysis, we excluded spare buses due to their low mileage. The analysis of Fredericksburg City Public School's school bus fleet to electric school buses (ESBs) was broken down into 4 sections, gasoline buses to ESBs with fast charging, gasoline buses to ESBs with Level 2 charging, diesel buses to ESBs with Fast Charging, and diesel buses to ESBs with Level 2 charging. For this analysis, we used the incentive amounts that were advertised in the first round of the EPA's Clean School Bus Program, $250,000 for the incremental cost of the bus and $13,000 for infrastructure. At this time, funding is vital for ESBs to reach payback and make financial sense for school districts to make the switch. For the DC Fast Chargers, we utilized the 25kW chargers available on the state contract under Sonny Merryman.

Since most FCPS buses have relatively low daily mileage (our calculations are based on annual mileage capping at around 60 miles per day), most buses will not need high-powered DC Chargers. Many routes could be served by high-powered 19.2 kW chargers or low-powered 25 kW DC chargers. In cases where Thomas Built buses are procured, DC Charging will be required due to their onboard charging systems, by utilizing lower-powered 25 kW DC chargers FCPS can achieve significant cost savings compared to higher-powered charger costs.

For example, a Thomas Built Jouley electric school bus has a 226 kW battery with 138 miles of range (in optimal conditions), even if the battery were to be drawn down to zero, it could fully recharge in just over 9 hours on a low-powered DC charger. To calculate charging time from empty you simply take the battery size, 226 kW, and divide it by the speed of your charger, 25 kW.

25 kW DC charger: 226kW ÷ 25 kW = 9.04 hrs

19.2 kW Level 2 charger: 226kW ÷ 19.2 kW = 11.77 hrs

Likewise, on school buses equipped with level 2 charging, a 19.2 kW charger would still be able to recharge the bus overnight. Fredericksburg's school buses are unlikely to run their battery to zero on an average day and have consistent overnight dwell times that allow for ample charging time. Furthermore, school buses typically have dwell time between morning and afternoon routes that allow them to top their charge during the day as needed. These factors allow lower-powered, less expensive charging to be an ideal option for the fleet.

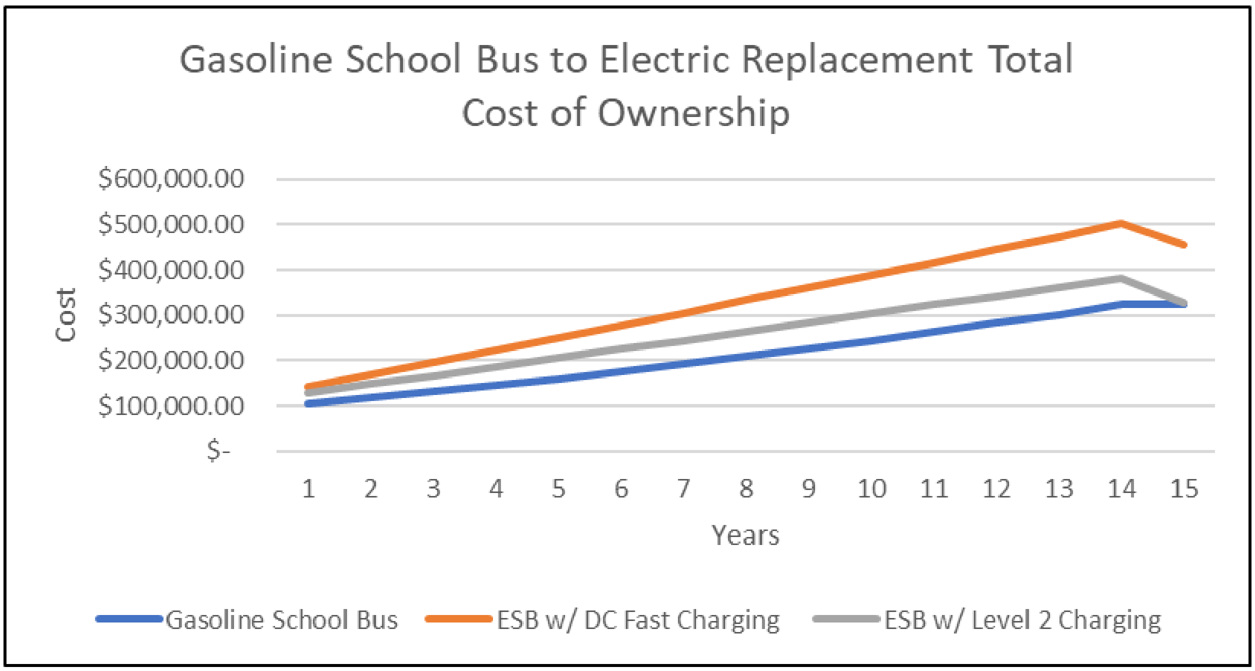

Figure 8: 2022 Gasoline School Bus TCO Replacement Comparison, Average FCPS Utilization of 7,306 annual miles, 6.8 mpg, 15-year Lifecycle

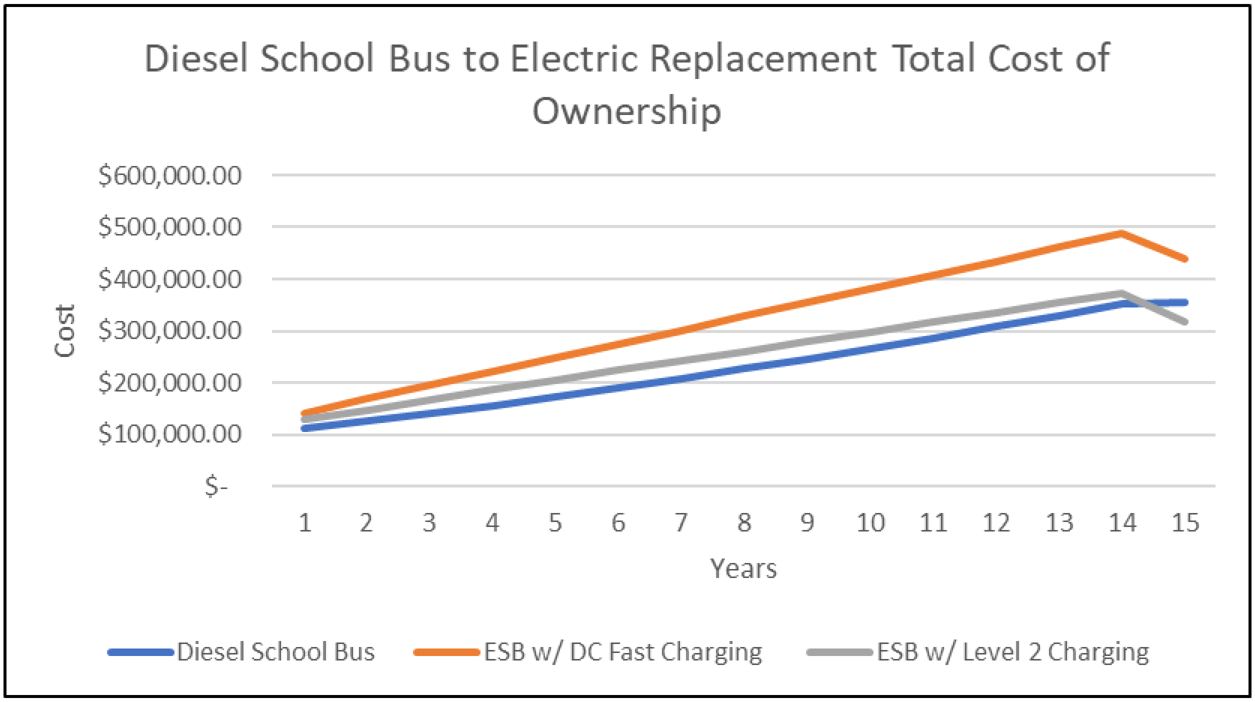

Figure 9: 2022 Diesel School Bus TCO Replacement Comparison, Average FCPS Utilization of 6,380 annual miles, 8.2 mpg, 15-year Lifecycle

The initial analysis shown above in figures 8 and 9 demonstrates the total cost of ownership of diesel and gasoline school buses using the default mpg that we would expect from diesel and gasoline school buses, 8.2 and 6.8 mpg respectively. However, from the data provided by FCPS, Fredericksburg school buses are getting much lower mpg at 1.8 mpg diesel and 1.1 mpg gasoline. This is likely due to high levels of idling. When adjusting the analysis to include FCPS's significantly lower miles per gallon, payback is achieved much faster even for buses with DC Fast Chargers as seen in figures 10 and 11.

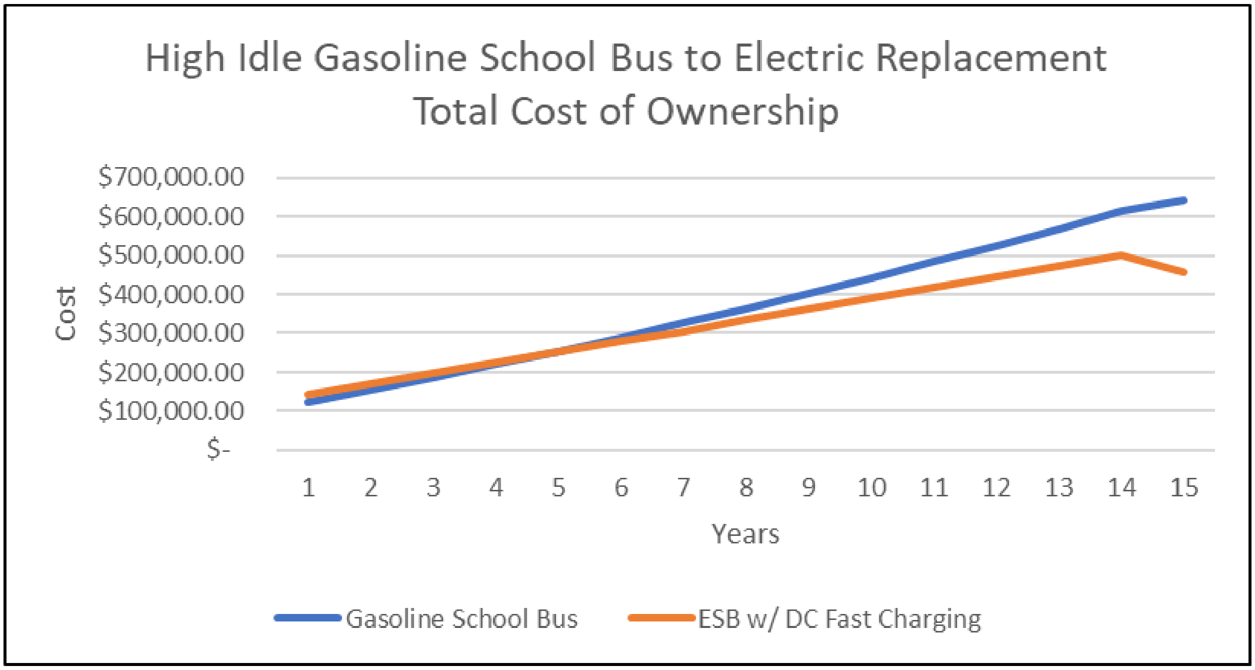

Figure 10: 2022 High Idle Gasoline School Bus TCO Replacement Comparison, Average FCPS Utilization of 7,306 annual miles, 1.1 mpg, 15-year Lifecycle

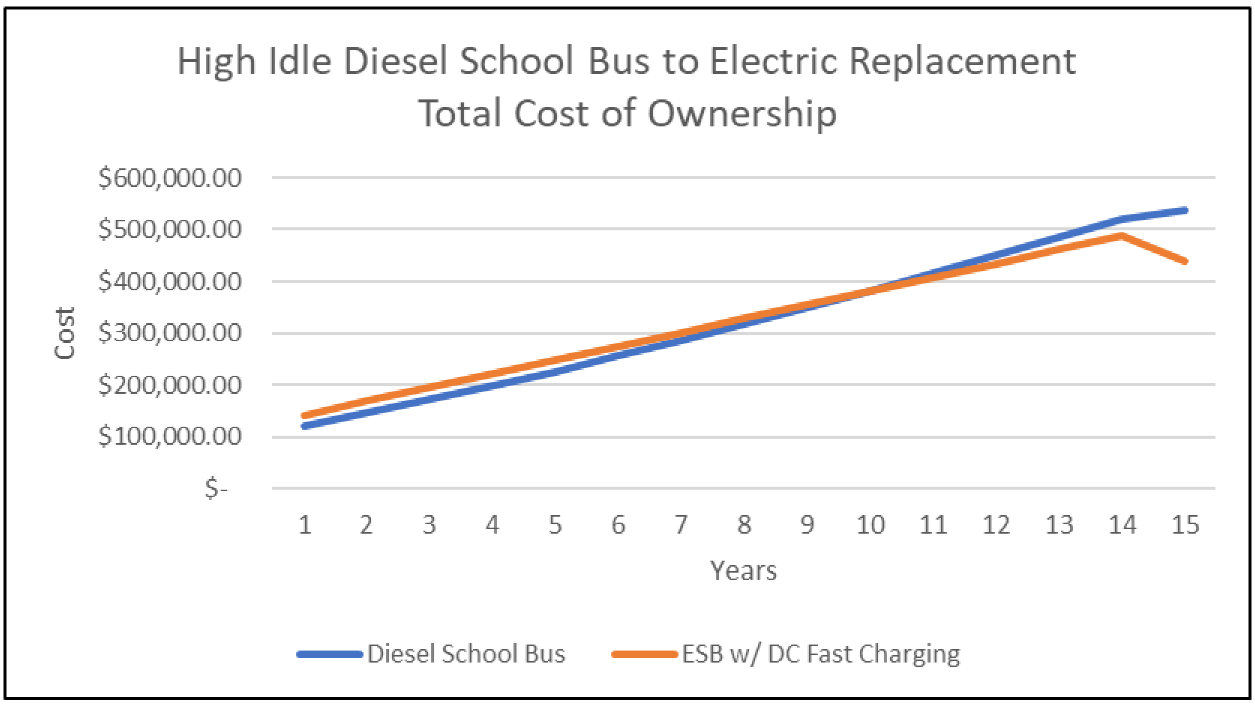

Figure 11:2022 High Idle Diesel School Bus TCO Replacement Comparison, Average FCPS Utilization of 6,380 annual miles, 1.8 mpg, 15-year Lifecycle

As with all fleets, we recommend replacing your oldest diesel vehicles with the highest annual mileage first, this will make the biggest impact on your fleet's emissions and result in a quicker payback period. In many federal and state funding programs older diesel vehicles are prioritized for replacement. For example, in the latest round of EPA Clean School Bus Funding, diesel vehicles with model year 2011 engines or older were prioritized for funding. Thirty-two of FCPS's current school buses meet those criteria. Since all of FCPS's gasoline buses are 2018 or newer and gasoline will have a longer payback period than diesel, we do not recommend replacing fleet gasoline buses until all diesel vehicles have been replaced.

We also recommend considering a fleet of mixed electric school bus brands that includes buses that can charge on Level 2 chargers. Currently, all of the electric school buses on the market can charge on DC charging, but having buses rely primarily on Level 2 chargers can significantly reduce charger installation and maintenance costs. At this time, without proper incentives, there is no way to reach payback with electric buses. We recommend FCPS be on the lookout for programs that cover the incremental cost of the bus and include large charging incentives. Unfortunately, currently charging incentives are more difficult to find, so choosing technology that lower-level EVSE can support can make a large difference. In addition to federal and state incentives, we also encourage school bus fleets to pay attention to private companies and utilities who may also be offering funding or other support. For example, in alignment with the last round of EPA funding, Dominion Energy and Secure Futures Solar provided programs to help pay for the costs of the charging infrastructure.

GHG Emissions Savings

In this section, we compare the annual and lifetime GHG emissions savings for each vehicle replacement based on the average fleet vehicle. Replacement with EVs will always result in a higher reduction of GHGs than their HEV counterparts. These GHG reduction comparisons along with the previous total cost of ownership analysis can help the City of Fredericksburg weigh its environmental goals with its budget. EVs and PHEVs running only on electricity have zero tailpipe emissions, but emissions may be produced by the source of electrical power, such as a power plant. In geographic areas that use relatively low-polluting energy sources for electricity generation, PHEVs and EVs typically have a well-to-wheel emissions advantage over similar conventional vehicles running on gasoline or diesel. These GHG emission calculations were created using Fredericksburg's local energy mix breakdown, detailed in figure 12.

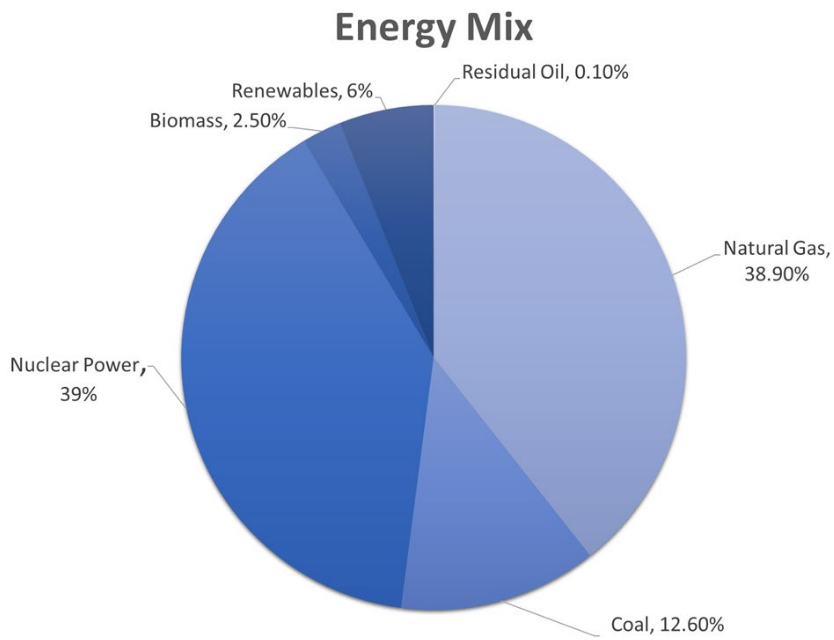

Figure 12: Fredericksburg, VA electric grid mix https://www.epa.gov/egrid/power-profiler#/SRVC

Transportation

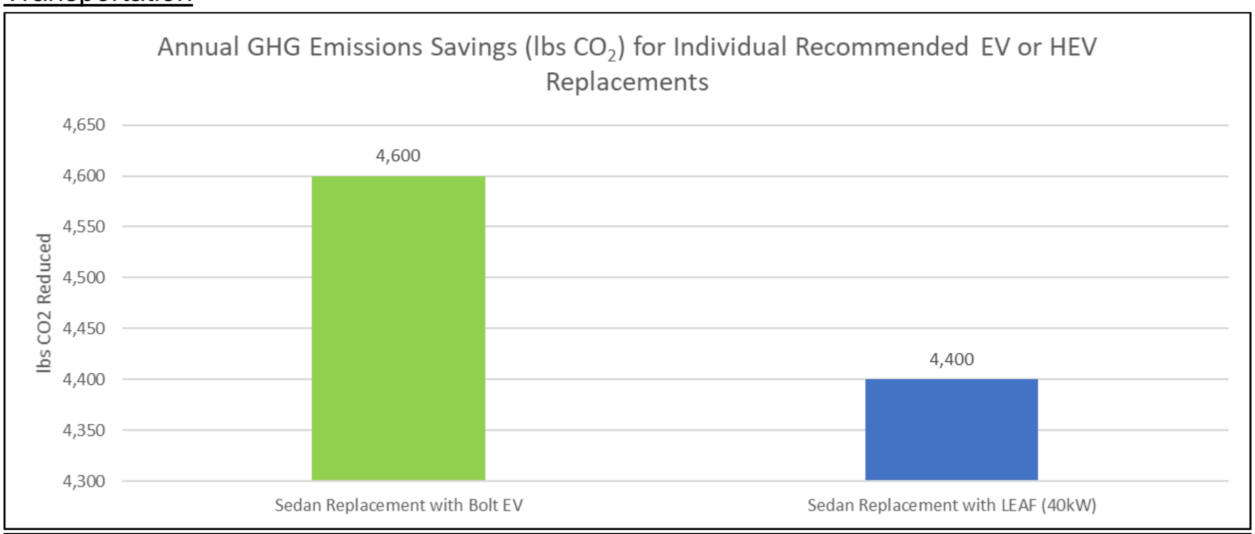

Figure 13: Sedan Annual GHG Emissions Savings

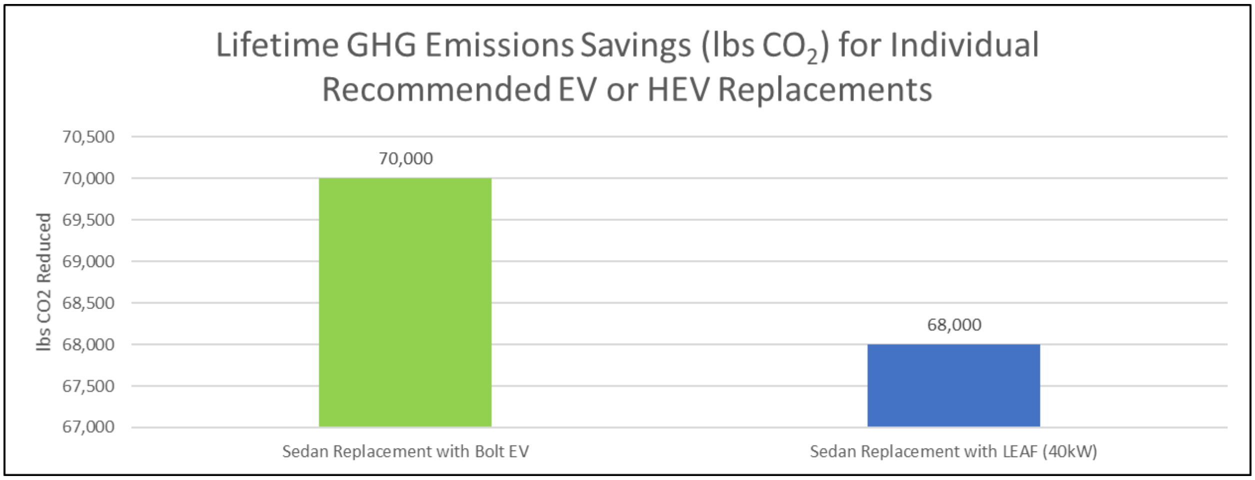

Figure 14: Sedan Lifetime GHG Emissions Savings

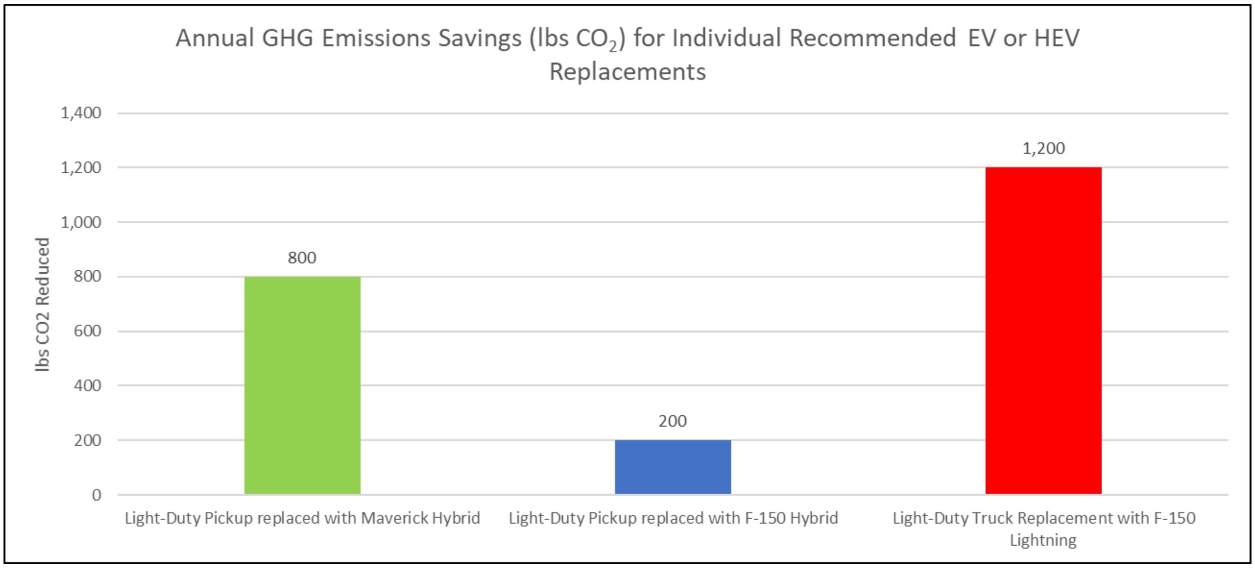

Figure 15: Light-Duty Transportation Truck Annual GHG Emissions Savings

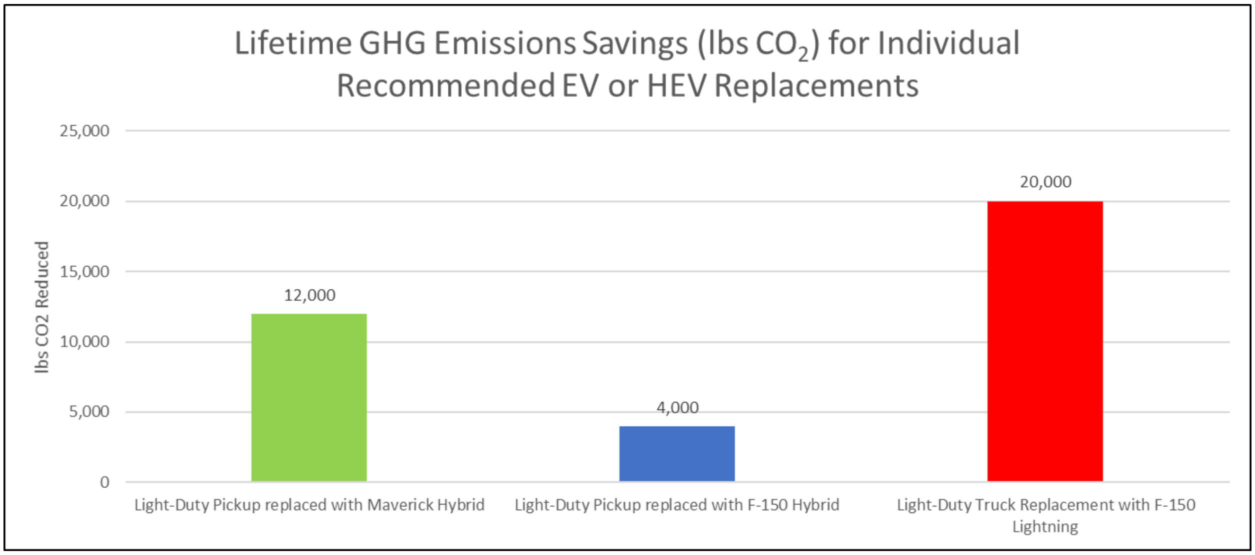

Figure 16: Light-Duty Transportation Truck Lifetime GHG Emissions Savings

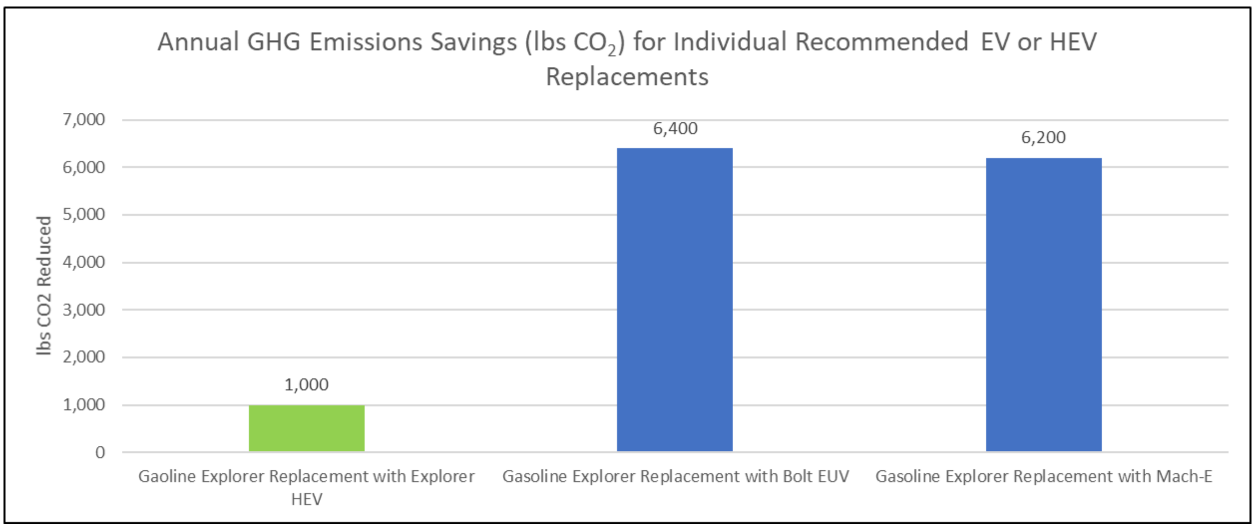

Figure 17: SUV Annual GHG Emissions Savings

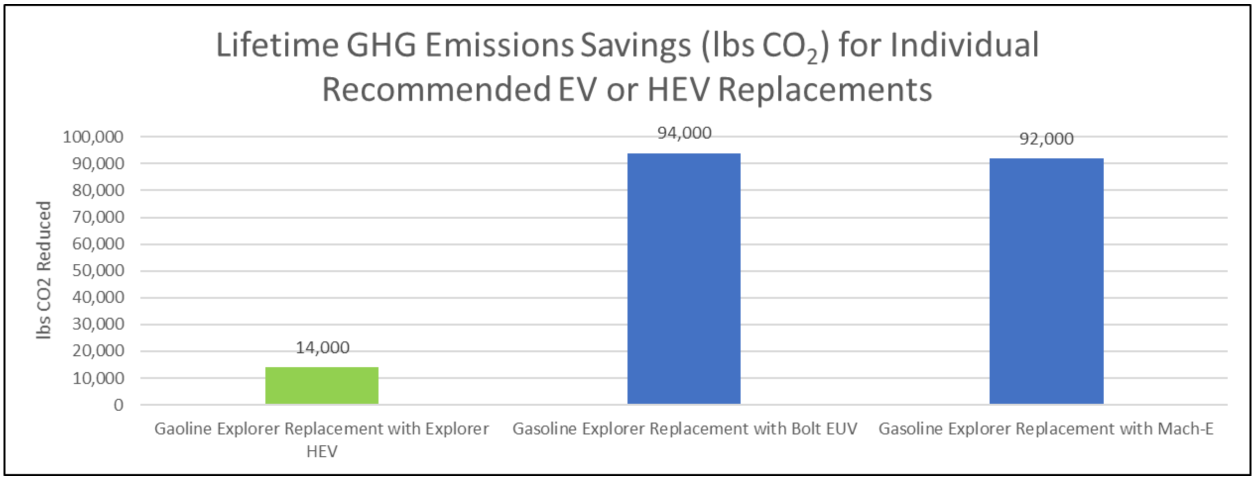

Figure 18: SUV Lifetime GHG Emissions Savings

Maintenance

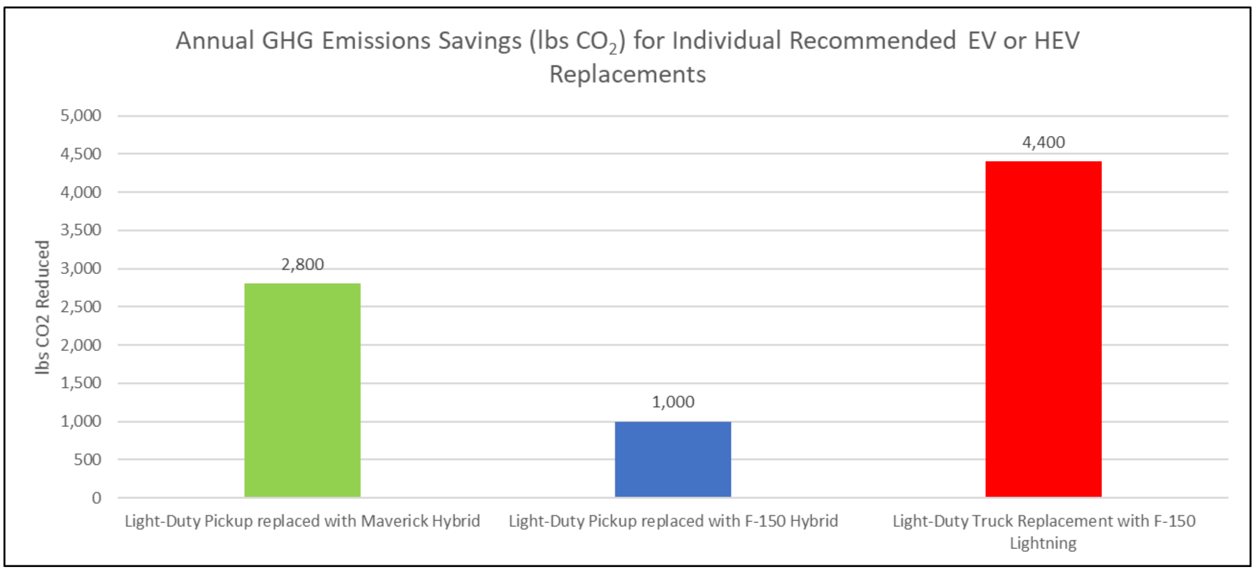

Figure 19: Light-Duty Maintenance Truck Annual GHG Emissions Savings

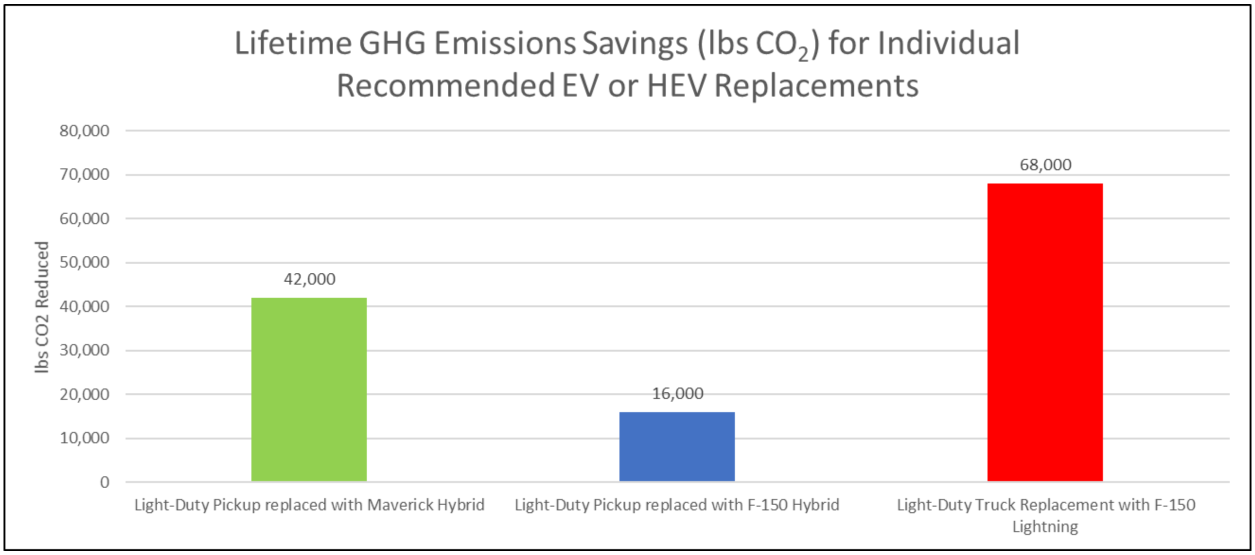

Figure 20: Light-Duty Maintenance Truck Lifetime GHG Emissions Savings

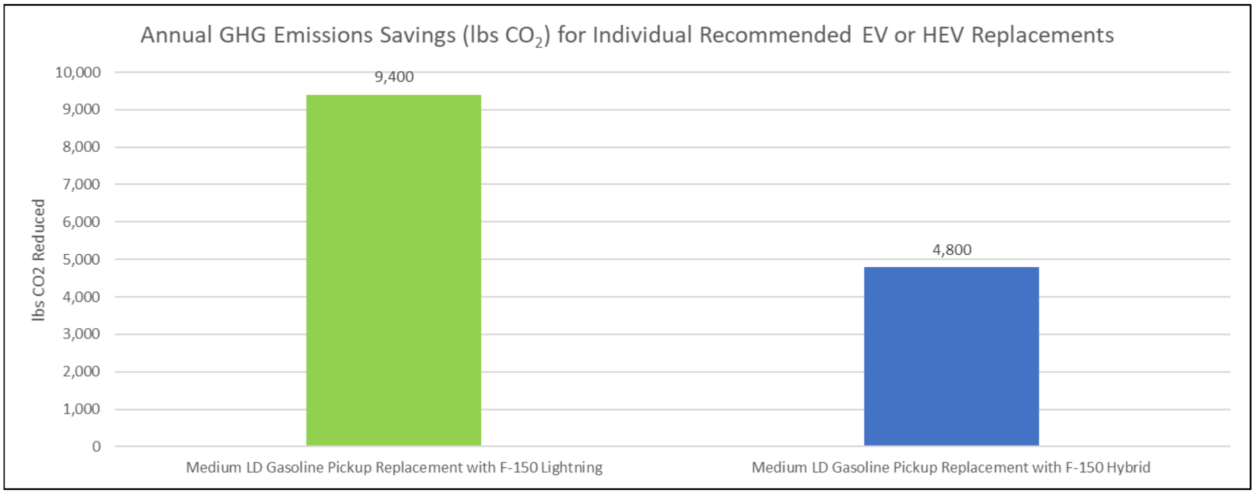

Figure 21: Medium Light-Duty Pickup Annual GHG Emissions Savings

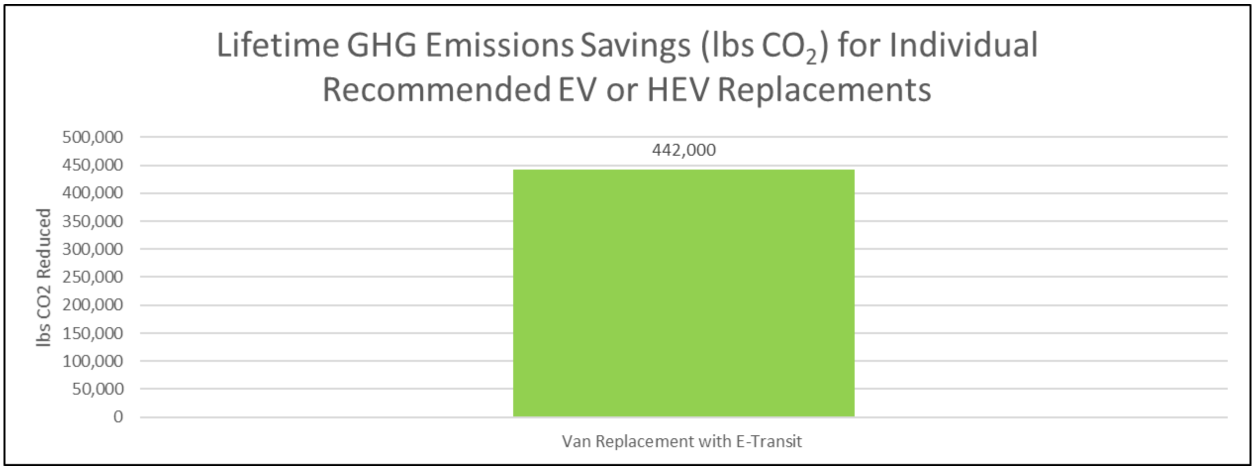

Figure 22: Medium Light-Duty Pickup Lifetime GHG Emissions Savings

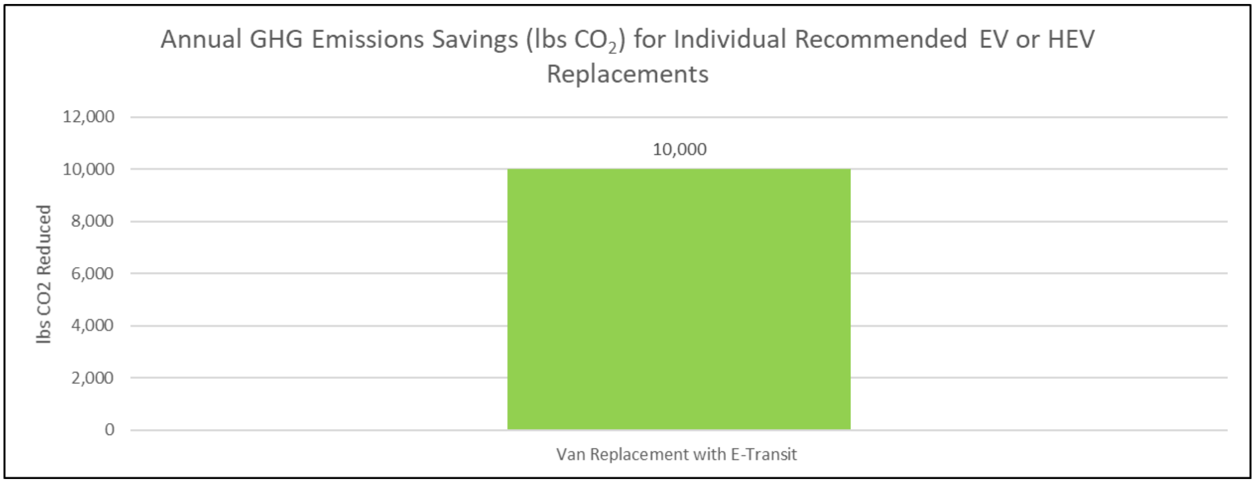

Figure 23: Cargo Van Annual GHG Emissions Savings

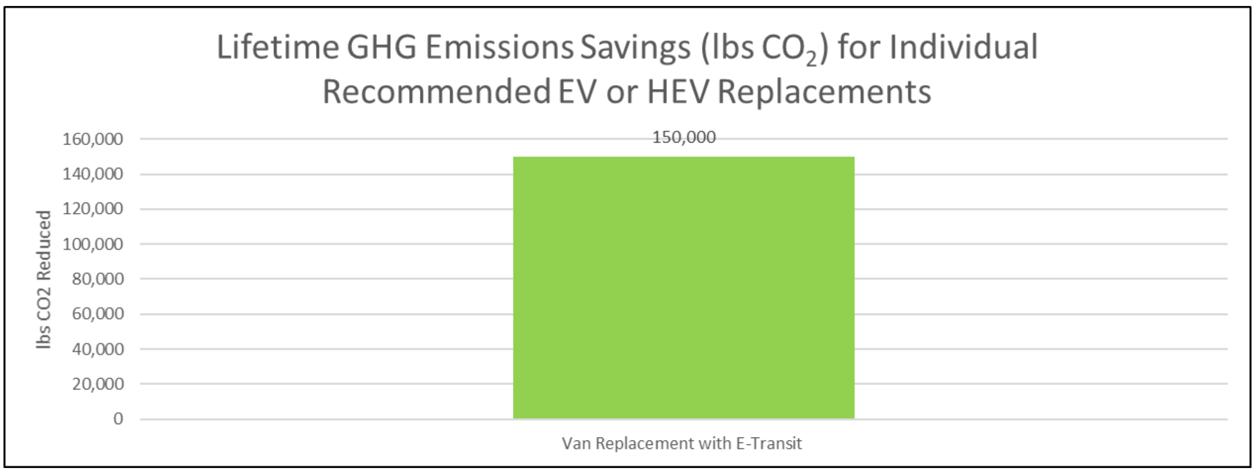

Figure 24: Cargo Van Annual GHG Emissions Savings

School Buses

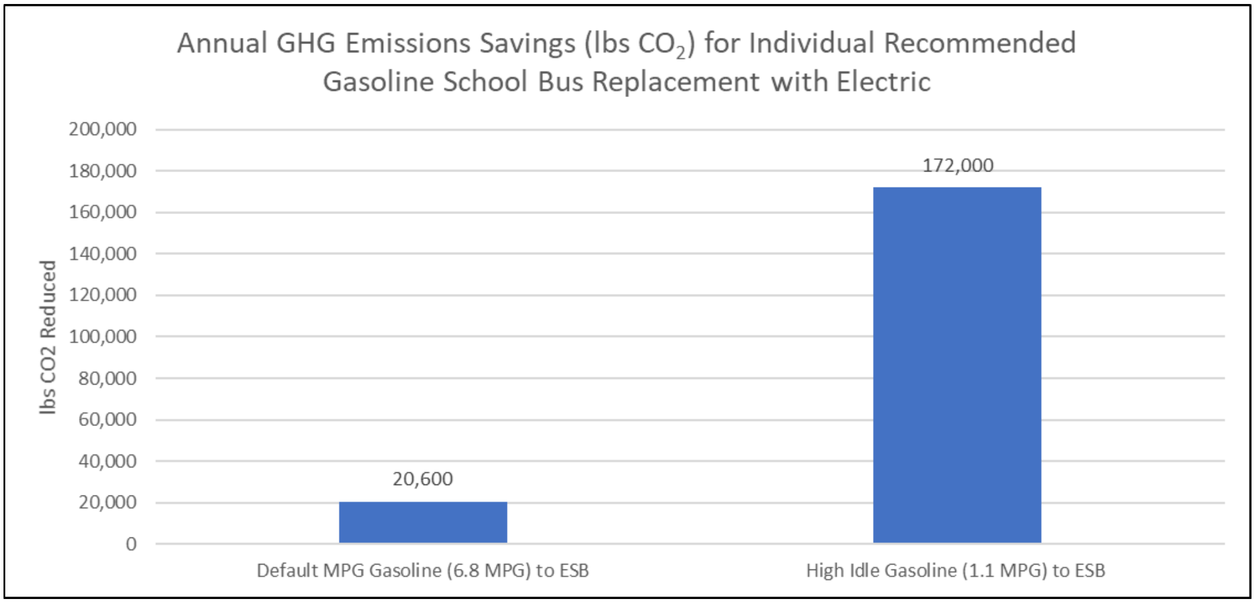

Figure 25: Gasoline School Bus Annual GHG Emissions Savings

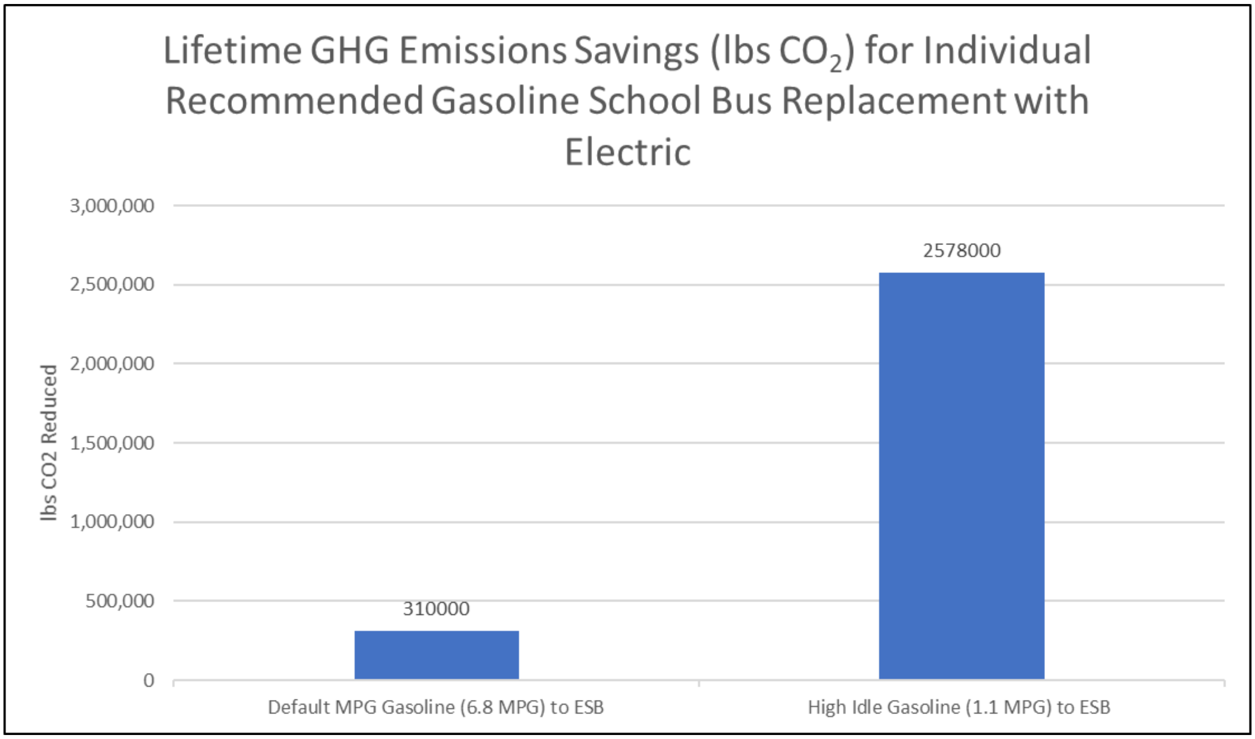

Figure 26: Gasoline School Bus Lifetime GHG Emissions Savings

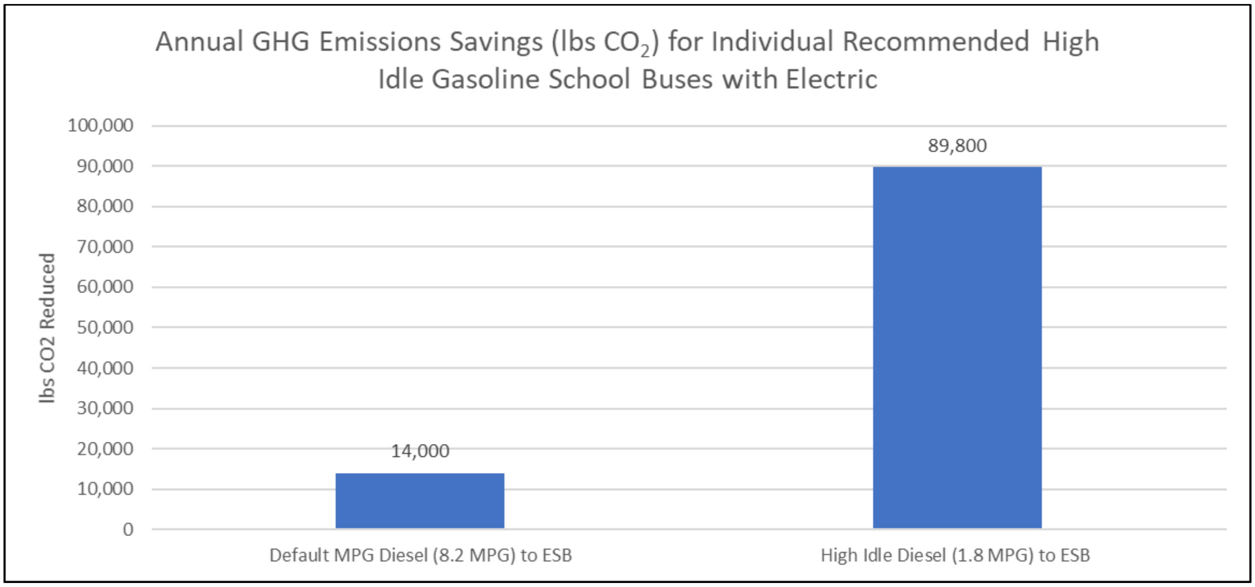

Figure 27: Diesel School Bus Annual GHG Emissions Savings

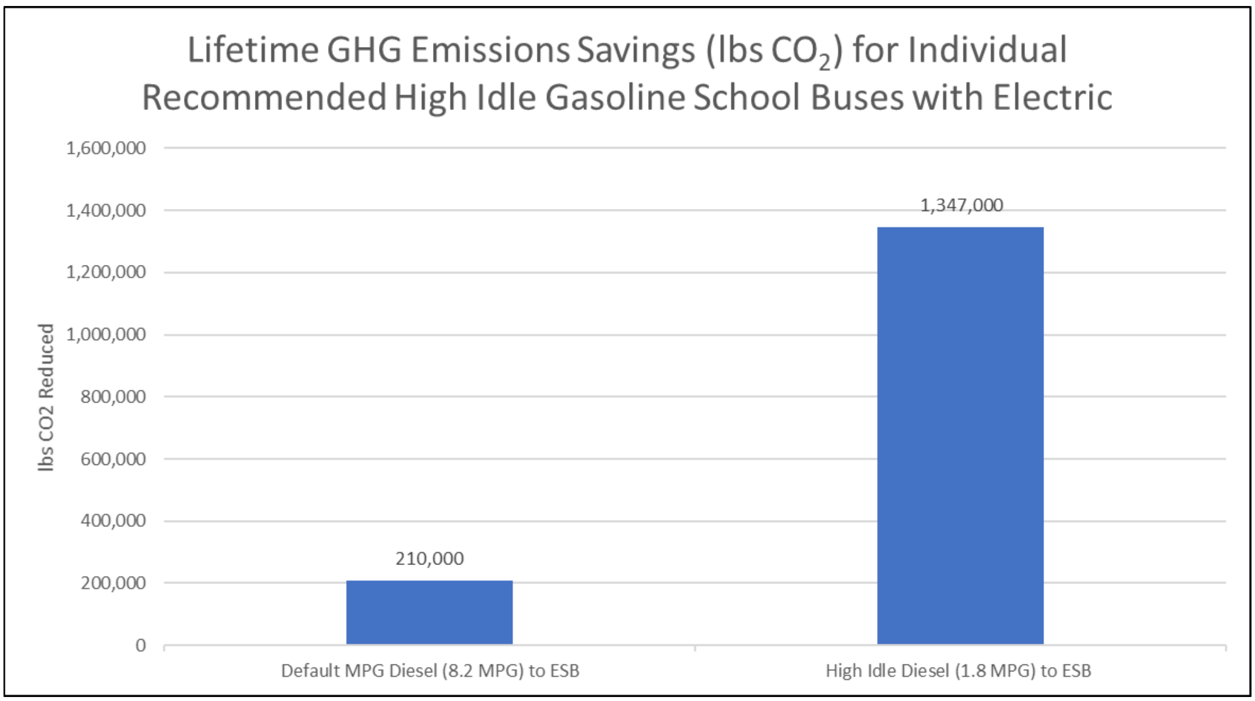

Figure 28: Diesel School Bus Lifetime GHG Emissions Savings

Fleet and vehicle right-sizing

Fleet right-sizing is also a valuable strategy for reducing operations and maintenance costs. Fleet right-sizing can be done in two ways, first by reducing the number of vehicles in a fleet, and second by decreasing the size of the vehicle in a fleet. Alternative fuels achieve higher TCO savings at higher utilization rates. This is because the biggest money-saving factor of alternative fuel vehicles is their less expensive fuel costs. By removing lesser-used vehicles from their fleet and distributing those miles across the remaining vehicles, the Fredericksburg City Public Schools could increase the impact of alternative fuel vehicle replacements through less expensive fuels and fewer vehicles to maintain. The school district could also decrease its vehicle costs and emissions by vehicle right-sizing. Please see FCPS's expected TCO for SUVs and Compact trucks in the previous section as an example.

FCPS should also engage in right-sizing its EV charger planning. Not all vehicles need their gas tanks refilled daily, and the principle same applies to EVs. Planning charging infrastructure that allows vehicles with lower daily mileage to share a charger can significantly reduce infrastructure costs. If vehicles are parked alone but have consistent dwell times such as overnight, the fleet may consider a slower but less expensive charger option, such as a 110V wall outlet.

As with all electric fleets, being prepared for expansion can save money and time down the road. Some of the highest costs of charger installation are trenching, extending the conduit, and expanding electrical capacity. Due to this, we recommend implementing practices to make fleet depots "EV Ready" when available. For example, if a fleet is working to install 5 EV chargers that require trenching and conduit extension and they know that they plan to install 5 more in a year's time, it will often save money to lay the conduit for those next 5 chargers while the ground is already disturbed for the first round of charger installations. It is not feasible to replace an entire school bus fleet or any fleet at once, so planning for phased installations can help manage costs and keep the momentum moving forward as new buses are acquired.

Key Recommended Actions
EV Options Assessment

1. Near term (next two to three years)
    a. Consider where fleet right-sizing can occur
        i. Remove vehicles that accumulate low annual miles and redistribute their use across remaining vehicles
        ii. Consider what vehicles can be replaced with smaller vehicles ex: Ford F-150s that can be replaced with smaller Ford Hybrid Mavericks

b. Replace the oldest diesel school buses with electric school buses i. Focus efforts around funding opportunities that cover the full incremental cost of the bias and infrastructure funding to achiev e payback **c. Phase in the procurement of Nissan LEAFs or Chevy Bolt EVs to replace the oldest and heist mileage sedans. Phase in the procurement of Ford Maverick Hybrids for the oldest light-duty pickups. Phase in procurement of E-Transit Cargo Vans for Cargo Vans traveling 6,000 annual miles or more. Downsize and replace the fleet daily use SUV with a Chevy Bolt EUV.** **i. Prioritize the oldest vehicle and those with the highest annual mileage first** **ii. Utilize immediate payback from replacements with Maverick Hybrids to offset the more expensive Ford F-150 Lightning replacements for light-duty trucks that have use cases that cannot be served by Maverick Hybrids**
2. Long Term (next 4+ years) **a. *Ford F-Series Pickup Trucks and Comparable Models*** ***i. Where use case allows, replace fleet F-250s (and equivalent) with Ford F-150 Lightnings*** **ii. *Currently, the Ford Lightning only comes in the F-150 pickup option: should Ford begin releasing similar options for the rest of the F-Series, these should be considered under comparable market and utilization conditions.*** ***b.* As payback is accumulated from replacing light-duty trucks with Maverick Hybrids, the school district should consider replacing the remaining light-duty trucks whose use cases could not be served by Maverick Hybrids with F-150 Lightning battery electric trucks** **c. Once all diesel school buses have been replased, begin to replace gasoline school buses with electric alternatives.**
EVSE Procurement and Installation Recommendations
1. *Pay attention to the needs of different brands of buses. Some bus brands, such as Thomas Built, currently only allow for DC Fast Charging (Level 3). DC fast charging, while quicker than Level 2 charging, is significantly more expensive.* ***a. When looking for ESB funding opportunities, look for programs that fund charging infrastructure, or partners like Dominion who might be able to help cover those costs.***
2. *Consider level 1 chargers for vehicles running 35 miles/day or less, approximately 8,500 annual miles, if they can be charged overnight for 8 hours after each use.*

3. ***Based on the above EV assessment and the data provided, the following are our recommendations for prioritizing the procurement and installation of Level 2 charging stations:*** a. ***Prioritize installations at locations where multiple vehicles park. The creation of central hub locations for charging infrastructure, that allow multiple vehicles to share one charger, has the best current financial case for electrification. Like conventional ICE vehicles, most EVs will not need to be charged every day, so can share a charger.***
4. **Plan for future EV charging.The highest costs of charger installation are trenching, extending the conduit, and expanding electrical capacity. When installing capacity for chargers, consider if it makes sense to expand conduit/ capacity for more chargers down the line now when trenching is already occurring. This is especially relevant for paved parking lots.**
Exploring Fleet Management Options
1. ***Create Right-Sizing Policies and Procedures for all new vehicle and equipment acquisitions.***
2. ***Conduct a detailed fleet vehicle utilization study and develop a process for regular review. Establish procedures to ensure fleet size matches current staffing levels and overall operational needs. Coordinate strategic higher utilization and down-sizing when appropriate to increase cases where an EV replacement results in TCO savings.***
3. ***Create new procedures to establish vehicle lifecycle and replacement schedules that will maximize useful life of equipment while reducing operational and maintenance costs.***
4. ***Develop procedures to track and eliminate unnecessary vehicle idling including:*** a. ***Creation of a clear tracking system*** b. ***Development of Idle Reduction Training Program for Equipment Operators*** c. ***Deployment of cost-effective technologies such as GPS tracking systems, engine timers, auxiliary power systems, and automatic engine shutdown devices***

Additional Background

Hybrid Electric Vehicles

Today's hybrid electric vehicles (HEVs) are powered by an internal combustion engine in combination with one or more electric motors that use energy stored in batteries. HEVs combine the benefits of high fuel economy and low tailpipe emissions with the power and range of conventional vehicles.

Help from an Electric Motor

In an HEV, the extra power provided by the electric motor may allow for a smaller combustion engine. The battery can also power auxiliary loads and reduce engine idling when the vehicle is stopped. Together, these features result in better fuel economy without sacrificing performance.

An HEV cannot plug in to off-board sources of electricity to charge the battery. Instead, the vehicle uses regenerative braking and the internal combustion engine to charge. The vehicle captures energy normally lost during braking by using the electric motor as a generator and storing the captured energy in the battery.

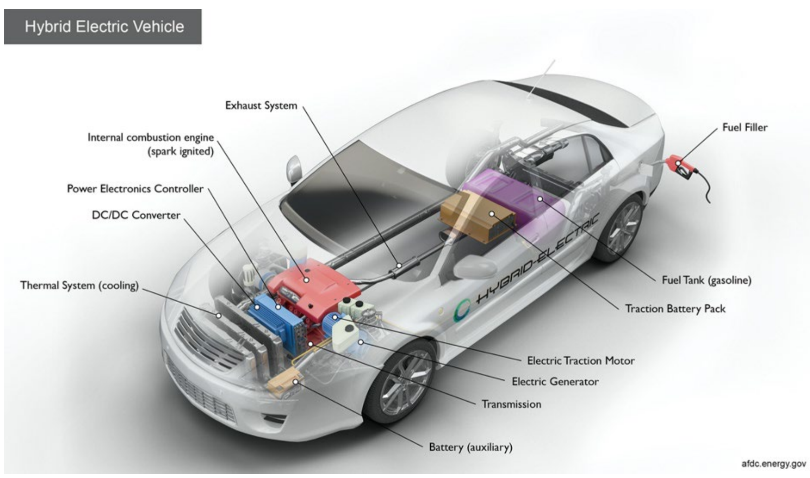

Figure 1: Key Components of a Hybrid Electric Car

HEVs can be either mild or full hybrids, and full hybrids can be designed in series or parallel configurations.

- **Mild hybrids**—also called micro hybrids—use a battery and electric motor to help power the vehicle and can allow the engine to shut off when the vehicle stops (such as at traffic lights or in stop-and-go traffic), further improving fuel economy. Mild hybrid systems cannot power the vehicle using electricity alone. These vehicles generally cost less than full hybrids but provide less fuel economy benefit than full hybrids.

- **Full hybrids** have larger batteries and more powerful electric motors, which can power the vehicle for short distances and at low speeds. These vehicles cost more than mild hybrids but provide better fuel economy benefits.

Plug-in Hybrid Electric (PHEV)

Plug-in hybrid electric vehicles (PHEVs) use batteries to power an electric motor, as well as another fuel, such as gasoline or diesel, to power an internal combustion engine or other propulsion source. PHEVs can charge their batteries through charging equipment and regenerative braking. Using electricity from the grid to run the vehicle some or all of the time reduces operating costs and fuel use, relative to conventional vehicles. PHEVs may also produce lower levels of emissions, depending on the electricity source and how often the vehicle is operated in all-electric mode.

PHEVs have an internal combustion engine and an electric motor, which uses energy stored in batteries. PHEVs generally have larger battery packs than hybrid electric vehicles. This makes it possible to drive moderate distances using just electricity (about 15 to 60-plus miles in current models), commonly referred to as the "electric range" of the vehicle.

During urban driving, most of a PHEV's power can come from stored electricity. For example, a light-duty PHEV driver might drive to and from work on all-electric power, plug the vehicle in to charge at night, and be ready for another all-electric commute the next day. The internal combustion engine powers the vehicle when the battery is mostly depleted, during rapid acceleration, or when intensive heating or air conditioning loads are present.

PHEV batteries can be charged by an outside electric power source, by the internal combustion engine, or through regenerative braking. During braking, the electric motor acts as a generator, using the energy to charge the battery, thereby recapturing energy that would have been lost.

PHEV fuel consumption depends on the distance driven between battery charges. For example, if the vehicle is never plugged in to charge, fuel economy will be about the same as a similarly sized hybrid electric vehicle. If the vehicle is driven a shorter distance than its all-electric range and plugged in to charge between trips, it may be possible to use only electric power. Therefore, consistently charging the vehicle is the best way to maximize the electric benefits.

Battery Electric Vehicles (EV)

All-electric vehicles (EVs), also referred to as battery electric vehicles, use a battery pack to store the electrical energy that powers the motor. EV batteries are charged by plugging the vehicle in to an electric power source. Although electricity production may contribute to air pollution, the U.S. Environmental Protection Agency categorizes all-electric vehicles as zero-emission vehicles because they produce no direct exhaust or tailpipe emissions.

Light-duty EVs are commercially available. EVs are typically more expensive than similar conventional and hybrid vehicles, although some cost can be recovered through fuel savings, a federal tax credit, or state incentives.

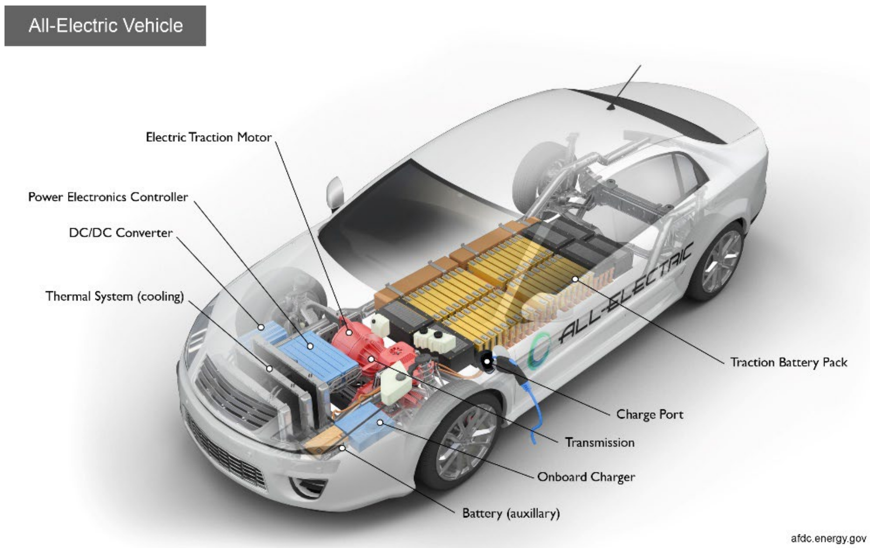

Figure 2: Key Components of an Electric Vehicle

Today's EVs generally have a shorter range (per charge) than comparable conventional vehicles have (per tank of gas). However, the increasing range of new models and the continued development of high-powered charging equipment is reducing this gap. The efficiency and driving range of EVs varies substantially based on driving conditions. Extreme outside temperatures tend to reduce range, because more energy must be used to heat or cool the cabin. EVs are more efficient under city driving than highway travel. City driving conditions have more frequent stops, which maximize the benefits of regenerative braking, while highway travel typically requires more energy to overcome the increased drag at higher speeds. Compared with gradual acceleration, rapid acceleration reduces vehicle range. Hauling heavy loads or driving up significant inclines also has the potential to reduce range

For PHEVs and electric vehicles additional infrastructure will be necessary. These electric police vehicles are designed to charge on a J1772 standard electric vehicle chargers operating at medium amperage. While equipment for medium amp electric vehicle chargers are currently listed at between $200 to $2,000 from many vendors, the installation, wiring, conduit, and appropriate siting of the charger may represent a project of far greater cost. For pilot projects, ease of installation of equipment and lowering costs with close proximity to available electrical equipment and limited trenching should be considered.

An example of a portable 15-amp level 1 electric vehicle charger which would charge vehicles at up to 1 kWh. All EVs come equipped with this equipment.

An example of a wall or pedestal mounted 40-amp level 2 electric vehicle charger capable of charging vehicles at up to 7.7 kWh.

Battery Overview

Energy storage systems, usually batteries, are essential for all-electric vehicles, plug-in hybrid electric vehicles (PHEVs), and hybrid electric vehicles (HEVs).

Lithium-ion batteries are currently used in most portable consumer electronics such as cell phones and laptops because of their high energy per unit mass relative to other electrical energy storage systems. They also have a high power-to-weight ratio, high energy efficiency, good high-temperature performance, and low self-discharge. Most components of lithium-ion batteries can be recycled, but the cost of material recovery remains a challenge for the industry. The U.S. Department of Energy is also supporting the Lithium-Ion Battery Recycling Prize to develop and demonstrate profitable solutions for collecting, sorting, storing, and transporting spent and discarded lithium-ion batteries for eventual recycling and materials recovery. Most of today's all-electric vehicles and PHEVs use lithium-ion batteries, though the exact chemistry often varies from that of consumer electronics batteries. Research and development are ongoing to reduce their relatively high cost, extend their useful life, and address safety concerns in regard to overheating.

Since Electric-drive vehicles are relatively new to the U.S. auto market, only a small number of them have approached the end of their useful lives. As electric-drive vehicles become increasingly common, the battery-recycling market may expand.
Widespread battery recycling would keep hazardous materials from entering the waste stream, both at the end of a battery's useful life and during its production. The material recovery from recycling would also reintroduce critical materials back into the supply chain and would increase the domestic sources for such materials. Work is now underway to develop battery-recycling processes that minimize the life-cycle impacts of using lithium-ion and other kinds of batteries in vehicles. But not all recycling processes are the same and require different methods of separation for material recovery:

- Smelting: Smelting processes recover basic elements or salts. These processes are operational now on a large scale and can accept multiple kinds of batteries, including lithium-ion and nickel-metal hydride. Smelting takes place at high temperatures where organic materials, including the electrolyte and carbon anodes, are burned as fuel or reductant. The valuable metals are recovered and sent to refining so that the product is suitable for any use. The other materials, including lithium, are contained in the slag, which is now used as an additive in concrete.

- Direct recovery: At the other extreme, some recycling processes directly recover battery-grade materials. Components are separated by a variety of physical and chemical processes, and all active materials and metals can be recovered. Direct recovery is a low-temperature process with minimal energy requirement.
- Intermediate processes: The third type of process is between the two extremes. Such processes may accept multiple kinds of batteries, unlike direct recovery, but recover materials further along the production chain than smelting does.
-

Separating the different kinds of battery materials is often a stumbling block in recovering high-value materials. Therefore, battery design that considers disassembly and recycling is important in order for electric-drive vehicles to succeed from a sustainability standpoint. Standardizing batteries, materials, and cell design would also make recycling easier and more cost-effective.

The U.S. Department of Energy (DOE) and its national laboratories are researching ways to reduce the lifecycle impacts of lithium-ion batteries. One of the National Renewable Energy Laboratory's (NREL) research objectives is to achieve a circular vision for lithium-ion batteries (e.g., see the following study https://www.nrel.gov/news/program/2021/pathways-to-achieve-new-circular-vision-for-lithium-ion-batteries.html).

In addition to battery recycling, second-life applications for batteries can extend the useful life of the technology. There are currently growing opportunities for EV batteries to be reused for a second life, such as to support the electricity grid. Here in Virginia, Dominion Energy is planning to pilot this technology with their deployment of electric school buses. By using a battery in a post-vehicle application, the lifetime value of the battery increases, and the cost of the battery can be shared between both the primary and secondary users. This could help resolve lithium-ion battery cost barriers to the deployment of both EVs and grid-connected energy storage.

This and more alternative fuel information can be found on the U.S. Department of Energy's Alternative Fuels Data Center.

About VCC

Virginia Clean Cities at James Madison University (VCC-JMU) is a university hosted government- industry partnership designed to promote healthful air through the reduction of petroleum consumption in the transportation sector by advancing the use of alternative fuels and vehicles, idle reduction technologies, hybrid electric vehicles, fuel blends, and fuel economy. Virginia Clean Cities is one of nearly 100 Department of Energy (DOE) sponsored coalitions across the U.S. that help meet the objectives of improving air quality, developing regional economic opportunities, and reducing the use of imported petroleum. Virginia Clean Cities was incorporated in November 2001 as a 501 (c) (3) non-profit corporation.

Appendix: Federal Tax Incentives and Programs

Alternative Fuels Excise Tax Credit. Section 13201 extends the $0.50 per gasoline gallon equivalent excise tax credits for alternative fuels from 2021 through 2024. Public transit agencies that fuel their vehicles with compressed natural gas (CNG), liquefied natural gas (LNG), or liquified hydrogen benefit from this tax credit. Transit agencies may file a claim for payment equal to the amount of the alternative fuel credit. The credit is first applied to the applicable excise tax liability under section 26 U.S.C. § 4041 or 26 U.S.C § 4081, and any excess credit may be taken as a payment.

Biodiesel and Renewable Diesel Excise Tax Credit. This section also extends the $1.00 per gallon excise tax credits for biodiesel and renewable diesel from 2022 through 2024. Transit agencies may file a claim for payment equal to the amount of the biodiesel or renewable diesel tax credit.

Alternative Fuel Vehicle Refueling Property Credit. Section 13404 extends the alternative fuel vehicle refueling property credit from 2021 through 2032, and substantially restructures the credit. Refueling property is property for the storage or dispensing of clean-burning fuel or electricity into the vehicle fuel tank or battery. Clean-burning fuels include CNG, LNG, electricity, and hydrogen. The bill clarifies that bidirectional charging equipment is eligible property. Tax credits for refueling property used in a trade or business are part of the general business credit. Generally, in the case of refueling property sold to a tax-exempt entity, the taxpayer selling the property may claim the tax credit.

This section also substantially restructures the tax credit. Under current law, taxpayers may claim a 30 percent credit for an alternative fuel property up to $30,000 per location. The bill provides a base credit of six percent up to $100,000 per project. In addition, it provides a bonus credit totaling 30 percent for expenses up to $100,000 for each project if the taxpayer satisfies Davis-Bacon prevailing wage requirements during construction of the project. In addition, under the bill, the alternative fuel property is only eligible for the credit if the property is placed in service in a low-income community (under 26 U.S.C. § 45D(e)) or rural census tract.

Under the provision, the 2021 rules of the alternative fuel vehicle refueling property credit apply in 2022. In 2023 and subsequent years, the restructured tax credit will apply.

Commercial Clean Vehicle Tax Credit. Section 13403 creates a new tax credit for commercial clean vehicles (e.g., zero-emission buses). The amount of the credit with respect to a qualified commercial electric vehicle is equal to the lesser of 30 percent of the cost of the vehicle or the incremental cost of the vehicle. The limit of the credit is $7,500 for a vehicle that weighs less than 14,000 pounds and $40,000 for all other vehicles. Commercial clean vehicles include battery electric and fuel cell vehicles. This 10-year tax credit takes effect in 2023 and expires December 31, 2032. In January 2023 the IRS issued guidance that tax-exempt organizations qualify for this tax incentive (https://www.irs.gov/credits-deductions/commercial-clean-vehicle-credit).

$1 Billion for Clean Heavy-Duty Vehicles. Section 60101 provides $1 billion to EPA to carry out a new Clean Heavy-Duty Vehicles program. Under the program, EPA will make grants and rebates to states, municipalities, Indian tribes, and eligible contractors to replace Class 6 or Class 7 heavy-duty vehicles as defined in 40 CFR 1037.801 (i.e., vehicles with a gross vehicle weight between 19,501 pounds and 33,000 pounds) with zero-emission vehicles.

The grants may pay up to 100 percent of costs for:

- the incremental cost of replacing eligible vehicles with zero-emission vehicles;

- purchasing, installing, operating, and maintaining zero-emission infrastructure;
- workforce development and training for zero-emission vehicles; and
- planning and technical activities to support adoption and deployment of zero-emission vehicles.