Fleet Electrification Analysis: City of Fredericksburg
EXECUTIVE SUMMARY

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Executive Summary:

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

After gathering fleet data from the City of Fredericksburg, VCC performed an analysis to create a baseline of current COF's 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, 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 city departments. The City of Fredericksburg 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 multiple medium and heavy-duty vehicles were provided by the city, there are few viable EV and HEV alternatives on the market at this time. Since few electric alternatives are available on the market, some of these vehicles were analyzed for propane auto-gas replacements and conversions.

The vehicle use case feasibility profiles were subdivided into three 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 those medium-to heavy-duty vehicles that would be better served by propane replacement. Figure 1 shows the 282-vehicle on-road fleet broken down by use case category.

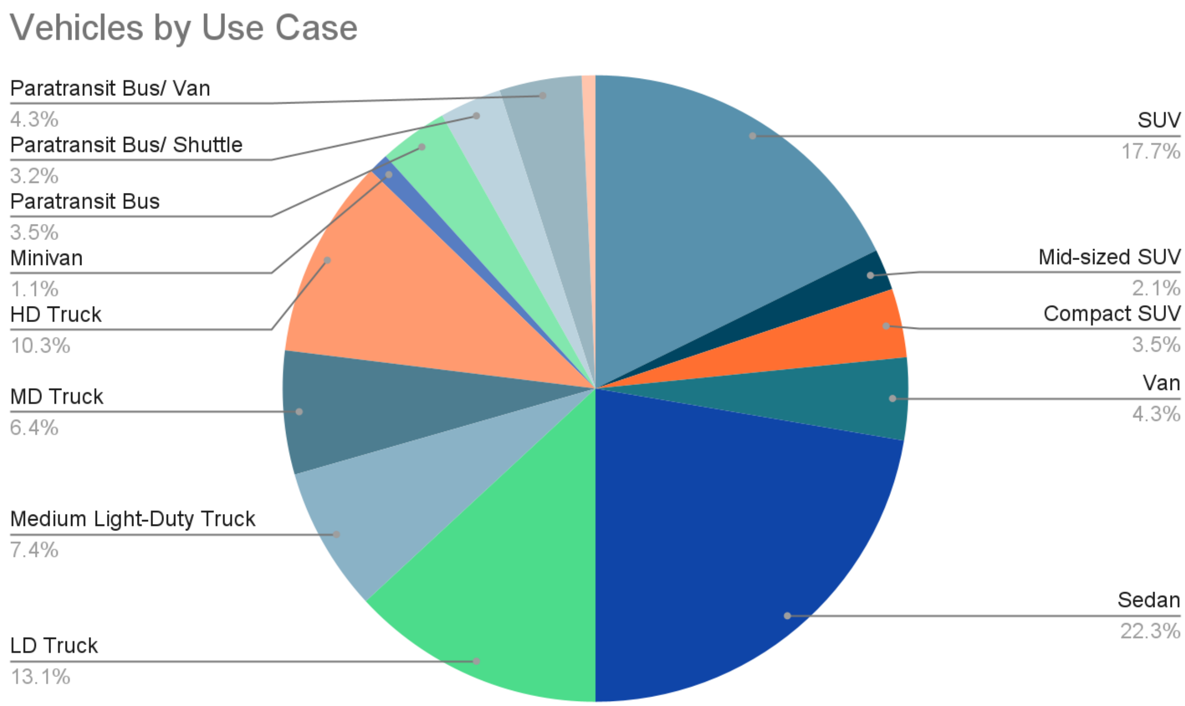

Figure 1: City of Fredericksburg Fleet Vehicles by Class

While we enthusiastically support the increased use of alternative fuel vehicles, it is unlikely that the City of Fredericksburg 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 $7500 and $40,000 per vehicle, depending on vehicle weight. More guidance is forthcoming from the Treasury and the City of Fredericksburg 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 and the total annual miles driven per year we can calculate the estimated baseline for fuel consumption (use and cost) and mileage for the City of Fredericksburg 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, and Propane vehicles 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
LD Truck	Ford F-150 Lightning	21	68	0.31	48	98	230	14,000
LD Truck	Ford F-150 Hybrid	21	25	0.84	-	-	613	12,000
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	12,000
SUV	Chevrolet Bolt EUV	23	120	0.19	28	65	259	2,500
SUV	Ford Mach-E	23	103	0.22	33	70	247	13,000
SUV	Ford Explorer HEV	23	27	0.85	-	-	486	No Payback
Sedan	Chevrolet Bolt EV	33	120	0.28	28	65	259	7,500
Sedan	Nissan LEAF (40kw)	33	111	0.30	30	40	149	5,500
Cargo Van	Ford E-Transit	16	63	0.25	50	68	126	5,500
Minivan	Chrysler Pacifica PHEV	15	30	0.73	41**	16	520	7,000
Minivan	Chevrolet Bolt EUV	15	120	0.28	28	65	259	3,500

Table 1: EV and HEV KPI Averages Across Fleet Vehicle Classes- City Departments

** when using electric drive only

EV and HEV KPI Averages Across Fleet Vehicle Classes- Law Enforcement								
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 ≤4 years
Police Sedan	Tesla Model 3 AWD	27	113	0.24	30	82	315	28,000
Police SUV	Mach-E	27	103	0.26	33	70	247	16,000
Police SUV	Hybrid Interceptor	17	24	0.71	-	-	-*	8,500

Table 2: EV and HEV KPI Averages Across Fleet Vehicle Classes- Law Enforcement

*not published

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 sedan, truck, SUV, minivan, and cargo van model availability, our recommendations for replacements are as follows:

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

1) Priority/near-term - The oldest Light Duty pickups with Ford Maverick Hybrids

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

3) F-250 class trucks with greater than 12,000 annual miles with F-150 Lightnings

4) SUVS with Bolt EUVs or Ford Mach-Es (based on appropriate use case/duty cycle)

5) Replace fleet cargo vans with greater than 5,500 annual miles with E-Transits

6) Law Enforcement SUVs with Hybrid Interceptors

7) Convert high mileage, heavy-duty vehicles to operate bi-fuel with renewable propane

7) Prepare for the next round of FTA funding to offset the costs of replacing transit vehicles with renewable propane

Other vehicles that the City should plan to replace in the medium and long term would be the minivans that cannot be downsized to Bolt EUVs to Hybrid Chrysler Pacificas, cargo vans with Ford E-transit 350s, and medium and heavy-duty trucks with electric alternatives that are expected to come to market or come down in price over the next decade. The City 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.

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 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 11 and 12 show the TCO comparisons over a 4-year lifecycle for replacing the average Law Enforcement fleet vehicle with EVs/HEVs versus ICE vehicles. Figures 11 and 12 also include a TCO scenario in which the cost of procuring and installing one Level 2 charging station for every EV is included in the upfront capital cost.

Figures 8-10 and 13-15 show the TCO comparisons over a 10 to 15-year lifecycle for replacing the average Heavy-Duty and Transit fleet vehicle with propane conversions versus ICE vehicles.

Total cost of ownership analysis

This Total Cost of Ownership section will be broken into 3 parts: city departments, law enforcement, and transit. For this analysis, all vehicle comparisons utilize the base contract price provided on the Virginia Sheriff's contract unless otherwise specified. This rideable contract allows 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 City Departments and 1 charger per vehicle for Law Enforcement Departments.

City Departments

For the analysis of the City fleets, the following fuel prices were used as provided: City Departments (including law enforcement) $3.07/ gallon gas, $3.74/ gallon diesel, and $0.10/ kWh electricity and Transit $2.69/ gallon gas, $3.08/ gallon diesel. The estimated propane autogas price of $1.64/ gallon was provided by technology expert Roush CleanTech. As with many fleet fueling options, propane fuel price contracts can be negotiated based on bulk consumption. Few departments from the City of Fredericksburg were able to supply their daily or annual mileage, as a result, **the default mileage for each vehicle type was used in the initial analysis (average mileage noted under each figure)**.

For fleet compact and 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 City'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 **14,000** annual miles and a Ford F-150 Hybrid would need to drive at least **12,000** 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.

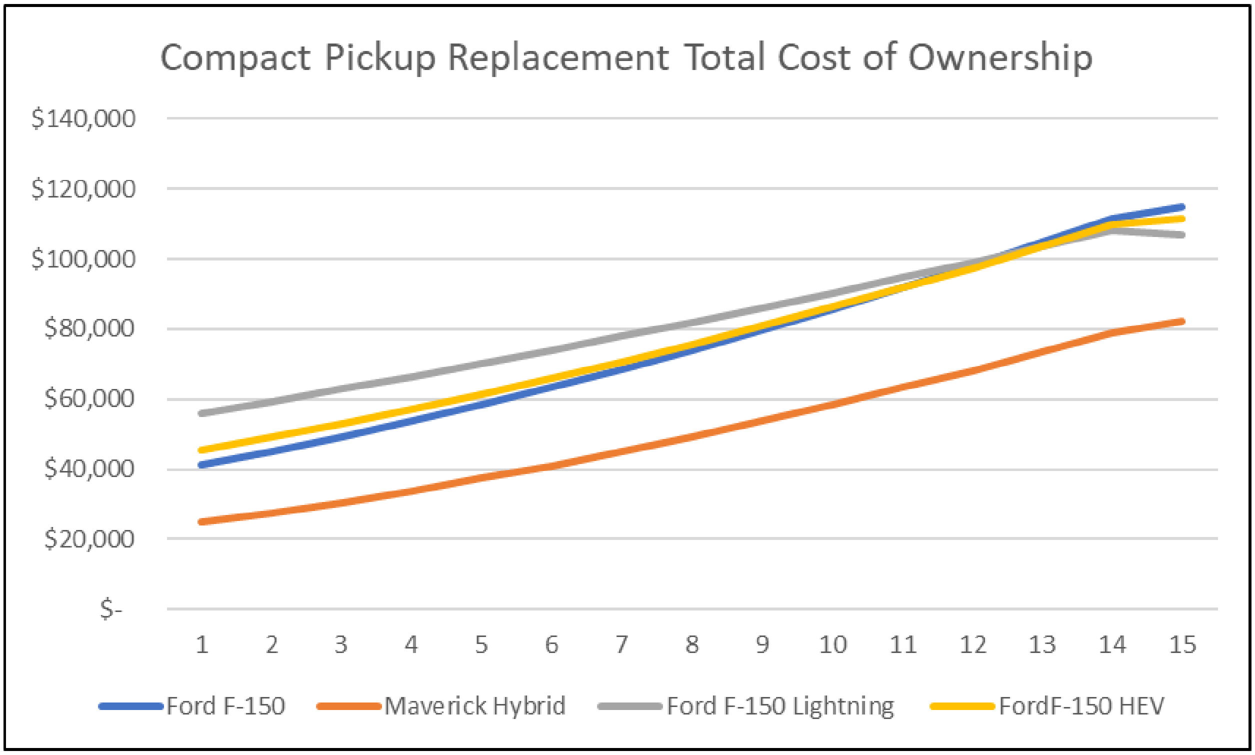

Figure 2: 2022 Compact Truck, TCO Replacement Comparison, Default Utilization of 11,400 annual miles, 15-year Lifecycle

The Ford F-150 Lightning does 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 **12,000** miles a year. 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. Replacement with the Ford F-150 Lightning would result in payback in approximately 5 years (figure 3).

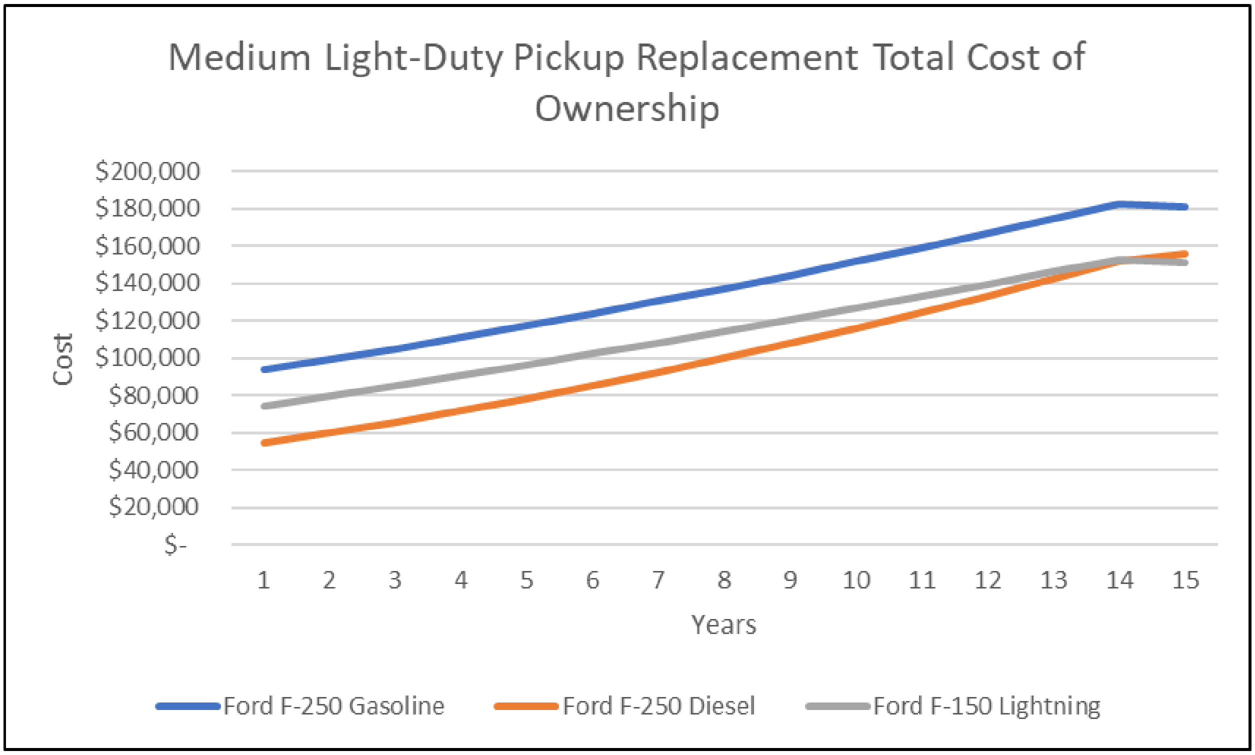

Figure 3: 2022 Medium Light-Duty Pickup, TCO Replacement Comparison, Default Utilization of 11,400 annual miles, 15-year Lifecycle

Full-sized SUVs, such as Ford Explorers, traveling at least **2,500** annual miles would expect to reach immediate payback if replaced with a Chevrolet Bolt EUV. Mid-sized and compact SUVs that drive **6,500** miles or more annually would reach payback in approximately 8.5 years if replaced with a 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. To achieve payback in less than 10 years, a Mach-E would need to drive at least **13,000** 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. Price savings from replacements that produce immediate payback, such as Ford Explorers to Bolt EUVs, may be able to offset this cost difference for Hybrid Explorer vehicles. Please see figure 4 for an SUV Total Cost of Ownership Comparison.

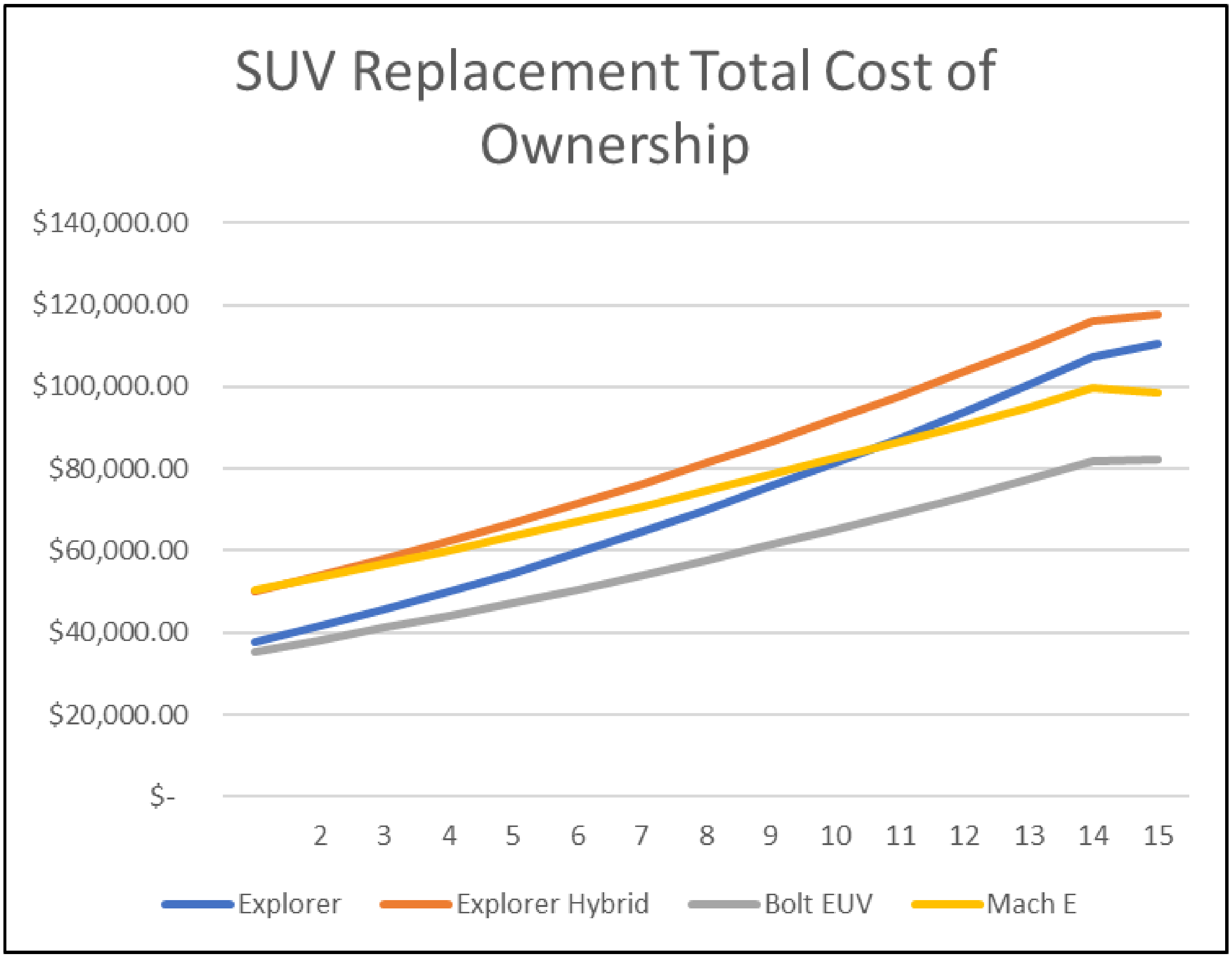

Figure 4: 2022 Ford Explorer TCO Replacement Comparison, Default Utilization of 13,000 annual miles, 15-year Lifecycle

Across the City's fleets there were 13 types of sedans listed. 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. We recommend that the City prioritize replacing sedan vehicles with Chevrolet Bolt EVs and Nissan LEAFs (figure 5). The Nissan LEAF (40kW) is the most affordable option and will achieve payback in less than 10 years by vehicles that drive at least **5,500** annual miles, vehicles with fewer annual miles will not be served by this replacement. It is also 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. The Chevrolet Bolt EV will achieve payback in less than 10 years for vehicles accumulating **7,500** annual miles or more. The Bolt EV's range maxes out at 259 miles, making it a better fit for vehicles that are expected to do regional travel as the charging network becomes more robust.

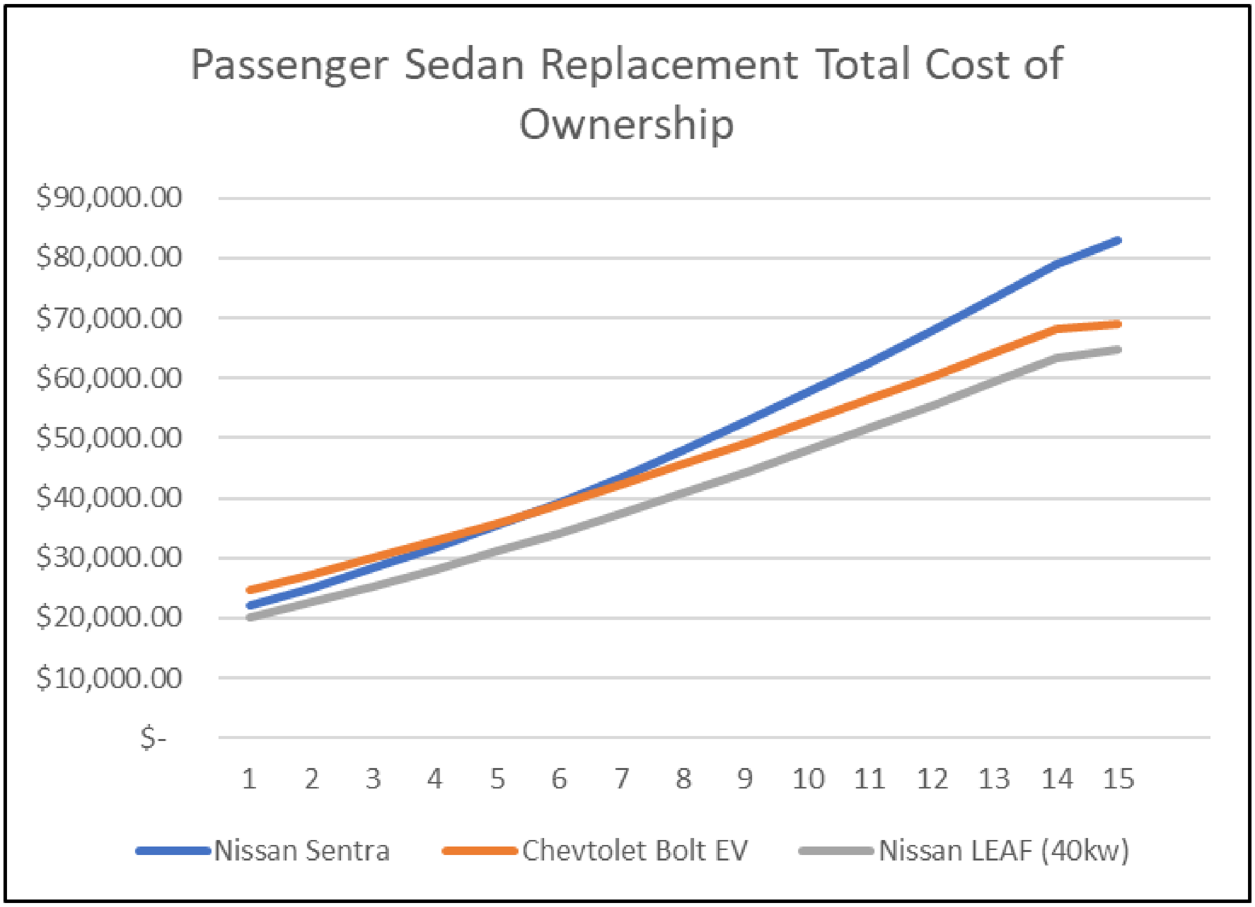

Figure 5: 2022 Passenger Sedan TCO Replacement Comparison, Default Utilization of 12,400 annual miles, 15-year Lifecycle

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 **5,500** miles annually. Replacing gasoline cargo vans that travel at least 5,00 miles annually with EVs would result in payback in less than 5 years.

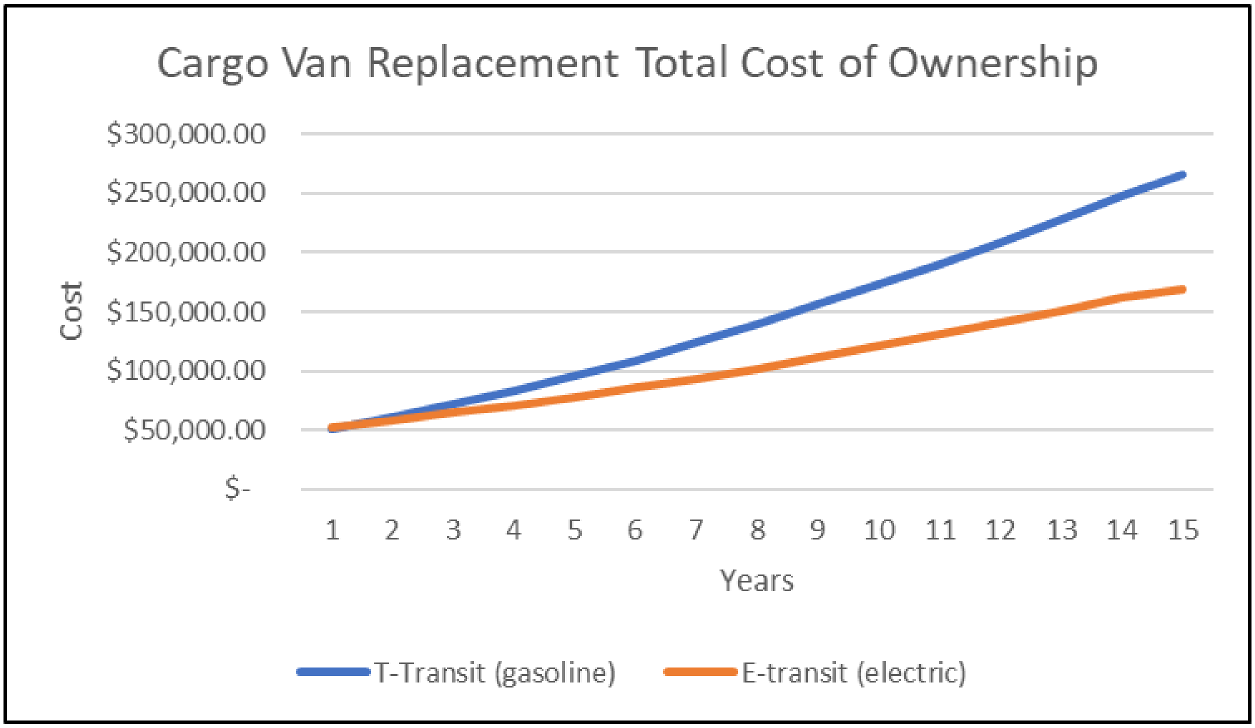

Figure 6 : 2022 Cargo Van TCO Replacement Comparison, Default Utilization of 27,000 annual miles, 15-year Lifecycle

At this time, we do not recommend the replacement of passenger vans with alternative fuel vehicles 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 city 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.

For the fleet minivans, we recommend replacement with either Chevrolet Bolt EUVs or Chrysler Pacifica Hybrids (figure 7). Replacement with Chevy Bolt EUVs would result in immediate payback in vehicles that drive **3,500** miles a year or more, however, Bolt EUVs are limited to 5 seats and are configured as a compact crossover SUV. For vehicles that require replacement with a transitional minivan configuration, we recommend the Chrysler Pacifica Hybrid. In order for the Pacifica Hybrid to reach payback in under 10 years the vehicle would need to travel at least **7,000** annual miles. The Pacifica Hybrid is a Plug-in Hybrid vehicle which means that it can travel approximately 32 miles on electric propulsion only before switching to gasoline and the hybrid battery. Fleet vehicles that travel less than 7,000 miles annually, but that travel less than 32 miles a day and utilize the vehicle's electric range can also expect to reach payback in less than 10 years.

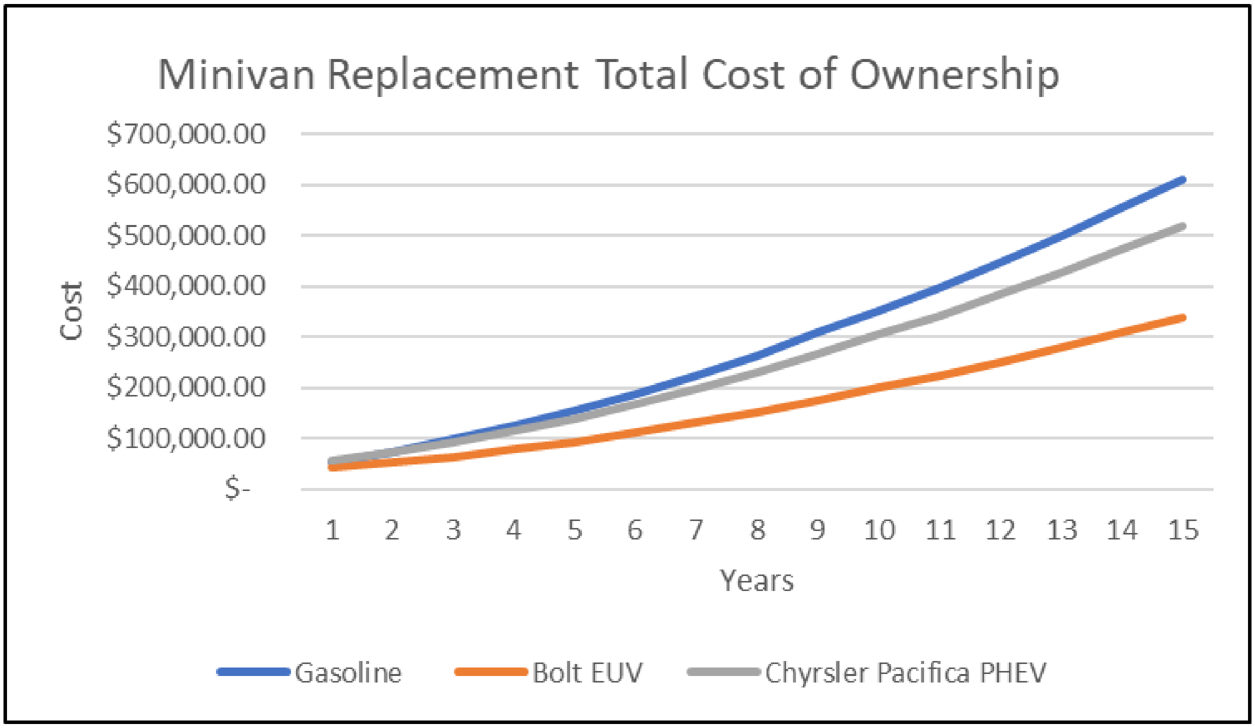

Figure 7: 2022 Minivan TCO Replacement Comparison, Default Utilization of 65,000 annual miles, 15-year Lifecycle

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.

The $10,000 incremental costs provided by CMAQ funding should cover the cost of conversion for most vehicles. Since the city's transit department already had a propane pad, and the fleets would expect to purchase or convert more than 10 vehicles to propane, it is very likely that the City would be able to have a skid-mounted dispenser installed at no cost. For these reasons, we have not included a price for a propane station in the cost of this analysis.

They City has a diverse fleet of Medium and Heavy-Duty Vehicles. For the purposes of this analysis, we have grouped them into Single Unit Short Haul Dump Trucks, Combination Short Haul Freight Trucks, and Refuse Trucks.

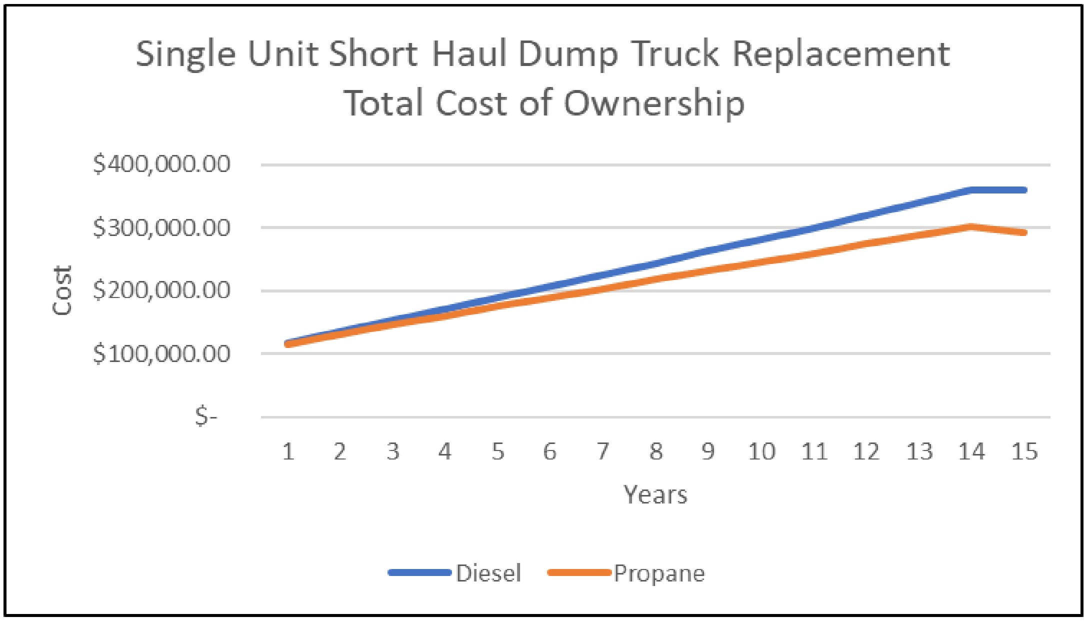

Figure 8: 2022 Single Unit Short Haul Dump Trucks, TCO Replacement Comparison, Default Utilization of 10,000 annual miles, 15-year Lifecycle

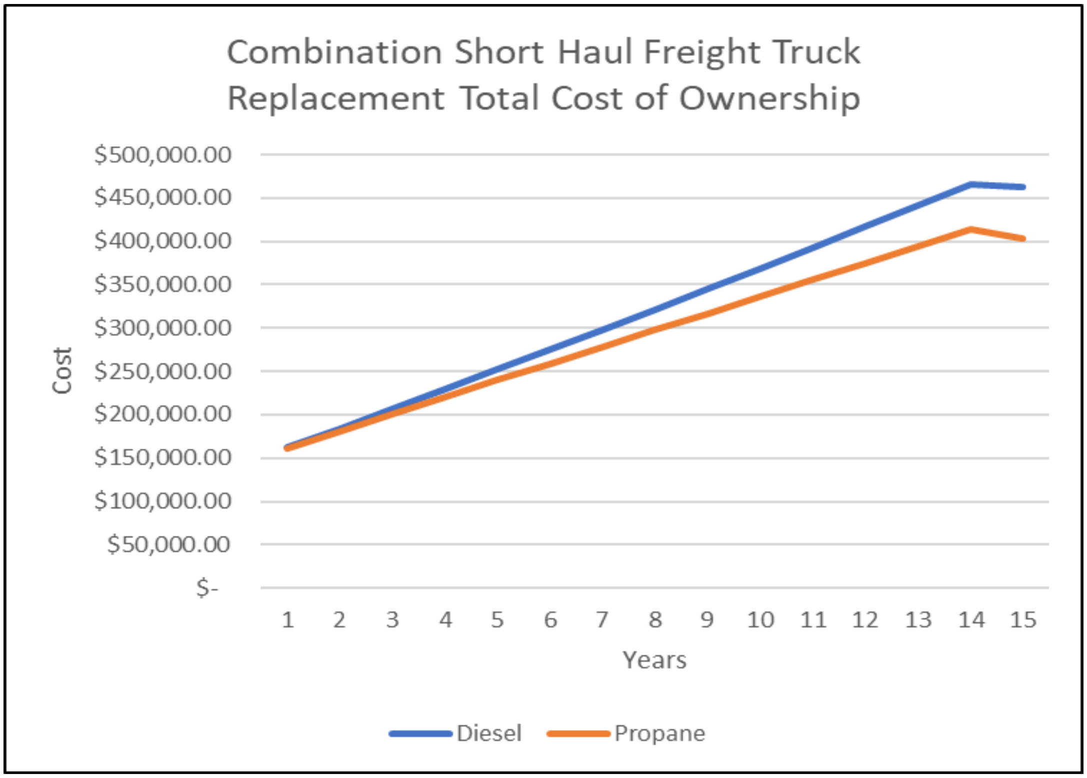

Figure 9: 2022 Combination Short Haul Freight Truck, TCO Replacement Comparison, Default Utilization of 10,000 annual miles, 15-year Lifecycle

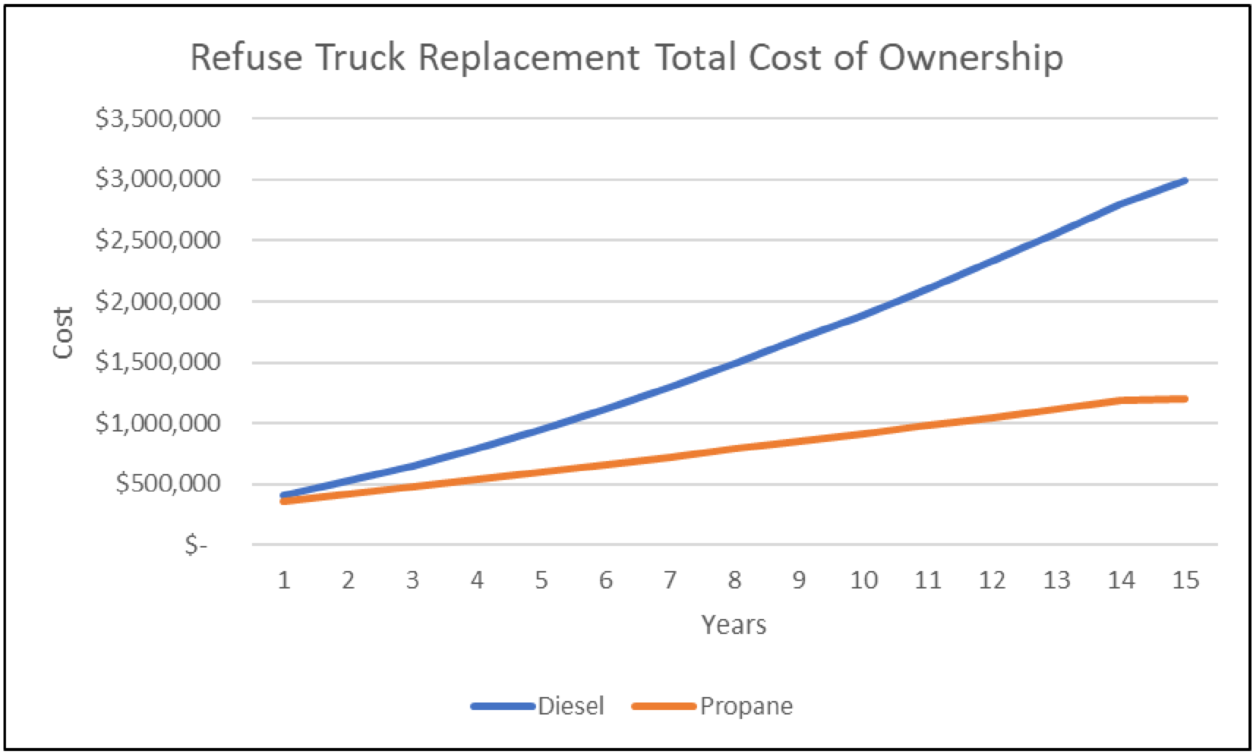

Figure 10: 2022 Refuse Truck, TCO Replacement Comparison, Default Utilization of 23,4000 annual miles, 15-year Lifecycle

Law Enforcement: Sheriff and Police Fleets

Law enforcement fleets were analyzed separately for this report due to several differences they will have from their average city fleet counterparts. These differences include shorter expected life spans, higher idling time, and significantly larger annual miles. For this analysis, we are estimating a 4-year lifespan. For law enforcement vehicles, we have also recommended that each EV be assigned its own charger due to the need for fast turnaround times.

Virginia Clean Cities completed an analysis of Fredericksburg's Police fleet in the Spring of 2021, and the results of this report remain similar. In this report, we will provide more information about EV options the fleet may have, but we still largely recommend replacements with Hybrid Interceptors as they significantly improve gas mileage, decrease fuel consumption from idling, and do not require dwell time for charging. A comparison calculator of the Ford's Standard and Hybrid Interceptors can be found here. We recommend EV replacements only for those high-mileage vehicles that have consistent dwell times or are not expected to make quick shifts or emergency turnarounds that would be hindered by charging time. Our recommendations for the Sheriff's fleet echoes those of the Police fleet.

Fleet transition to electric and hybrid electric vehicles would cause a significant reduction in greenhouse gas emissions, petroleum use, and air pollutants is possible from a transition to an electric or gas-hybrid fleet. The replacement of gasoline vehicles with hybrid vehicles results in an estimated 62% lifetime reduction in petroleum use and a 62% lifetime reduction in greenhouse gas emissions from these vehicles. One of the benefits of a PHEV or HEV is the operational savings and emissions reductions that can be achieved through idle reduction. When the vehicle is parked the engine switches to a battery as the source of its energy. This enables the vehicle's systems to continue operation. Data provided by the City of Fredericksburg Police Department shows that the patrol fleet vehicles have an average idle rate of 50.35%. On a standard 11-hour shift that represents more than 5.5 hours of idling per Patrol vehicle. The average Patrol vehicle consumes 663 gallons of gasoline per year, half of which is consumed while idling.

For potential Law Enforcement EV replacements, we analyzed the Tesla Model 3 (Performance AWD) and Ford Mach-Es as sedan replacements. To achieve payback in 4 years or less, vehicles replaced with the Tesla Model 3 will need to drive at least **28,000** annual miles. To achieve payback in 4 years or less, vehicles replaced with the Mach-E will need to drive at least **16,000** annual miles. This analysis was completed assuming one level 2 charger per vehicle. The fleet may be interested in DC fast charging infrastructure to allow quicker charging times, however, fast chargers would not be a cost-effective solution. Compared to Level 2 chargers that top out below $10,000 for high-powered options, DC Fast chargers are much more expensive in the $50,000 to $100,000 range and charging can incur demand payments. Unless the fleet were generating very high annual mileage, DC Fast charging would prevent EV vehicles from reaching payback. This is why we suggest EV replacements for vehicles that are expected to have regular dwell times.

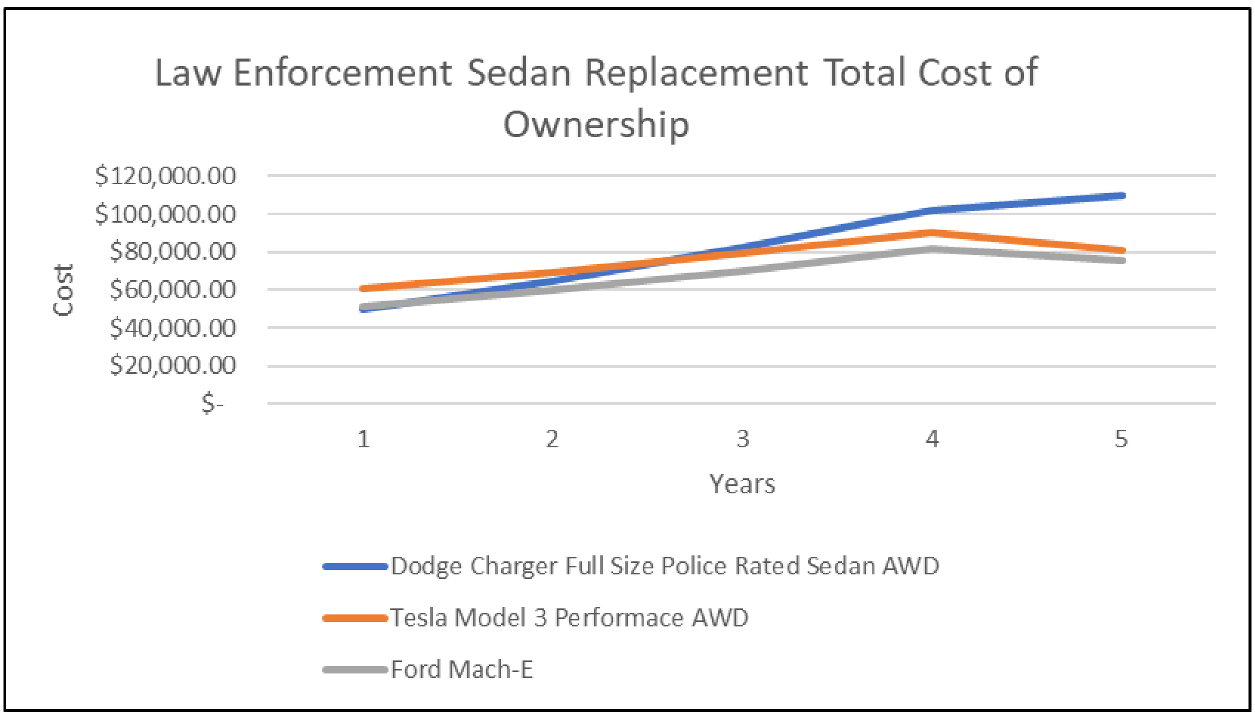

Figure 11: 2022 Law Enforcement Sedan, TCO Replacement Comparison, Default Utilization of 54,250 annual miles, 4-year Lifecycle

For law enforcement interceptors, we compared the gasoline-powered Ford Interceptor Utility to its Hybrid Alternative, in order to reach payback in 4 years or less, police interceptors will need to travel at least **8,500** annual miles. As with all fleets, it is important to remember that once payback is achieved the costs that were offset by transitioning to an alternative fuel vehicle can be used to cover the costs of vehicle replacements that won't reach payback during the vehicle's expected lifetime. This is a way for a fleet to reduce its GHGs while maintaining its budget.

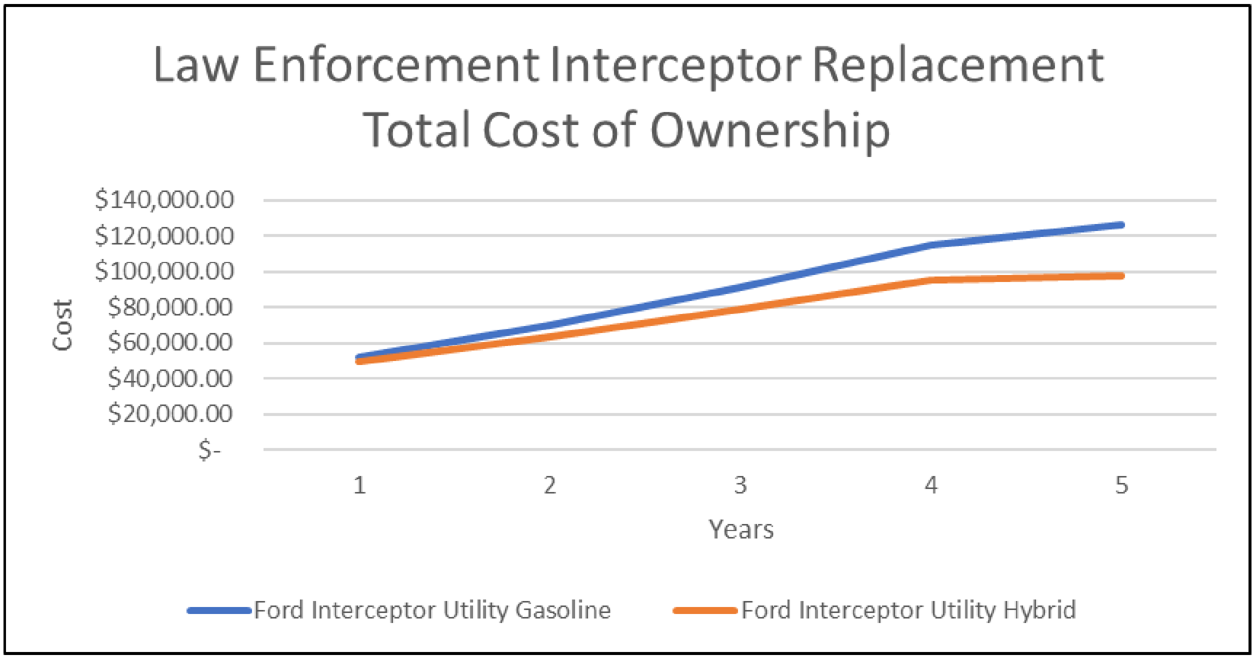

Figure 12: 2022 Law EnforcementInterceptor, TCO Replacement Comparison, Default Utilization of 50,500 annual miles, 4-year Lifecycle

Transit

Since the City of Fredericksburg Transit Department was able to share their annual miles, fleet average annual mileage by vehicle type (excluding outliers) were utilized for this analysis. For this analysis, we grouped transit vehicles into three categories, Paratransit Vans, Paratransit Shuttles, and Paratransit Buses. As can be seen in figures 13-15, transit ownership costs for propane are often equal to those of gasoline and diesel vehicles. A benefit of propane is that when petroleum prices fluctuate, propane fuel costs often remain more stable. Transit buses, unlike other fleet vehicles in Fredericksburg, would not be eligible for CMAQ funding. This is due to funding provided by the Federal Transit Administration through the FTA Low No Program and the FTA Buses and Bus Facilities Program. The program isn't currently open for 2023, but as these programs have been recurring we expect another round of funding to open up sometime this year.

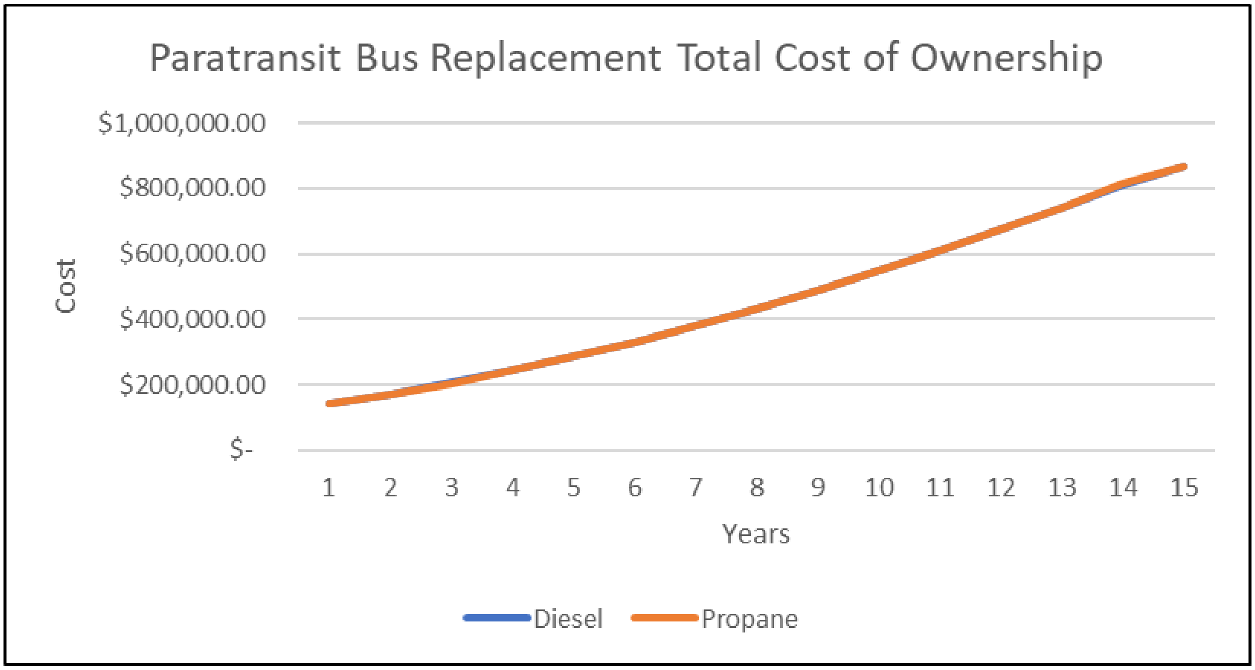

Figure 13: 2022 Paratransit Bus, Average Transit Department Utilization of 950 annual miles, 15-year Lifecycle

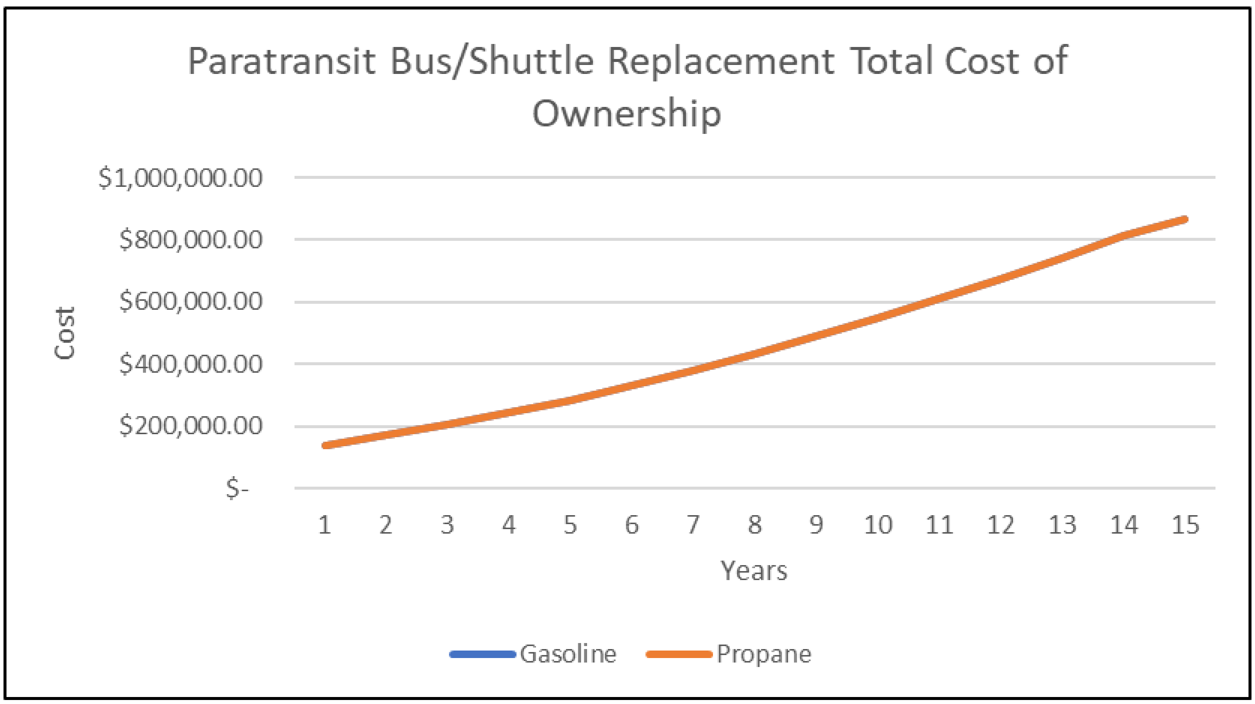

Figure 14: 2022 Paratransit Bus/ Shuttle, Average Transit Department Utilization of 32,349 annual miles, 15-year Lifecycle

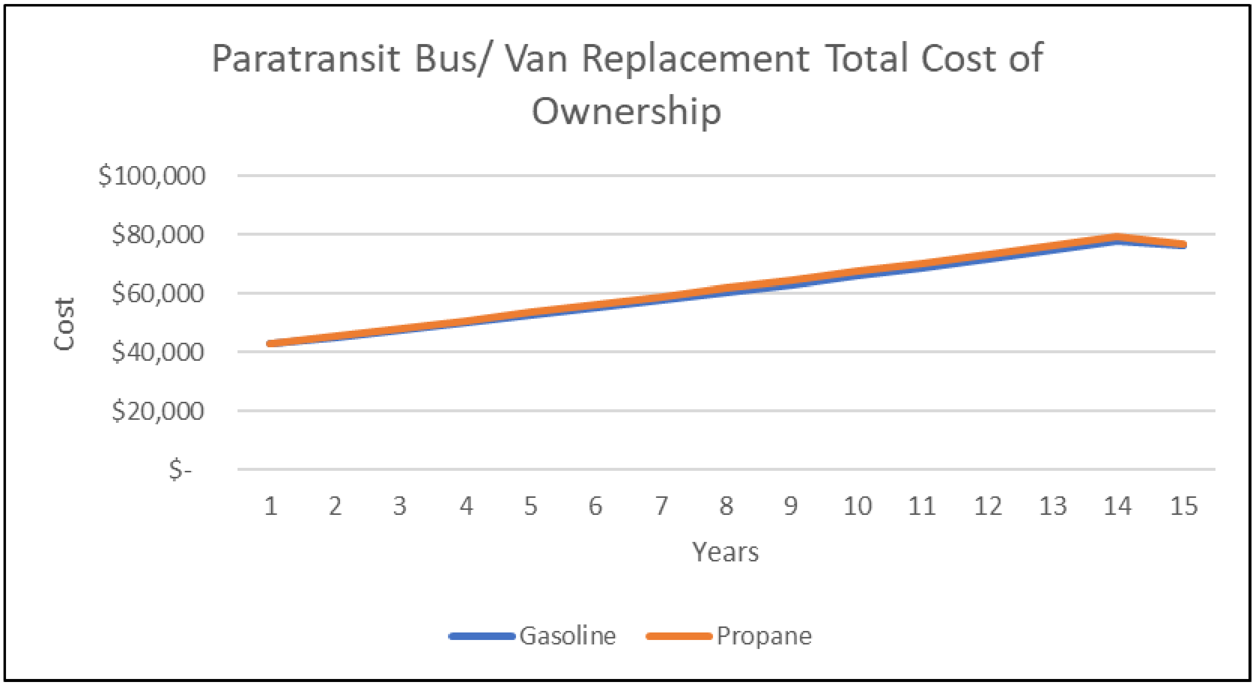

Figure 15: 2022 Paratransit Bus/ Van, Average Transit Department Utilization of 3,753annual miles, 15-year Lifecycle

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 16.

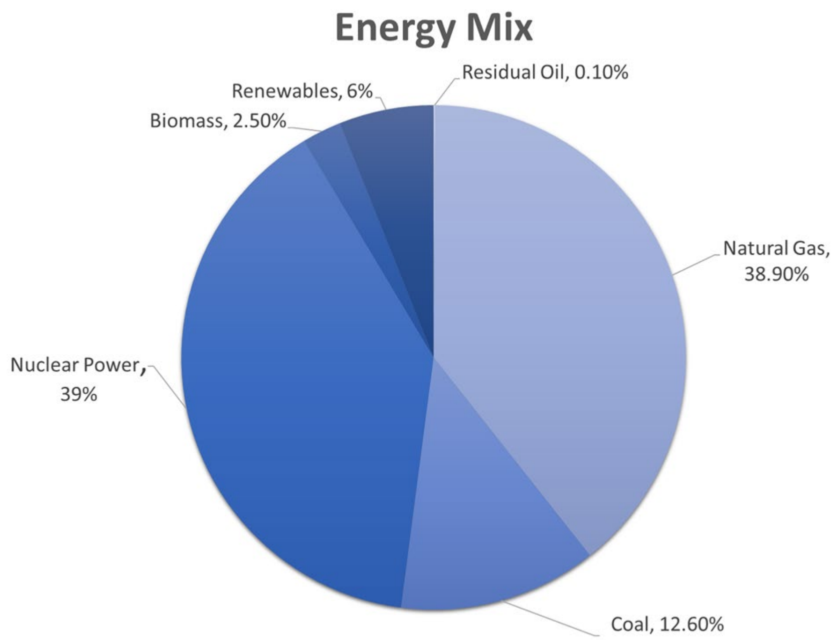

Figure 16: Fredericksburg, VA electric grid mix https://www.epa.gov/egrid/power-profiler#/SRVC

Since many City of Fredericksburg Departments were unable to provide annual mileage, all GHG calculations were created using the national annual mileage defaults provided by the AFLEET tool. These averages can be referenced in the Total Cost of Ownership section above.

<u>City Departments</u>

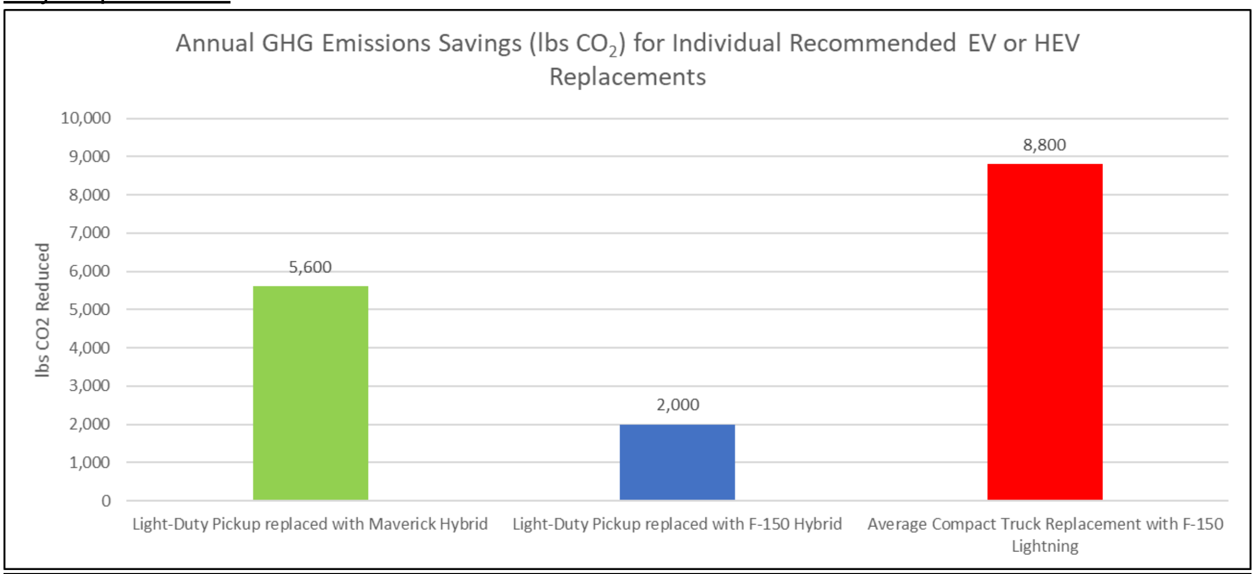

Figure 17: Compact/ Light-Duy Truck Annual GHG Emissions Savings

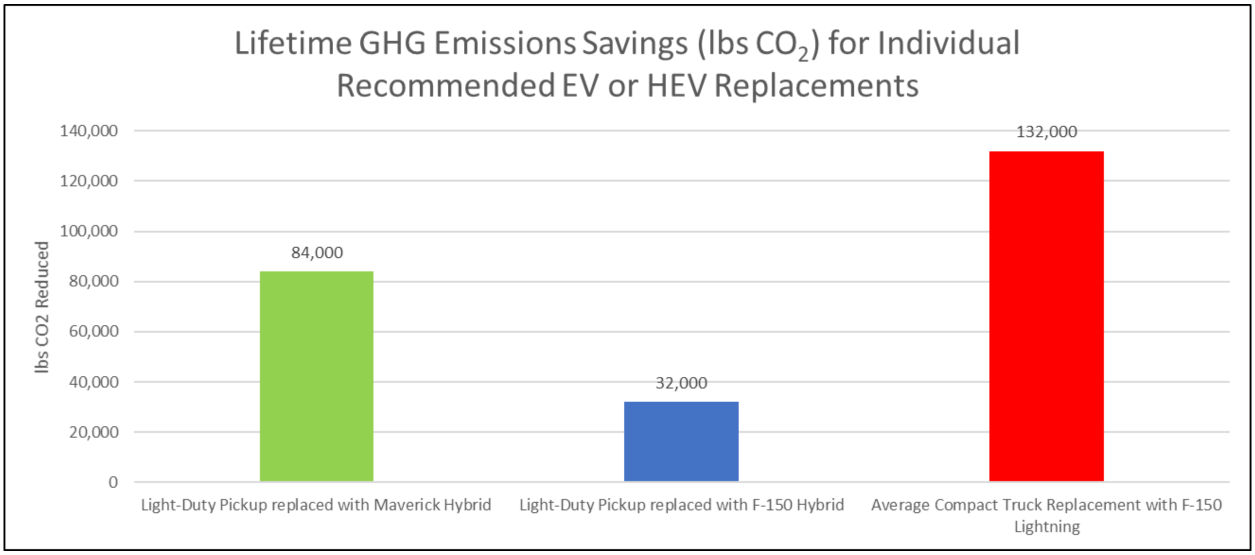

Figure 18: Compact/ Light-Duty Truck Lifetime GHG Emissions Savings

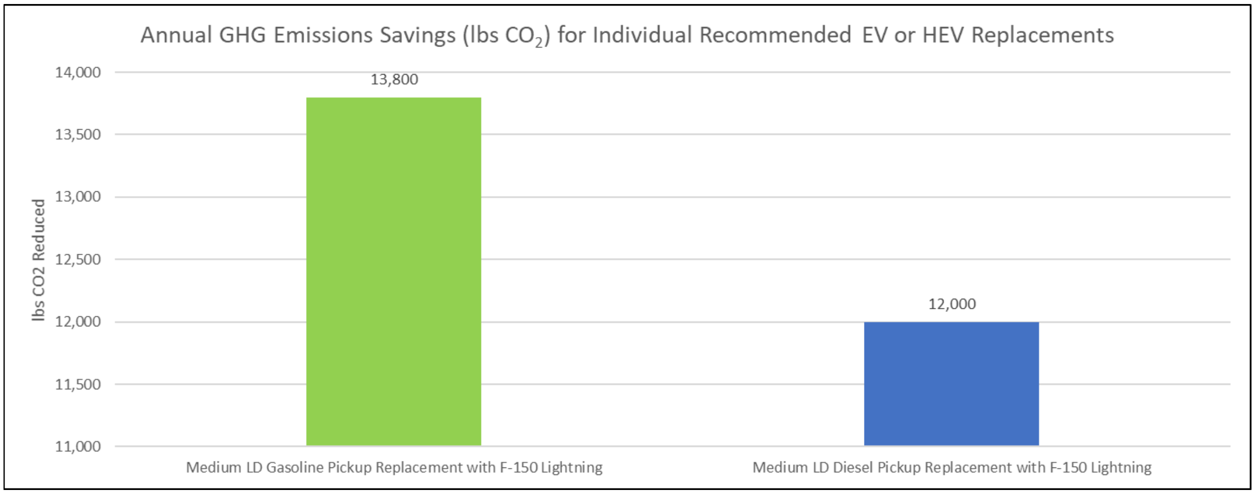

Figure 19: Medium Light-Duty Truck Annual GHG Emissions Savings

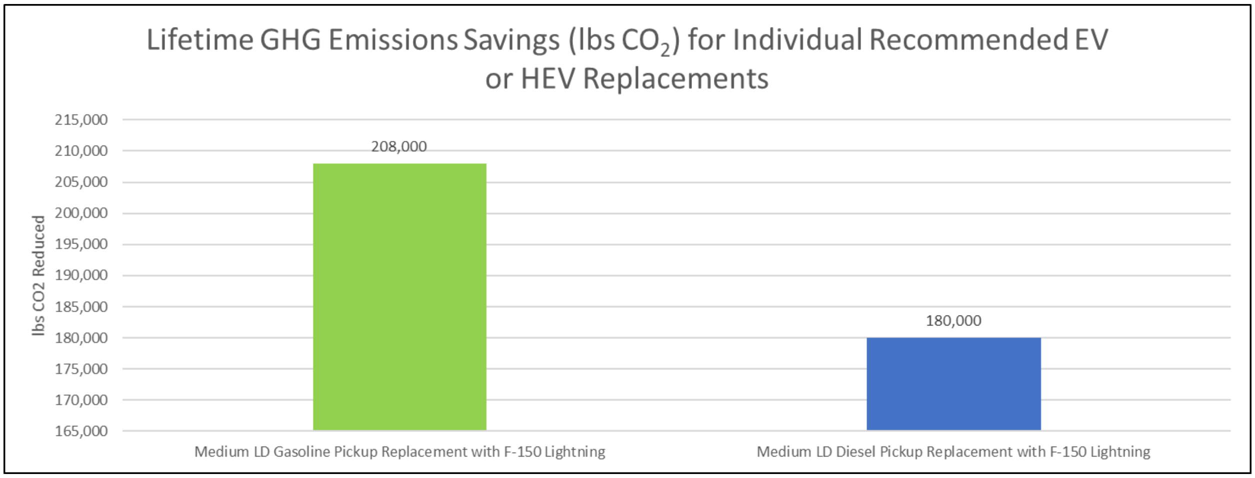

Figure 20: Medium Light-Duty Truck Lifetime GHG Emissions Savings

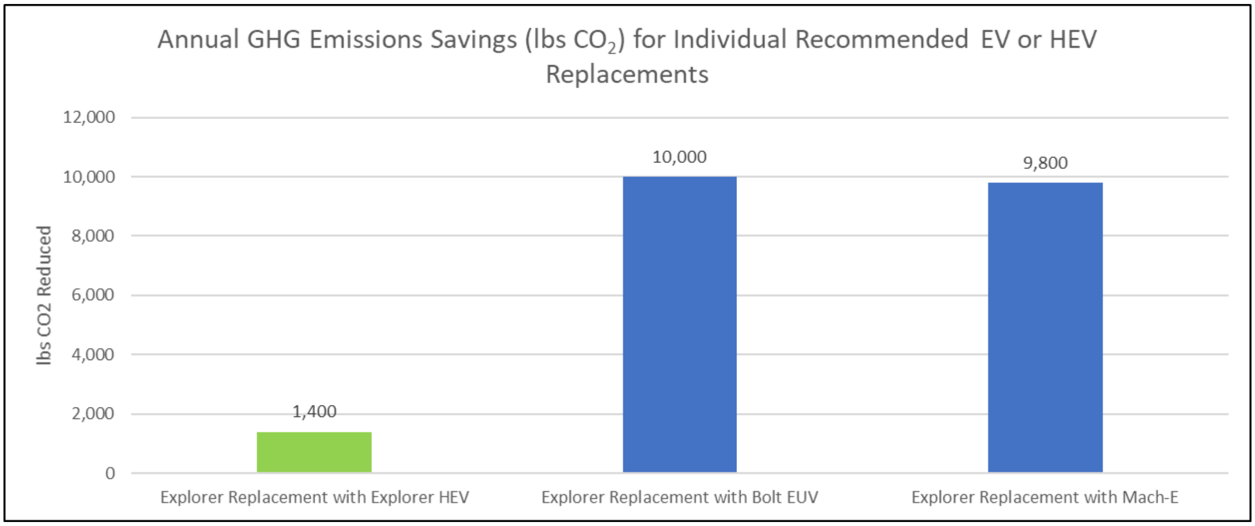

Figure 21: SUV Annual GHG Emissions Savings

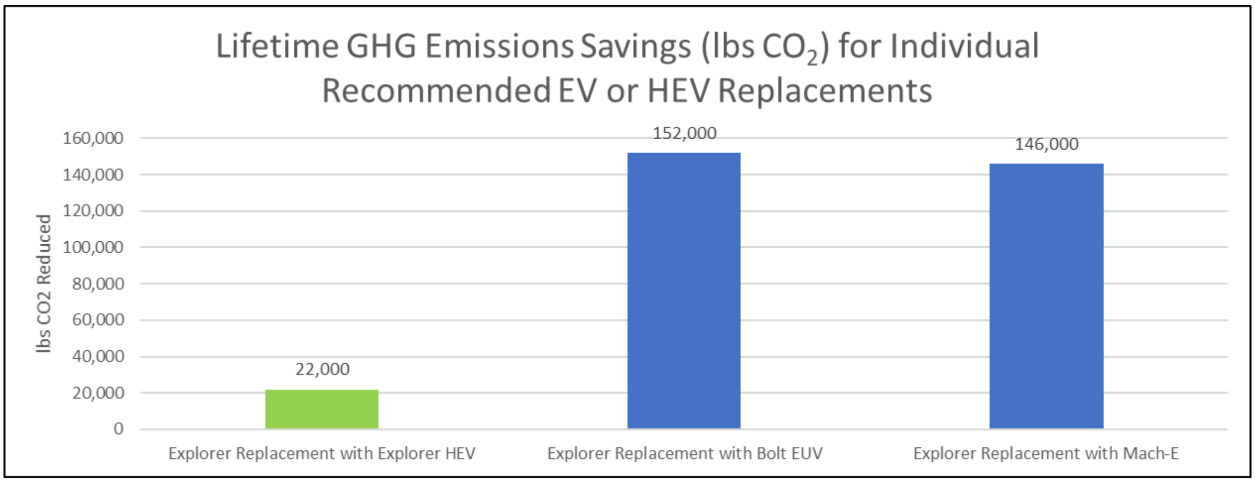

Figure 22: SUV Lifetime GHG Emissions Savings

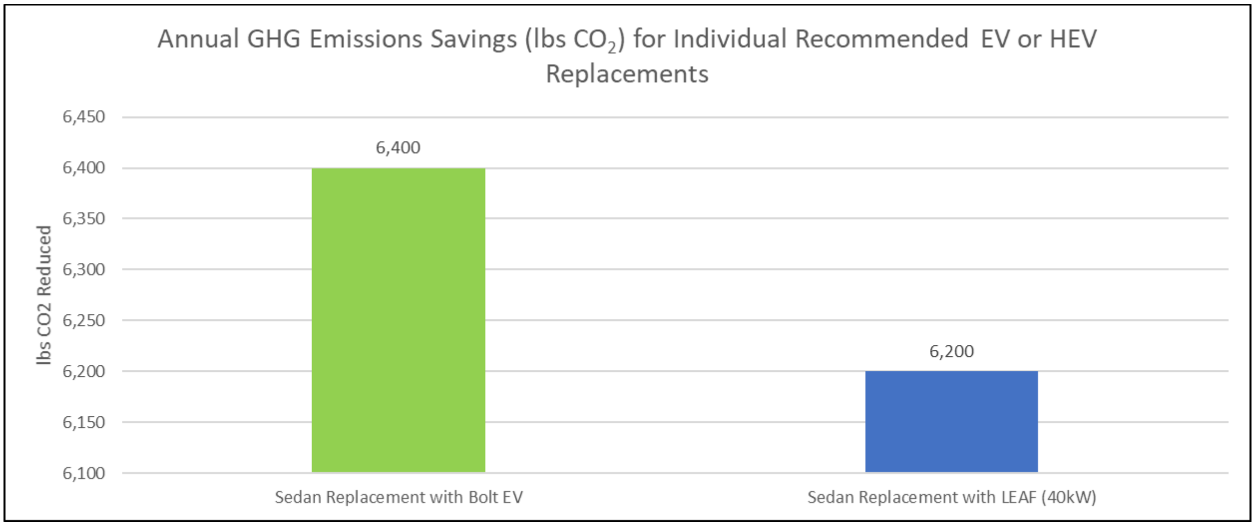

Figure 23: Sedan Annual GHG Emissions Savings

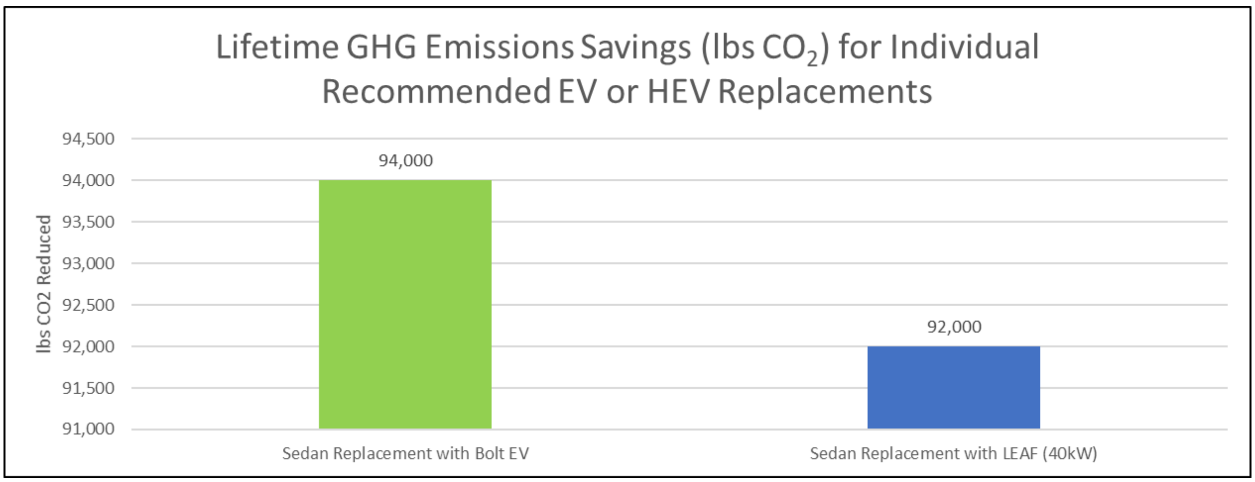

Figure 24: Sedan Lifetime GHG Emissions Savings

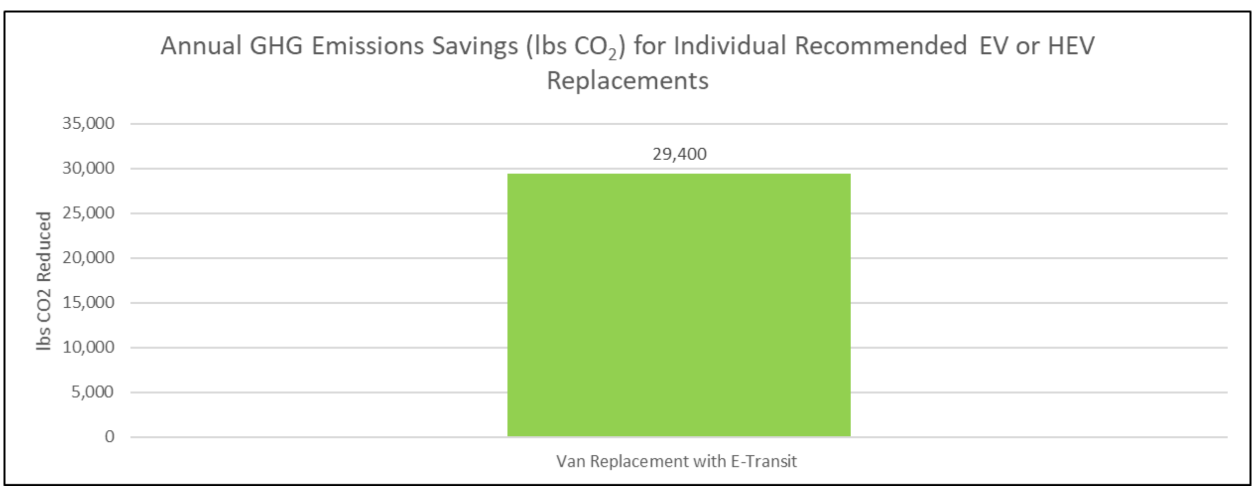

Figure 25: Cargo Van Annual GHG Emissions Savings

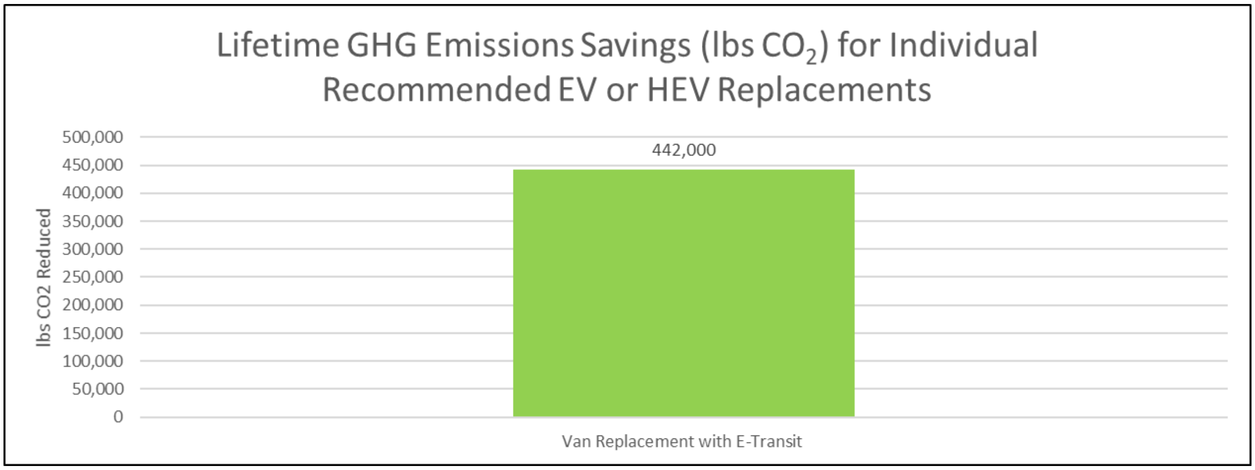

Figure 26: Cargo Van Lifetime GHG Emissions Savings

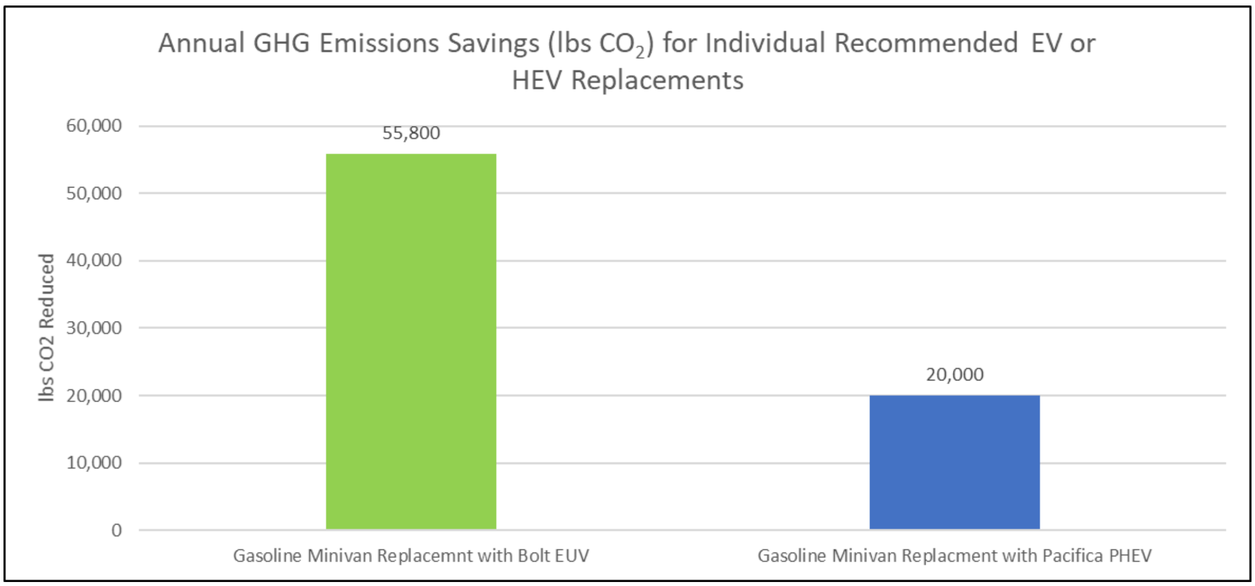

Figure 27: Minivan Annual GHG Emissions Savings

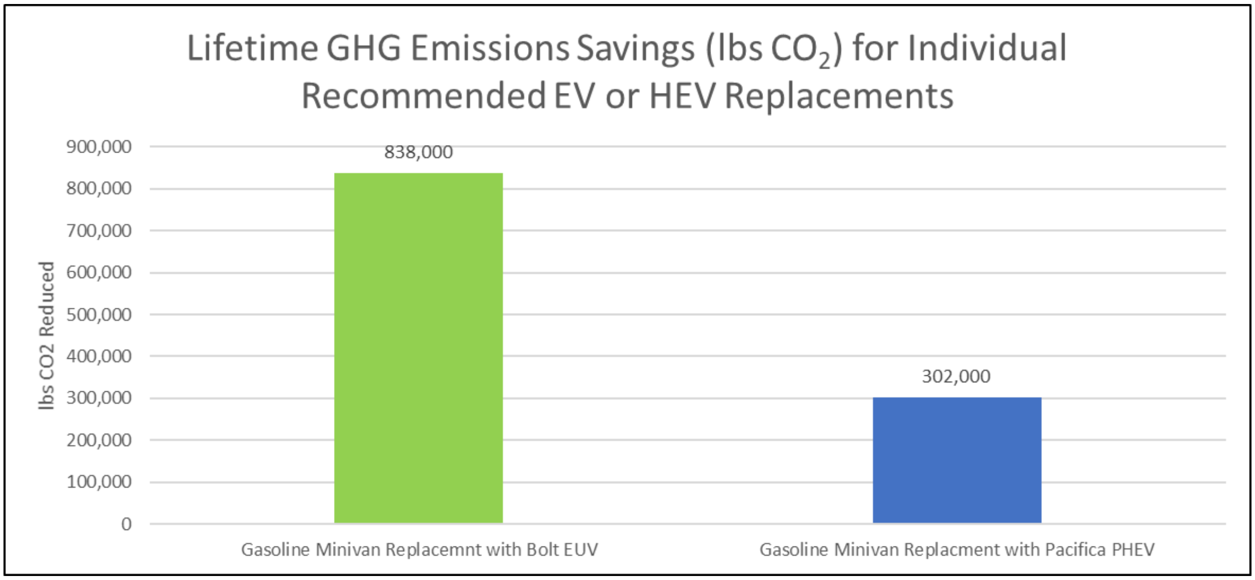

Figure 28: Minivan Lifetime GHG Emissions Savings

<u>Law Enforcement: Sheriff and Police Fleets</u>

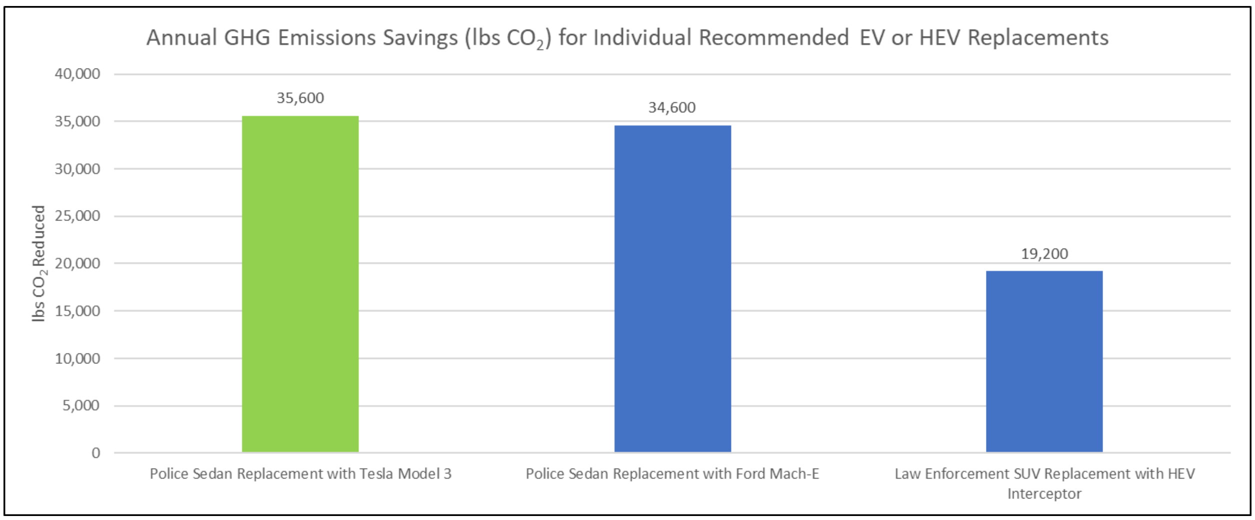

Figure 29: Law Enforcement Vechile Annual GHG Emissions Savings

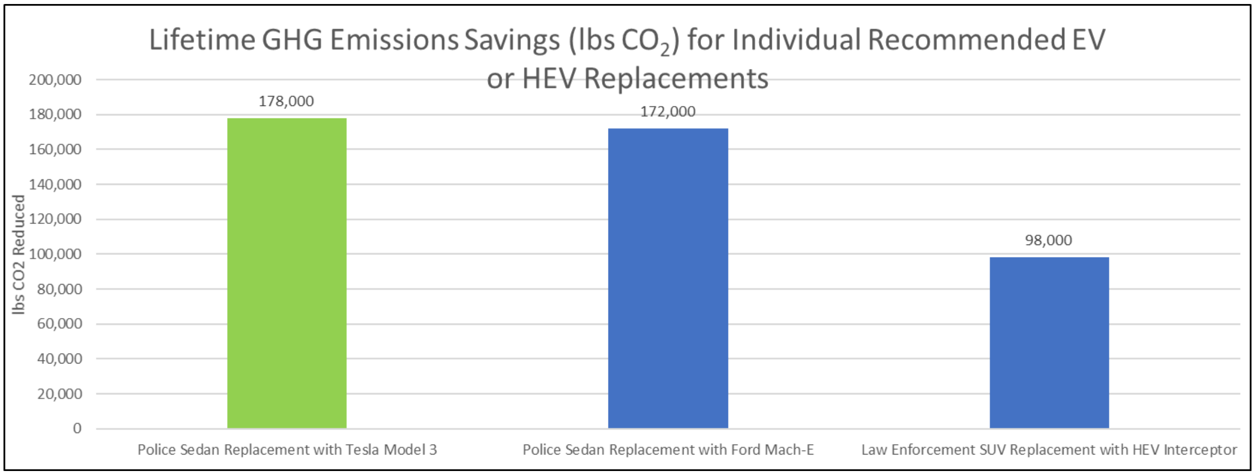

Figure 30: Law Enforcement Lifetime GHG Emissions Savings

The AFLEET tool used for this analysis does not provide the same level of GHG analysis for propane as it does for EVs. Propane fuel has a lower carbon content than conventional gasoline and diesel fuel and contains no methane. Propane use reduces GHG emissions by nearly 13%, and when derived as a by-product of natural gas production, propane reduces petroleum use by 99%. The fuel also generates fewer tailpipe emissions than diesel and gasoline, compared to diesel propane has close to zero particulate matter emissions and 96% fewer NOx. Emissions can be even further reduced by using renewable propane such as that derived from animal fat, algae, and cooking oil. According to the California Air Resources Board, renewable propane has a carbon intensity of 45, compared to gasoline at 96, thereby reducing emissions by 53%. In addition to these emissions benefits, propane is a domestic fuel, meaning that it creates American jobs and is less susceptible to fuel price fluctuations caused by international conflicts.

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 City of Fredericksburg could increase the impact of alternative fuel vehicle replacements through less expensive fuels and fewer vehicles to maintain. The City could also decrease its vehicle costs and emissions by vehicle right-sizing. Please see the City's expected TCO for SUVs and Compact trucks in the previous section as an example.

The City should also engage in right-sizing its 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, you may consider a slower but less expensive charger option.

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 or Ford Explorers that can be replaced with smaller Bolt EUVs**
    b. **Phase in the procurement of Ford Maverick Hybrids for the oldest light-duty pickups. Phase in procurement of Nissan LEAFs or Chevy Bolt EVs for the oldest sedans. Phase in procurement of Chevy Bolt EUVs or Mach-Es for fleet SUVs. Phase in procurement of Hybrid Interceptors for Law Enforcement SUVs. Phase in procurement of E-Transit Cargo Vans for Cargo Vans traveling 5,500 annual miles or more.**
        i. **Prioritize the oldest vehicle and those with the highest annual mileage first**
        ii. **Utilize immediate payback from replacements with Maverick Hybrids and Bolt EUVs 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**
    c. **Convert high-mileage, Heavy-Duty vehicles to propane**
    d. **Prepare for the next round of FTA funding to offset the costs of replacing transit vehicles with propane**

2. **Long Term (next 4+ years)**
    a. ***Ford F-Series Pickup Trucks and Comparable Models***
        i. ***The forthcoming 2022 Ford F-150 Lightning is very close to producing an ROI for the average use case in the fleet: should the MSRP drop from a 48% price increase to a 31% price increase compared to the ICE F-150, or the average mileage utilization of the fleet F-Series vehicles increase to 13,500 miles annually, these should be considered feasible replacement options.***
        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. ***Passenger/Cargo Vans***

i. *Currently, the E-Transit only comes in cargo van options: should Ford begin releasing similar options for passenger vans, these should be considered under comparable market and utilization conditions.* 1. *Customization for passenger van configurations is available, however, current price estimates exceed $100,000.* c. *If downsizing minivans to smaller vehicle types is not feasible in the short term, replacement with Chrysler Pacifica Hybrids in the medium term should be considered as the cost of the technology decreases or as savings are accumulated from other vehicle replacements* *d.* As payback is accumulated from replacing light-duty trucks with Maverick Hybrids, the City 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
EVSE Procurement and Installation Recommendations
1. *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.*
2. *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 electrifying. Like conventional ICE vehicles, most EVs will not need to be charged every day, so can share a charger.*
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.

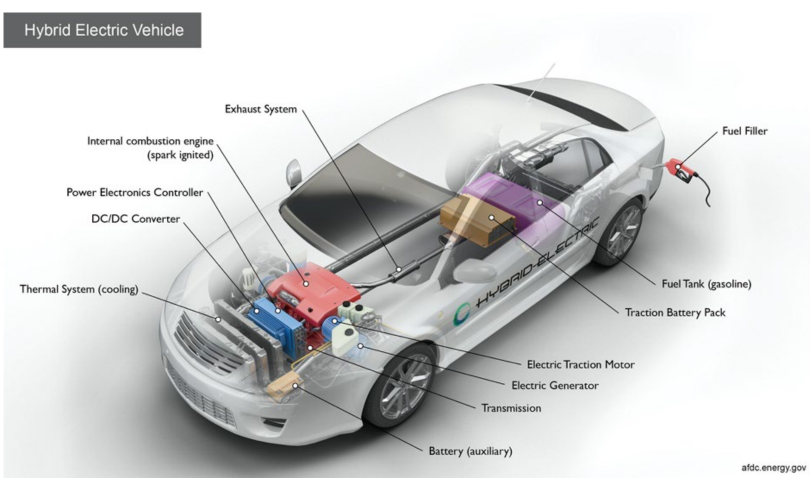

Figure 1: Key Components of a Hybrid Electric Car

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.

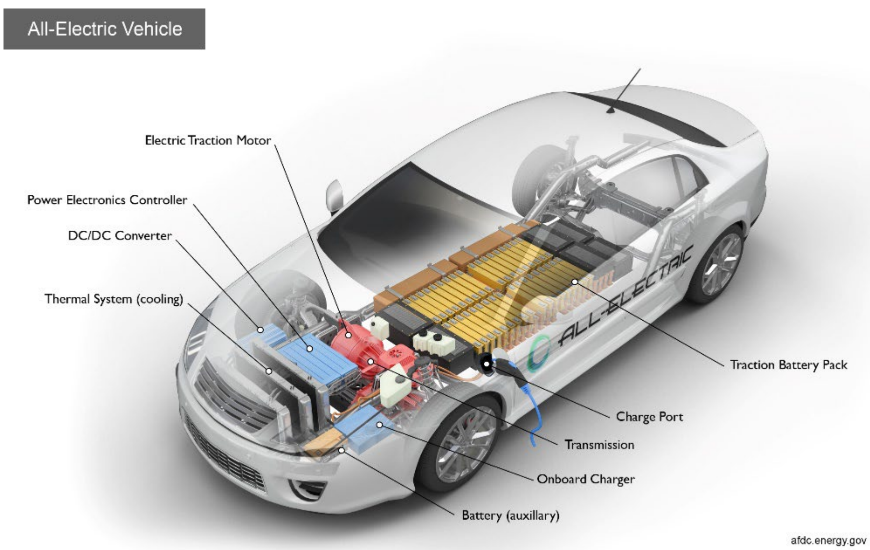

Figure 2: Key Components of an Electric Vehicle

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.

Propane Vehicles

Propane, also known as liquefied petroleum gas (LPG), or propane autogas, is considered an alternative fuel under the Energy Policy Act of 1992. According to the Propane Education & Research Council, there are nearly 60,000 on-road propane vehicles with certified fuel systems in the United States. Many are used in fleet applications, such as school buses, shuttles, and police vehicles.

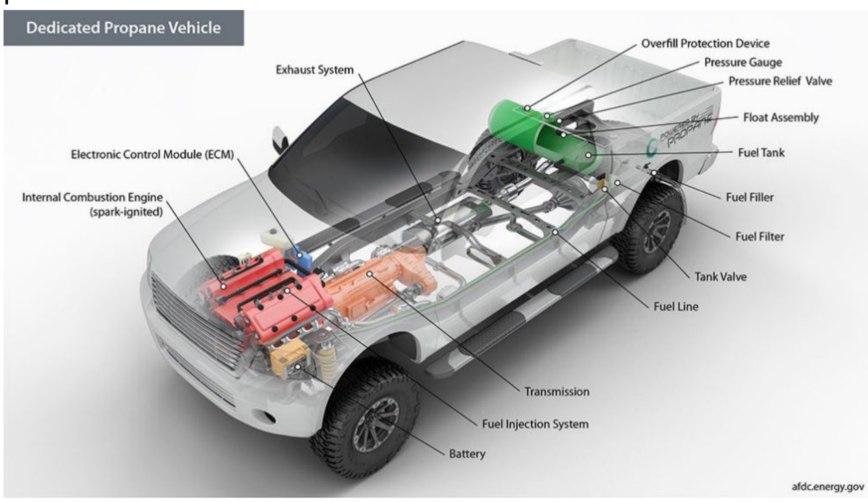

Figure 3: Key Components of a Propane Vehicle

Inert Propane Image
Propane vehicles are available from original equipment manufacturers (OEMs) or via a conversion. Propane engines and fueling systems are also available for heavy-duty vehicles, such as step vans and school buses, including some prep-ready engines from OEMs. Propane vehicles have been widely used and refined for decades, and a propane vehicle's power, acceleration, and cruising speed are similar to those of conventionally fueled vehicles. There are two types of propane vehicles: dedicated and bi-fuel. Dedicated propane vehicles are designed to run only on propane. Bi-fuel vehicles have two separate fueling systems, enabling the vehicle to run on either propane or gasoline. This provides the flexibility of using either fuel, which typically provides bi-fuel vehicles a greater range than dedicated propane or gasoline vehicles. Extra storage tanks can increase range, but the tank size and additional weight affect payload capacity.

Because a gallon of propane has 27% less energy than a gallon of gasoline, the fuel economy of propane vehicles is slightly lower. However, propane has a higher octane rating than gasoline (104–112 compared to 87–92 for gasoline), and some OEMs offer dedicated engines optimized to take advantage of this higher rating. This can result in improved performance and fuel economy over non-optimized engines.

The potential for lower maintenance costs is one reason behind propane's popularity for use in light- and medium-duty vehicles, such as trucks and taxis, and for heavy-duty vehicles, such as school buses. Propane's low carbon and low oil contamination characteristics may result in longer engine life. Propane performs well in cold weather climates because the fuel's mixture (propane and air) is completely gaseous when it enters the injection system and engine. This factor allows propane-powered vehicles to avoid many cold-start issues associated with using diesel.

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: Vehicles by Use Case

SUV
Ford Explorer
Ford Compass
Ford Escape
Chevrolet Suburban
Chevrolet Tahoe
Ford Expedition

Mid-sized SUV
Dodge Journey
Nissan Rogue
Chevrolet Traverse

Compact SUV
Toyota Rav 4
Hundai SUV
Saturn Vue

Van
GMC Savana 2500
Chevrolet Express
Nissan NV200
UCBC Step Van
GMS Step Van
Ford E150
GMC Value Van

Sedan
Ford Focus
Mazda Tribute
Ford Crown Victoria
Chevrolet Impala
Ford Fusion
Dodge Charger
Nissan Altima
Ford Tarus
Chevrolet Malibu
Honda Accord
Nissan Ultima
Buic Verano
Honda Civic

LD Truck
Ford Ranger
Ford F-150
Chevrolet 1500
Mazda Pickup
GMC 1500
Dodge Ram 1500

LD-MD Truck
Ford F-250
Ford F-350
GMC 2500
GMC 3500
Chevrolet Silverado 3500

MD Truck
Ford F-450
Ford F-550
Ford F-650

HD Truck
Ford F-750
Freightliner M2106 Flatbed
Freightliner M2112 Refuse Packer

M2106 Freightliner w/Dump Body
Isuzu Truck
International 2 1/2 ton dump
Freightliner Vactor Jet/Vac Truck
Freightliner M2
Freightliner Schwarze A7000 Sweeper
Dodge Ram 5500
Mack Roll-Off Truck

Minivan
Dodge Caravan
Dodge Grand Caravan

Paratransit Bus
Freightliner S/C2 BOC

Paratransit Bus/ Shuttle
Ford E-450 BOC

Paratransit Bus/ Van
Chevy Express 3500

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.