Arlington County (VA) Comparative Transportation Electrification Analysis

February 2023

Contents

List of Acronyms

AFLEET - Alternative Fuel Lifecycle Environmental and Economic Transportation Tool developed by Argonne National Lab

AWD – All-Wheel Drive

AEV - All Electric Vehicle (*also commonly known as Battery Electric Vehicles (AEVs)*)

CEP – Arlington Community Energy Plan

EV – Plug-in Electric Vehicle, including both AEV and PHEV models

EVSE – Electric Vehicle Supply Equipment, often referred to as EV charging equipment

ICE – Internal Combustion Engine

LDV – Light duty vehicle

M/HDV – Medium/Heavy Duty Vehicle

MPGGE – Miles Per Gallon Gasoline Equivalent, used to compare fuel economy of EVs

MSRP – Manufacturer's Suggested Retail Price

PHEV - Plug-In Hybrid Electric Vehicle

SUV – Sport Utility Vehicle

TCO – Total Cost of Ownership

Executive Summary

This report was completed for Arlington County's Office of Sustainability and Environmental Management (OSEM, a Division of the Department of Environmental Services) to analyze the potential for all-electric vehicles (AEVs)[1] to realize financial and environmental benefits for the residents and the government of Arlington County, Virginia. While many AEVs have purchase prices that are higher than comparable internal combustion engine (ICE) vehicles, AEVs are generally understood to have lower operational costs and emissions. The expected total cost of ownership (TCO)[2] of selected light-duty AEVs (sedans and SUVs) was compared to internal combustion engine (ICE) vehicles for both personal and government use in Arlington County[3]. In addition, the expected lifecycle emissions of light-duty AEVs was compared to ICE vehicles for the Arlington County vehicle fleet.

AEVs are expected to dramatically reduce well-to-wheel emissions[4] from the County's fleet of non-public safety sedans and SUVs, even when accounting for emissions due to electricity production. Replacing each of County's non-public safety sedans and SUVs with AEVs would reduce annual GHG emissions and criteria air pollutants from these vehicle classes by 66% and 98%, respectively.

For Arlington County fleet vehicles, AEVs are expected to realize significant lifetime financial savings in the Small SUV vehicle class (19% lower TCO) and to be essentially cost-neutral in the Sedan vehicle class (TCO within 2% of ICE vehicles). On average, County fleet AEVs would achieve 78% lower fuel/energy costs and 32% lower maintenance and repair costs compared to ICE vehicles. Note, however, that the calculation for government vehicles may be altered by a number of existing and future impacts including but not limited to: low purchase prices available to the County for ICE vehicles, relatively low expected annual mileage, potential state and federal tax incentives.

For privately owned light-duty vehicles in Arlington County, AEVs are expected to realize significant lifetime financial savings in almost every scenario. On average, privately owned AEVs were found to have a 17% lower TCO than comparable ICE vehicles. This calculation can be impacted by public charging for AEVs, which generally offers faster charging speeds than home charging but can be more than twice as expensive than home charging. When applicable, state

[1] All-Electric Vehicles (AEVs) are powered solely by electric energy stored in their battery. Plug-In Hybrid Electric Vehicles (PHEVs) may operate solely from battery power over moderate distances but use a gasoline engine. Electric Vehicles (EVs) include both AEVs and PHEVs.

[2] Total cost of ownership (TCO) is a comprehensive assessment of the overall cost of a product throughout its lifecycle, including purchase price and operational costs.

[3] The TCO analyses for the County vehicle fleet and for privately owned vehicles are based on different assumptions of costs and vehicle use, and are not directly comparable.

[4] Well-to-wheel emissions include all emissions related to fuel production, processing, distribution, and use.

and federal tax incentives will provide financial savings that are nearly equal to those from all other categories combined.

For both County fleet and privately owned vehicles in Arlington County, the greatest potential financial savings from AEVs is expected to come from reduced fuel/energy costs and maintenance and repairs, both of which accrue with vehicle use over time. To maximize the financial benefits that are possible with AEVs, the County government and local residents should choose an AEV with a lower purchase price, take full advantage of state and federal tax credits, charge at home whenever possible, and utilize the AEV more often and over a longer period of time.

Introduction

In recognition of the planet's climate crisis, Arlington County (VA) updated its Community Energy Plan (CEP) in 2019, setting the goal of becoming carbon neutral for County operations by 2035 and countywide by 2050. The plan calls for a reduction in carbon emissions from the transportation sector in Arlington County by 81% between 2020 and 2050. The primary strategies the County is pursuing to achieve this goal are decarbonizing the County government vehicle fleet (Arlington will consider alternative fuel sources beyond electrification, particularly for its bus fleet), promoting AEV deployment in the community, strategizing installations of electric vehicle supply equipment (EVSE), and continuing to encourage the community to limit automobile usage. Two other planning efforts are happening alongside this report - a Carbon Neutral Transportation Master Plan and a Zero Emissions Bus Study.

A diversified transportation fuel/power portfolio provides an important opportunity to significantly reduce GHG emissions from the transportation sector. The CEP found that approximately 25% of greenhouse gas (GHG) emissions registered in Arlington County are produced by transportation within County boundaries, and an additional 12% of GHG emissions comes from transportation that passes through the County[5].

In support of the implementation of the CEP's transportation goals, this report provides analysis to facilitate County government and private citizens in transitioning to electric vehicles. This includes a high-level market assessment, an examination of the County's current vehicle fleet, estimates of emissions benefits from transitioning the County fleet to AEVs, and total cost of ownership forecasts for the most common vehicles throughout the community and the County fleet.

The information and analyses of this report will encourage the adoption of AEVs in Arlington County by highlighting the environmental and financial benefits of transitioning to AEVs, and addressing barriers that can limit their widespread adoption.

[5] The Commonwealth of Virginia signed a Statement of Support for the Regional Transportation & Climate Initiative-Program (TCI-P) to explore regional cooperation in reducing vehicle GHG emissions, potentially up to 26% by 2032. https://www.transportationandclimate.org/sites/default/files/TCI%20Next%20Steps%2012.20.pdf

It is important to note that while this report analyzes the total cost of owning several types of electric vehicles within the County fleet and the private sector, the reader should not make a strong comparison between the fleet vehicle and private vehicle analyses. Factors that affect the cost of owning a fleet vehicle are very different than those that affect the cost of owning a personal vehicle.

Benefits of Transportation Electrification

Among sedans and SUVs, all-electric vehicles (AEVs) produce significantly less GHG emissions than comparable gasoline-powered, internal combustion engine (ICE) vehicles, even when accounting for GHG emissions produced in electricity generation[6]. They provide significant ancillary benefits as discussed below.

Emissions Reduction: AEVs reduce tailpipe criteria pollutants and GHG emissions. Dominion Energy estimates that transitioning to an AEV from a typical gasoline-powered passenger vehicle in Virginia can reduce carbon emissions by as much as 66%[7]. As Virginia moves to cleaner electricity sources, EV lifecycle emissions will continue to decrease.

Hazardous Air Pollutant Reduction: AEVs reduce hazardous air pollutant emissions, which correlates to improved air quality and reduced negative health impacts of pollution[8].

Reduced Vehicle Maintenance: AEVs do not have an internal combustion engine and therefore do not require routine oil, filter, and timing belt changes, which saves on labor and parts. AEVs use regenerative braking to recapture power, minimizing brake wear and replacement.

Lower Fuel Costs and Price Volatility: Electricity supplies are relatively stable, and the steadier prices can make budgeting for operation costs easier and more reliable.

Lower Noise Pollution: AEVs operate more quietly than gasoline- or diesel-powered vehicles, providing a benefit to employees, the community, and the environment.

Decreased Road Pollution and Wear: Passenger AEVs do not contain fuel, motor oil and other toxic fluids that leak onto roads, and have lower operating engine temperatures than comparable ICE vehicles, allowing for less wear-and-tear on roads.

[6] US Department of Energy. Emissions from Electric Vehicles, State Averages for Virginia. Accessed September 2022. https://afdc.energy.gov/vehicles/electric_emissions.html.
[7] Dominion Energy. EV Carbon Calculator. https://dominionenergy.chooseev.com/carbon/.
[8] US Department of Energy. Emissions from Electric Vehicles. https://afdc.energy.gov/vehicles/electric_emissions.html

Market Assessment

Types Of Electric Vehicles

Light-duty plug-in electric vehicles (EVs) fall into two main categories – all-electric vehicles (AEVs), and plug-in hybrid electric vehicles (PHEVs). Electric vehicles have roots in the early stages of automobile development [9] but did not receive serious interest from modern automobile manufacturers until the 1970s energy crisis. More viable commercial options began to appear around 2010, and the commercial availability of new vehicles in both categories has grown significantly since that time, driven by significant advances in battery technology, increased concerns about oil prices and supply, interest in reducing transportation greenhouse gas emissions, and the driving performance of EV models.

Since 2010, over 2.3 million AEVs and PHEVs have been sold in the United States. In the first half of 2021, they represented 2.4% of all new-vehicle registrations. Nearly every major automobile manufacturer in the world is focusing future production on AEVs and PHEVs (see *Current EV Trends),* and they are quickly approaching mainstream adoption.

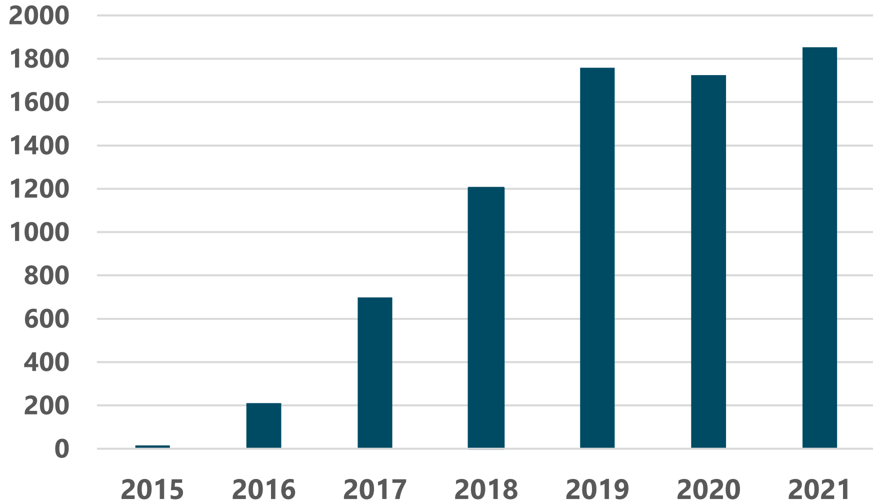
In Arlington County, electric vehicles registrations have risen exponentially since 2015, when there were less than twenty (20) AEV and PHEV registrations combined[10]. Currently, there are 11 EVs per 1,000 people in Arlington County, significantly higher than the state and national average[11].

[9] The first viable electric vehicle model launched in the late 1880s, and by 1900-1912, one third of all vehicles on the road were electric vehicles. https://www.energy.gov/timeline/timeline-history-electric-car.

[10] Atlas EV Hub. State EV Registration Data. https://www.atlasevhub.com/materials/state-ev-registration-data/

[11] Drive Electric VA. EV Dashboard. **https://driveelectricva.org/why-drive-electric/ev-dashboard**. The Virginia statewide average is 3.6 EVs per 1000 people (June 2022, see https://afdc.energy.gov/data/10962) ; and the national average calculated in 2020 at 5.2 EVs per 1000 people, see **https://www.statista.com/statistics/1256609/electric-cars-per-population-worldwide/**

Figure 1: Arlington County (VA) Combined AEV and PHEV Vehicle Registrations by Year[12]



All-Electric Vehicles

All-Electric Vehicles (AEVs) are powered exclusively by an electric powertrain. Equipped with significantly larger batteries than PHEVs, AEVs offer a greater range between charges. An important benefit of AEVs, over both conventional gasoline-powered vehicles and PHEVs, is lower maintenance costs due to the absence of many components related to internal combustion engines. A recent study found that scheduled maintenance costs for AEVs are 40% lower than for conventional gasoline-powered vehicles.[13]

As of September 2022, there were at least 32 AEV models available in the US market, from both traditional automobile manufacturers (Hyundai, Audi, Nissan, Chevy, Volvo, Mini, Porsche, Jaguar, Ford, Kia, BMW) and new AEV-only manufacturers (Tesla, Polestar, Rivian, Lucid Motors). Tesla has long been the leading seller of AEVs, with over 2/3 of AEVs sold since 2018, but its market share has recently declined with the proliferation of competing options.

[12] Atlas EV Hub. State EV Registration Data. https://www.atlasevhub.com/materials/state-ev-registration-data/
[13] US Department of Energy. 2021. Vehicle Technologies Office. https://www.energy.gov/eere/vehicles/articles/fotw-1190-june-14-2021-battery-electric-vehicles-have-lower-scheduled

Table 1. Summary of Specifications for Commercially Available New AEVs in the US, 2022[14]

	Highest Spec	Lowest Spec
Battery Range	516 miles	100 miles
Battery Size	205 kWh	33 kWh
Efficiency	4.41 miles / kWh	1.56 miles / kWh
Price (MSRP)	$154,000+	$27,800

Plug-In Hybrid Electric Vehicles

Plug-in Hybrid Electric Vehicles (PHEVs) have both an electric motor and an internal combustion engine. The primary distinguishing characteristic of PHEVs from other hybrid style is their batteries can be charged by plugging the vehicle in and they can travel from 10-80 miles on the battery before the gasoline engine would need to turn on to provide extended range. The primary benefit of PHEVs is they offer gasoline-independence for relatively short distances while also being suitable for long-distance travel between charges. Due to their ability to run on gasoline, they are especially helpful in areas with limited public charging availability.

As of September 2022, there were over 30 PHEV models available in the US market, from both domestic (Ford, Chrysler, Lincoln) and foreign manufacturers (Hyundai, Kia, Toyota, Porsche, Volvo, Audi, Subaru, BMW, Bentley, Land Rover, Ferrari). Vehicle types range from small sedans to large SUVs and are available in wide variety of features and price points. The table below summarizes the specifications for commercially available PHEVs in the U.S. in 2022. See Appendix 3 for a full listing of available vehicles.

Table 2. Summary of Specifications for Commercially Available New PHEVs in the US, 2022[15]

	Highest Spec	Lowest Spec
Battery Range	61 miles	9 miles
Battery Size	28 kWh	8 kWh
Efficiency	2.9 miles / kWh	1.13miles / kWh
Price (MSRP)	$145,000+	$25,590

[14] EVAdoption.com. AEV Models Available in the USA. Accessed September 2022. https://evadoption.com/ev-models/AEV-models-currently-available-in-the-us/

[15] EVAdoption.com. PHEV Models Available in the USA. Accessed September 2022. https://evadoption.com/ev-models/available-phevs/

EV Charging Infrastructure

Current EV charging technologies require a fundamental shift in how EV drivers access energy for their vehicles. Most EV drivers do 80% or more of their charging at home and/or workplaces (when charging is available).[16] These locations offer greater convenience and lower pricing than most public charging options. However, residential charging can be a challenge for those living in multifamily housing, those in urban areas without a dedicated parking space, and renters, who may be reluctant (or not permitted) to install equipment at a home they do not own. As such, the availability of public charging in Arlington County is critical to provide options for people who may not be able to charge at home or work, and to enable longer-distance travel.

EV charging is enabled through electric vehicle supply equipment (EVSE), which currently comes in three distinct levels:

1. **Level 1** – Level 1 charging uses the same 120-volt power found in standard household outlets and can be performed using equipment provided by EV automakers. Making this type of charging available can be as simple as using existing 120-volt outlets within 20 feet of vehicle parking. Level 1 charging typically adds 3-5 miles of range per hour of charging, so it may not be suitable for EV drivers traveling more than 50 miles per day, or those with longer range AEV models. A US Energy Information Administration (EIA) survey estimates about half of homes in New England have access to a 120-volt outlet within 20 ft of where their vehicle is parked.[17]
2. **Level 2** – Level 2 charging uses 240-volt power to enable faster charging, usually offering 10-20 miles of range per hour of charging. Level 2 charging requires installation of an EVSE unit or 240V receptacle a Level 2 EVSE can plug into. One potential barrier to accessing Level 2 charging is that older homes may not have adequate electric service or panel capacity to support an additional 240V circuit without a load management device or panel upgrade.
3. **Level 3 (also known as DC Fast Charging)** – DC fast charging provides compatible vehicles with an 80% charge in 30-60 minutes by converting high voltage AC power to DC power for direct storage in EV batteries. Because it is much more expensive to install and operate, fees associated with DC fast charging tend to be much higher than for Level 1 or Level 2 charging.

Note that public-access charging infrastructure is typically comprised of Level 2 and DC fast chargers, which offer faster speeds but higher prices than Level 1 residential charging.

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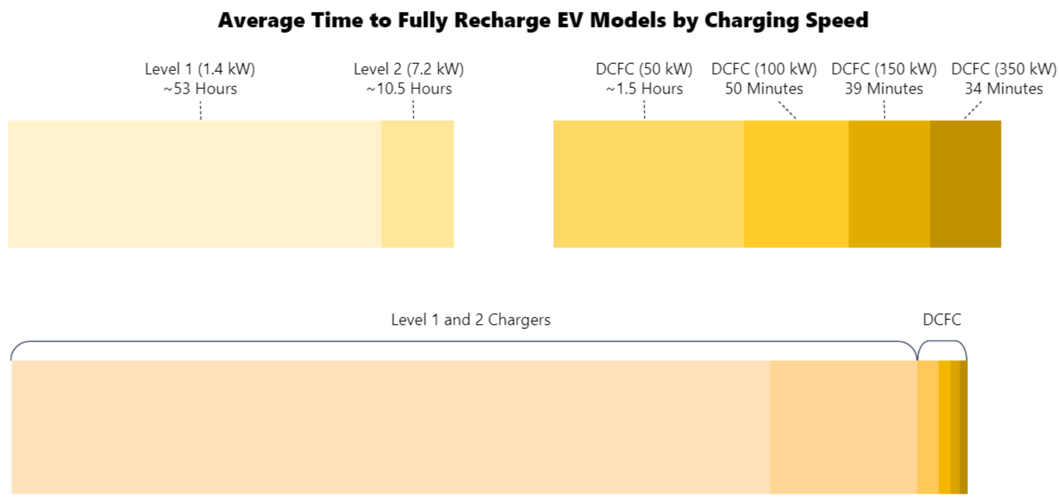
[16] NREL. National Plug-in Electric Vehicle Infrastructure Analysis. Sept 2017. https://www.nrel.gov/docs/fy17osti/69031.pdf
[17] US EIA. 2015 Residential Energy Consumption Survey (RECS). May 2018. https://www.eia.gov/consumption/residential/data/2015/hc/php/hc2.7.php

Figure 2 and Figure 3, below, show how types of EVSE differ and includes illustrations of the various plug shapes. All automakers except Tesla have standardized Society of Automotive Engineers (SAE) J-1772 plug connector for Level 1 and 2 charging. Tesla uses their own proprietary plug design, but they do have adapters available for Tesla drivers to plug into J-1772 equipment.

Figure 2. Time to fully recharge EV models by charger capacity[18]



For DC fast charging, most automakers use a variation on the J-1772 connector called the SAE combined charging system (CCS). Nissan and Mitsubishi have used a different fast charging standard called CHAdeMO, but Nissan has indicated future vehicles will be moving to the SAE CCS standard for fast charging. Tesla also has an adaptor that allows drivers to use CHAdeMO equipment and has announced a SAE CCS adapter that is expected to be available in the near future. Importantly, there are no adapters available now that would allow non-Tesla drivers to access Tesla fast charging locations - commonly referred to as Superchargers. Tesla has suggested they will open their network to other EV owners in the future and has started to pilot this capability in Europe.

[18] Recharge time is based off the average battery size of new model battery electric vehicles. Time estimates do not include tapering charge.

Figure 3. Electric Vehicle Charging and Plug Types

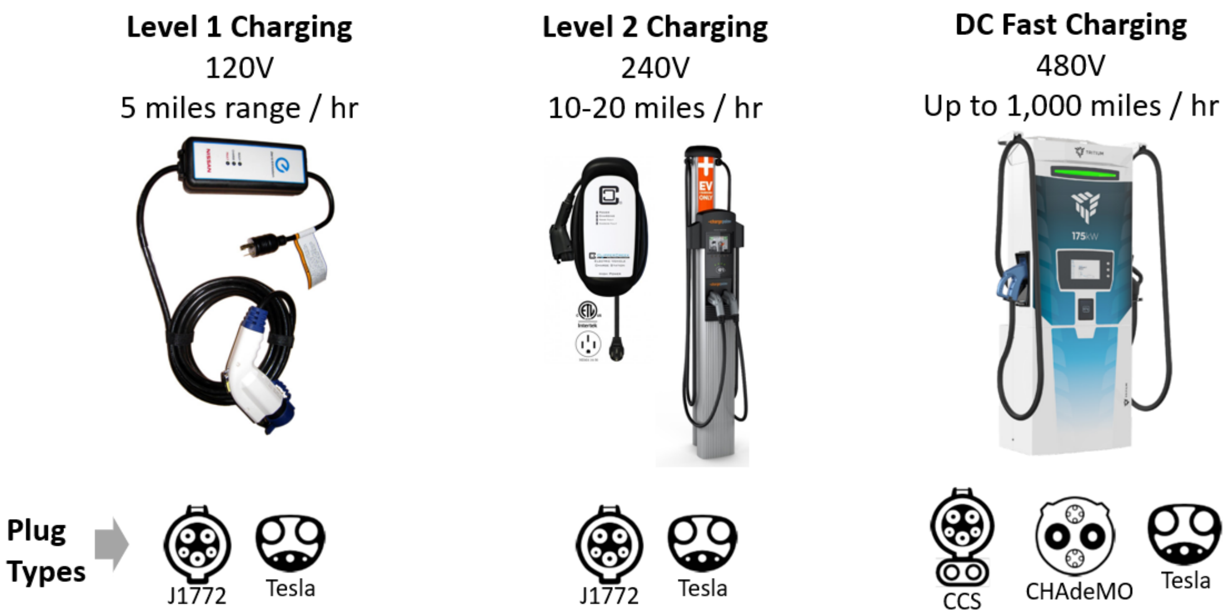


Table 3. Median EVSE Capital Costs from Recent Installations[19]

Charger Type	Labor & Supplies	EVSE Equipment	Total Cost per Port
Level 2 (residential)	$1,300	$550	$1,900
Level 2 (public)	$2,500	$3,500	$6,000
Level 3 DCFC 50 kW (public)	$20,000	$40,000	$60,000
Level 3 DCFC 150 kW (public)	$60,000	$90,000	$150,000

Table 3 shows median EVSE costs from a study of over 1,300 Level 2 and Level 3 installations in the United States (not including incentives or rebates)[20]. Level 1 chargers, which plug into standard 120V outlets, were not included in this study - they often come free with compatible vehicles and can be replaced for as little as $300. The cost to purchase and install Level 2 or Level 3 equipment generally increases in proportion to charging speed and is more expensive in commercial than residential applications. Note that costs can vary widely depending on site characteristics, and the quantity and type of equipment. As EVSE has become more prevalent, equipment prices and installations costs have decreased.

[19] Borlaug, B., et al. Levelized Cost of Charging Electric Vehicles in the United States. Joule, Volume 4, Issue 7, 2020. Accessed September 2020. https://www.sciencedirect.com/science/article/pii/S2542435120302312.
[20] Ibid.

Arlington County Fleet Vehicles

Existing County Fleet Composition and Usage

Data on Arlington County's existing vehicle fleet was provided by the Equipment Bureau of the Department of Environmental Services, which provides fleet management services for County Government and Arlington Public School (APS) vehicles (hereafter, "County fleet"). While individual departments and APS pay for their own vehicles, the Equipment Bureau provides a full suite of vehicle services that includes procurement, maintenance, repair, and disposal.

County Fleet Composition

As of July 2022, there were 1,173 vehicles and 88 unique combinations of vehicle make, model and end-uses under management by the Equipment Bureau. For the purposes of both emissions and total cost of ownership analysis, it is useful to categorize County fleet vehicles in two ways.

First, the vehicles are split into seven (7) vehicle classes, corresponding to the classifications used in the Carbon Neutral Transportation Master Plan. These vehicle classes are based on EPA regulatory classifications. Within each vehicle class, vehicles are expected to have roughly comparable characteristics, emissions, and costs. Table 4 shows the six (6) light-duty vehicles classes (LDV) and one (1) medium/heavy-duty vehicle class (M/HDV) used to categorize vehicles in this analysis.

Table 4. Vehicle Class Definitions

Vehicle Class	Type	Notes
Sedan	LDV	
Small SUV	LDV	Two-wheel drive SUVs under 6,000 pounds GVW
Standard SUV	LDV	Four-wheel drive SUVs under 6,000 pounds gross vehicle weight (GVW)[21] and all SUVs over 6,000 pounds GVW (including both two- and four-wheel drive SUVs)
Pickup	LDV	
Motorcycle	LDV	
Minivan/Van	LDV	
Medium/Heavy-Duty	M/HDV	Includes five body types: Refuse Truck; School Bus; Other Class 8 Truck; Delivery; Fire Truck

[21] Gross Vehicle Weight (GVW) is defined as the combined weight of the vehicle, passengers, and cargo for a fully loaded vehicle

Second, the vehicles owned and operated by public safety departments – the Police Department, Fire Department, and Sherriff's Department – are distinguished from vehicles that are owned and operated by non-public safety departments. As will be shown in the following section, public safety vehicles have distinct vehicle characteristics, use patterns, and maintenance schedules that warrants partitioning them from the emissions and total cost of ownership analysis in this report.

Table 5, below, shows the composition of the County fleet by vehicle class and designation. Overall, non-public safety vehicles makeup more than 2/3 (69%) of all vehicles. Analyzed by vehicle class, light duty vehicles predominate: 93% of public safety vehicles and 63% of non-public safety vehicles are in one of the six light-duty vehicle classes.

Table 5. County Vehicle Fleet Inventory By Vehicle Class and Designation, 2021

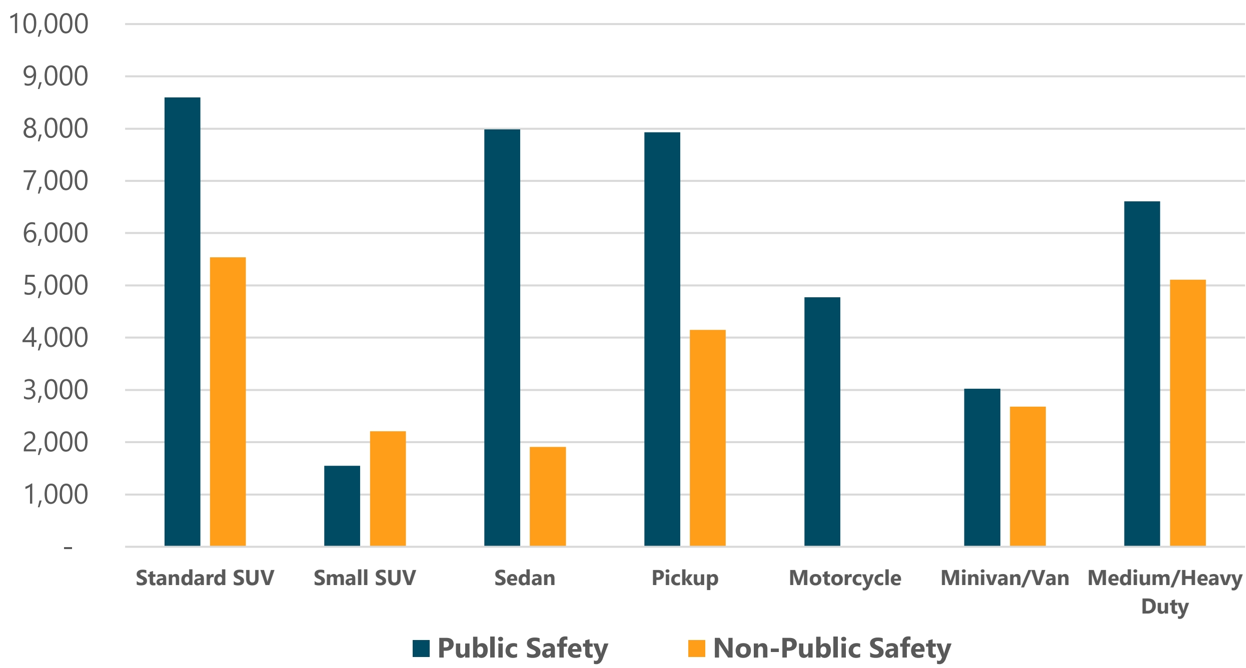
Vehicle Class	Designation		CY2021 Total
	Public Safety	Non-Public Safety	
Sedan	49	106	155
Small SUV	17	98	115
Standard SUV	216	13	229
Pickup	31	158	189
Motorcycle	16	0	16
Minivan/Van	12	137	149
Medium/Heavy-Duty	25	295	320
TOTAL	***366***	***807***	***1173***
% of All County Vehicles	**31%**	***69%***	***100%***
% Light Duty	**93%**	***63%***	***72%***

The distribution of vehicles across vehicle classes varies significantly between vehicle designation. For example, public safety departments own 94% of Standard SUVs while non-public safety departments own 92% of Medium/Heavy-Duty vehicles. This variation across vehicle classes indicates that the source and magnitude of vehicle emissions differs greatly between public safety and non-public safety vehicles.

County Vehicle Usage

Vehicle usage is another factor that influences emissions and total cost of ownership, and in which public safety and non-public safety fleets differ considerably. Vehicles that are utilized more often will tend to have higher annual costs due to increase fuel/energy use, maintenance, and repairs. All other things being equal, they will also produce more emissions on an annual basis than vehicles that are used less. Figure 4 shows that in nearly every vehicle class, with the exception of Small SUVs, public safety vehicles have higher median annual mileage than non-public safety vehicles.

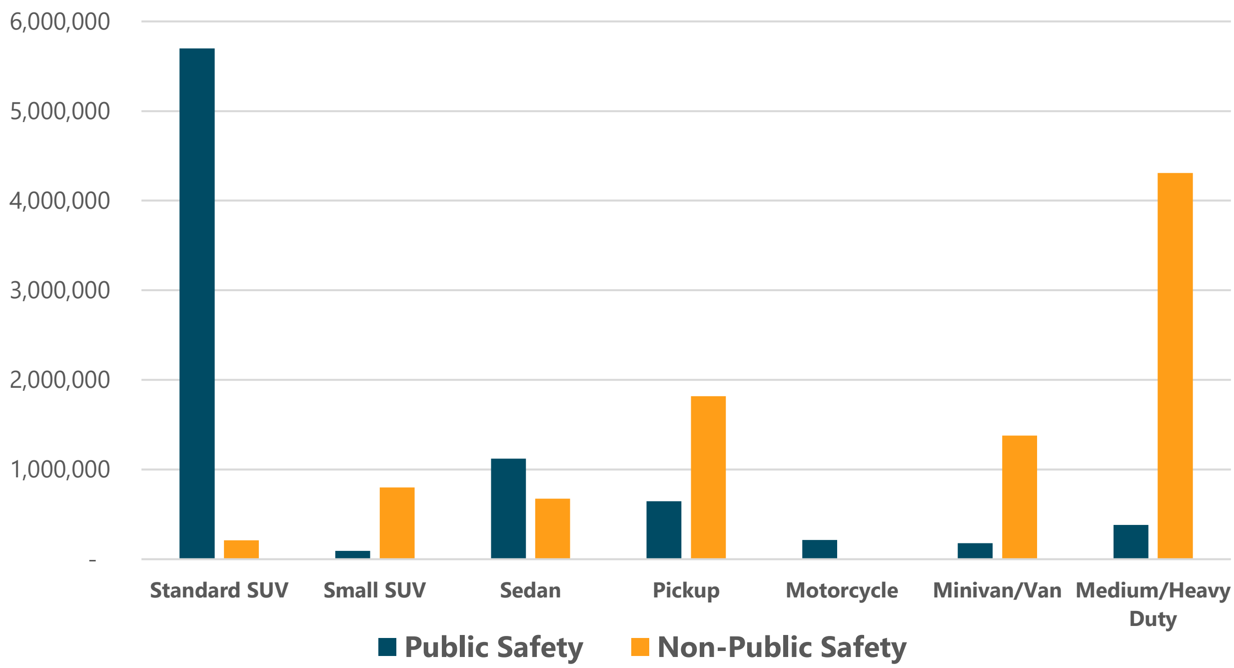
Figure 4. Median Annual Vehicle Miles Travelled by Vehicle Class and Agency, 2019 to 2021



The contribution of public safety and non-public safety vehicles to total vehicle miles looks very different. From 2019 to 2021, County vehicles accumulated 17,530,234 total vehicle miles travelled. These are essentially evenly split between public safety and non-public safety agencies, with 52% of total vehicle miles travelled attributable to non-public safety vehicles.

However, Figure 5 (below) shows that overall vehicle usage varies according to vehicle class and designation. For example, vehicles in the Standard SUV vehicle class account for 68% of vehicle miles travelled among public safety vehicles, but only 2% of vehicle miles travelled among non-public safety vehicles. Likewise, vehicles in the Medium/Heavy Duty vehicle class account for 47% of vehicle miles travelled among non-public safety vehicles, but just 5% of vehicle miles travelled among public safety vehicles. Note that among non-public safety vehicles, the Medium/Heavy Duty vehicle class includes 195 school buses out of 295 total vehicles (see Table 5).

Figure 5. Total Vehicle Miles Travelled by Vehicle Class and Agency, 2019 to 2021 (3 years)[22]



Non-Public Safety Vehicles

The previous section describes significant differences in composition and usage between public safety and non-public safety vehicles in the County fleet. The focus of the remainder of this report's coverage of the County fleet is on non-public safety vehicles.

The number of vehicles, type of vehicles, and vehicle miles travelled are key inputs to fleet-level emissions and financial considerations. As described in the previous section, non-public safety vehicles make-up 69% of all vehicles in the County fleet and are responsible for 52% of all vehicle miles travelled among County fleet vehicles. Among non-public safety vehicles only, SUVs and Sedans makeup 27% of all vehicles and 18% of vehicle miles travelled (Figure 6, below). Table 6 shows this information for each vehicle class.

Table 6. Classes of Non-Public Safety Vehicles and Vehicle Miles Travelled (VMT), 2021

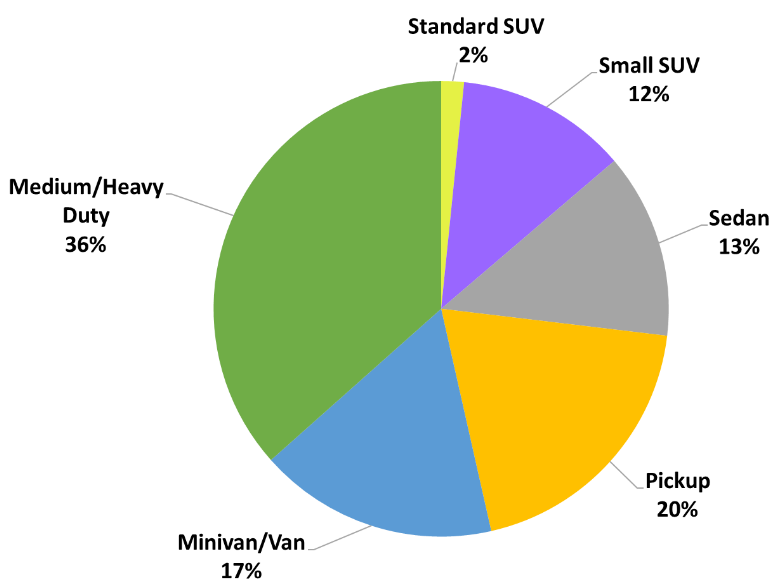
Vehicle Class	Number of Non-Public Safety Vehicles	% of Non-Public Safety

[22] In the non-public safety designation, Medium/Heavy Duty vehicles include 195 schools buses out of 295 total vehicles.

		VMT (2019-2021)
Sedan	106	7%
Small SUV	98	9%
Standard SUV	13	2%
Pickup	158	20%
Motorcycle	0	0%
Minivan/Van	137	15%
Medium/Heavy Duty*	295	47%
Total	807	100%

** Medium/Heavy Duty Vehicles include 195 school buses.*

Figure 6. Non-Public Safety Vehicle Inventory by Vehicle Class, 2021



While SUVs and Sedans makeup a small portion of non-public safety vehicles and the overall County fleet, they are important vehicle classes for the County to focus on in relation to transportation electrification goals. The primary reason, as described in the Market Assessment, is that these vehicle classes have the broadest and most mature commercially available electric vehicle offerings. Additionally, in general, the purchase price of SUVs and Sedans will be less than those of larger vehicle classes, which include some of the most specialized and expensive types of vehicles (school buses, street sweepers, etc.). As shown in Table 7, as of the end of 2021, there were ten (10) all-electric vehicles among non-public safety vehicles in the County fleet - all of which are all-electric Nissan Leaf sedans[23].

Table 7. Fleet Makeup of Non-Public Safety Vehicles by Fuel Type and Vehicle Class, 2021[24]

Vehicle Class	Gasoline	Diesel	Plug In Hyb (PHEV)	All-Electric (AEV)
Sedan	95	0	1	10
Small SUV	98	0	0	0
Standard SUV	13	0	0	0
Pickup	109	48	1	0
Minivan/Van	105	32	0	0
Medium/Heavy Duty	0	295	0	0
All Non-Public Safety Vehicles	420	375	2	10
Percentage of Non-Public Safety Vehicles	52%	46%	0.2%	1.2%

Vehicle Replacement Policy

Vehicle replacement policies are an important consideration affecting the County's progress towards reducing its vehicle fleet's emissions. Because of continuing technological advancements and increasingly stringent regulations, older vehicles tend to be more polluting than newer ones. Thus, replacing older and more polluting vehicles can be part of a strategy to accelerate emissions reductions in a fleet of vehicles. Fuel types also play a big role in types and levels of pollution. The large number of County-owned diesel fueled vehicles emit more greenhouse gas emissions and other pollutants than gas fueled vehicles.

The Equipment Bureau's current approach to vehicle replacements accounts for vehicle class, age, and mileage. The general standard for light-duty vehicles (SUVs, Sedans, Pickups, Minivans/Vans) is to consider replacement after 9 years and 50,000 miles. If a vehicle has not reached 50,000 miles after 9 years in service, it may be reconsidered and its useful life extended. Medium/Heavy Duty vehicles, many of which are special-purpose vehicles with unique and specific duty cycles, follow different procedures for replacement, but generally have a longer useful life than light-duty vehicles.

[23] 18 additional AEVs were purchased by the County in 2022, including Sedans, Pickups, and Minivan/Vans, and future purchases are planned. About 5% of non-public safety light-duty vehicles are AEVs, including 19% of Sedans.
[24] Ibid.

Table 8, below, shows the non-public safety light-duty vehicles that are currently at or above replacement age, as defined above (as of September 2022). Overall, 49% of non-public safety light-duty vehicles are at or above replacement age. Sedans are the oldest vehicle class, with 66% of these vehicles exceeding the typical replacement thresholds. Among Sedans and SUVs, there are 108 vehicles ready for replacement at the time of this report. Note that many vehicles included in this category have been deferred for replacement because they have not exceeded 50,000 miles.

Table 8. Non-Public Safety Vehicles At or Above Replacement Age by Vehicle Class, 2021

Vehicle Class	# of Vehicles At Or Above Replacement Age	% of Vehicles in Vehicle Class
Sedan	70	66%
Small SUV	34	35%
Standard SUV	4	31%
Pickup	72	46%
Motorcycle	0	-
Minivan/Van	77	56%
Total	392	49%

Moving forward, emissions impacts should be considered in vehicle replacement decisions in order to accelerate the County's progress towards meeting the transportation decarbonization goals. From this perspective, high-mileage and low fuel-economy vehicles should be prioritized for replacement with AEVs where viable market offerings exist – namely, Sedans, Small SUVs, and Standard SUVs. Medium/Heavy Duty vehicles, while they typically have the highest per-unit emissions, are difficult to prioritize for replacement due to high capital costs and low availability of market offerings (among some vehicle types). This will change to some extent over time. In addition, the County may consider practical strategies toward reducing the number of assigned fleet vehicles in favor of vehicle pooling, especially in a post-COVID world where remote meeting platforms and other technologies allow for reduction of VMT. Fleet reductions, where feasible, offer the ability to reduce not simply tailpipe emissions, but emissions embedded in the production, distribution, and powering processes.

County Fleet Emissions Analysis

The 2019 Arlington County Community Energy Plan calls for a significant reduction in greenhouse gas (GHG) emissions from the transportation sector. This section explores the potential emissions reductions from replacing County fleet Sedans and SUVs with all-electric vehicles (AEVs), using the most recent year of service data (2021).

Table 9, below, provides a baseline estimate of 2021 GHG emissions for the County fleet's non-public safety Sedans and SUVs. Emissions were estimated utilizing the Department of Energy's AFLEET emissions tool[25]. Average fuel economy for each vehicle class was calculated using EPA estimates for each make, model and year in the County fleet[26], and weighting the results by vehicle miles travelled. Emissions estimates associated with the electricity use of plug-in hybrid and all-electric vehicles were based on the sources of electricity generation specific to the mid-Atlantic region, which are provided by the AFLEET model. In total, these three vehicle classes emitted 452,000 lbs of GHGs in 2021, with Small SUVs being the largest contributor.

Table 9. GHG Emissions of Non-Public Safety Sedans and SUVs, 2021

Vehicle Class		ICE (Gasoline and Hybrid)	All-Electric (AEV)	Vehicle Class Total
Sedan	Number of Vehicles	96	10	106
	Vehicle Miles Travelled (VMT)	185,834	3,814	189,648
	Average Fuel Economy (MPGGE[27])	33	112	35[28]
	GHG Emissions Factor (lbs/mile)	0.766	0.284	0.757
Small SUV	Number of Vehicles	98	-	98
	Vehicle Miles Travelled (VMT)	236,695	-	236,695
	Average Fuel Economy (MPGGE)	25	-	25
	GHG Emissions Factor (lbs/mile)	0.937	-	0.937
Standard SUV	Number of Vehicles	13	-	13
	Vehicle Miles Travelled (VMT)	78,074	-	78,074
	Average Fuel Economy (MPGGE)	21	-	21
	GHG Emissions Factor (lbs/mile)	1.110	-	1.110

To estimate the GHG reductions that would result from converting the County fleet's non-public safety Sedans and SUVs to all-electric vehicles, it's useful to begin by comparing the expected emissions rates between gasoline/hybrid vehicles and all-electric (AEV) models. Table 9, above,

[25] US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

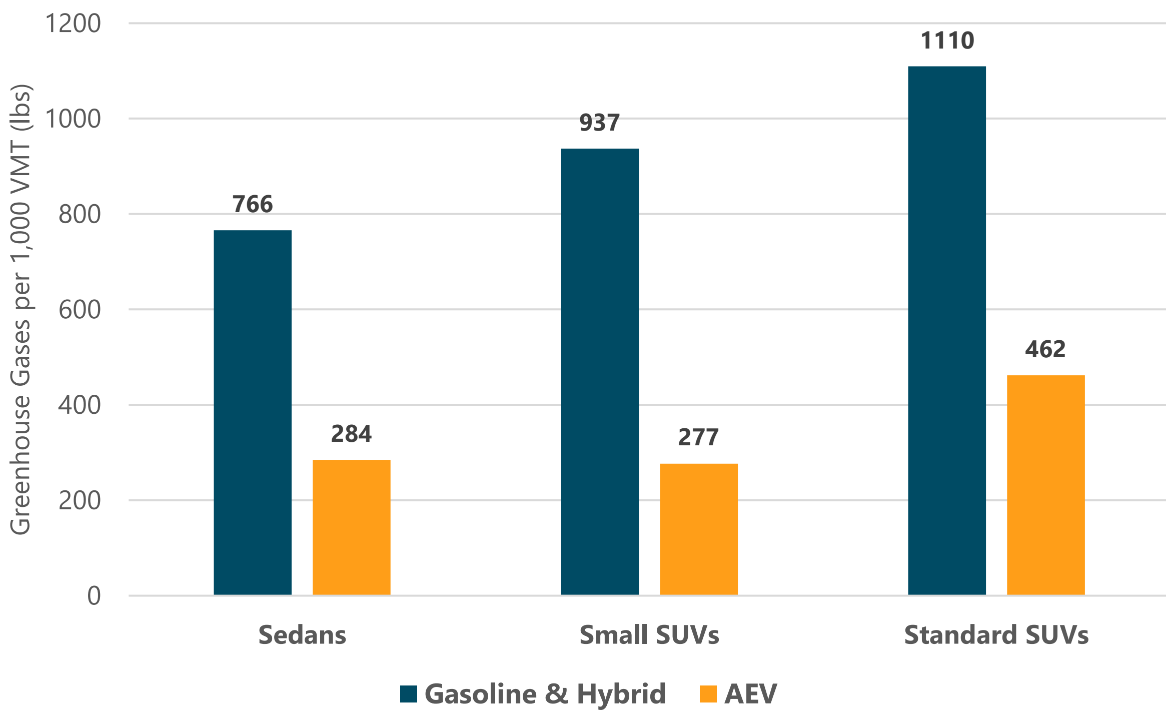
[26] US Environmental Protection Agency. FueEconomy.Gov. Accessed September 21, 2022. https://www.fueleconomy.gov/feg/epadata/emissions.csv.

[27] Miles per gallon of gasoline equivalent

[28] The average fuel economy for all Sedans weights each vehicle by vehicle miles travelled. Gasoline and Hybrid vehicles account for the vast majority of VMT in the Sedan class.

indicates that among County fleet Sedans in 2021, per-mile GHG emissions from AEVs were 59% lower than gasoline/hybrid vehicles. While the County fleet does not include any AEVs in the Small SUV and or Standard SUV vehicle classes, data from representative AEV models can be compared to the 2021 GHG emissions estimates for these vehicle classes. For this purpose, the Chevy Bolt EUV and the Rivian R1S are chosen as comparison AEVs for the Small SUV and Standard SUV classes, respectively (these same vehicles will also be used in the total cost of ownership analysis). Figure 7, below, shows the expected per-mile GHG emission rates of gasoline/hybrid and all-electric vehicles, using County fleet data from 2021 and EPA fuel economy estimates for the comparison vehicles described above.

Figure 7. Expected GHG Emissions per 1,000 miles, Non-Public Safety Vehicles, Gasoline/Hybrid Vehicles Compared to AEVs



AEVs are expected to emit 59% to 70% less GHGs per-mile than the County fleet's current gasoline/hybrid vehicles in the Sedan and SUV vehicle classes. As expected, gasoline/hybrid vehicle GHG emissions increase with vehicle size, with Standard SUVs having the highest per-mile GHG emissions. However, this pattern does not hold for the AEV vehicle classes. The particular AEV chosen for the Small SUV class, the Chevy EUV, happens to have a slightly more efficient EPA fuel economy rating than the existing AEVs in the Sedan vehicle class. The percentage of GHG improvement with AEVs instead of ICE vehicles, will continue to drop as our local electric grid becomes cleaner.

The results above can be extended to give a more complete picture of the expected GHG emissions benefits of all-electric vehicles. Converting the County's non-public safety Sedans and

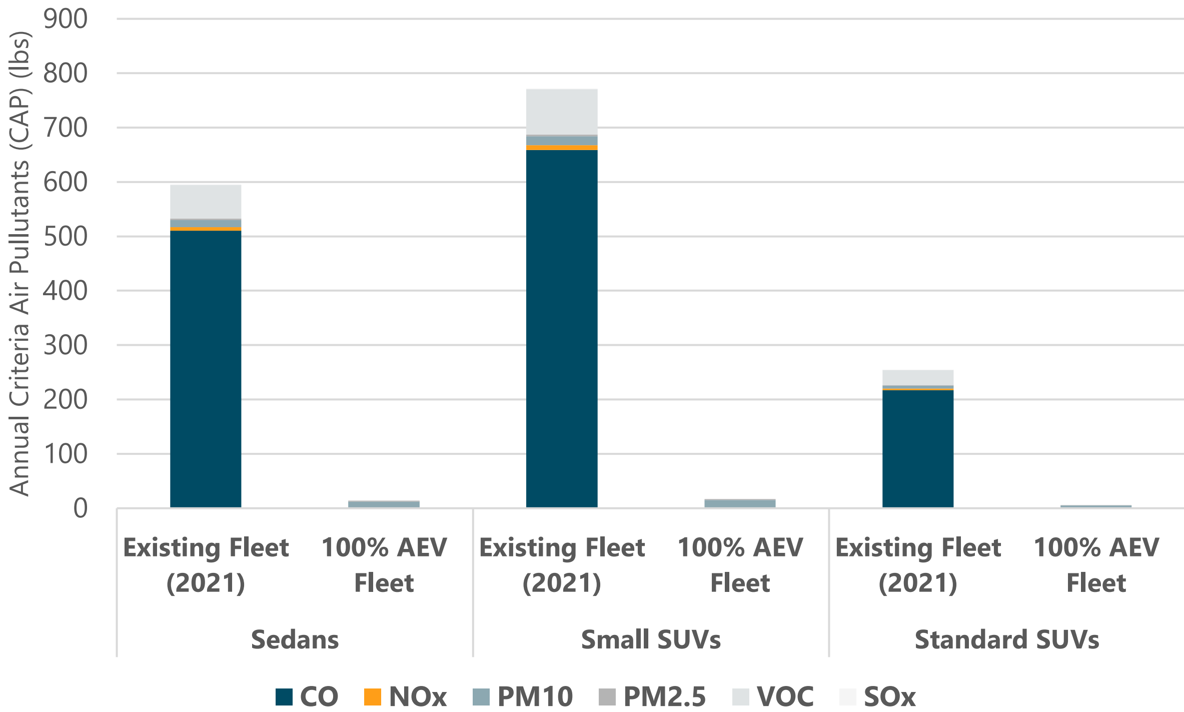
SUVs to all-electric vehicles is expected to reduce GHG emissions from these vehicle classes by 66% annually. As shown in Table 10, below, this estimate is derived by comparing the 2021 emissions in each vehicle class (Table 9) to the expected emissions from a 100% all-electric fleet (Figure 6).

Table 10. Expected Annual GHG Emissions, Non-Public Safety Vehicles Compared to 100% AEVs

Vehicle Class	Annual GHG Emissions (lbs)		
	Existing Fleet (2021)	100% AEV Fleet	% Reduction
Sedan	143,469	53,943	62%
Small SUV	221,800	65,568	70%
Standard SUV	86,628	36,046	58%
TOTAL	451,897	155,557	66%

AEVs will also considerably decrease criteria air pollutants (CAPs) such as nitrogen oxides (NO_x), particulate matter (PM_{10} and $PM_{2.5}$) and volatile organic compounds (VOC) compared to gasoline-powered vehicles (Figure 8). Replacing all of the County fleet's Sedans and SUVs with all-electric models should reduce CAPs by approximately 98%. Note that tire and brake wear produce particulate matter emissions (PM10, PM2.5) for all vehicles.

Figure 8. Expected Annual Criteria Air Pollutants, 2021 County Fleet Non-Public Safety Vehicles Compared to 100% AEVs



Total Cost of Ownership Analysis for County Fleet

As indicated in the Market Assessment, the purchase price of new AEVs is often more than comparable ICE vehicles. However, AEVs tend to have lower annual operating and maintenance costs. This section compares the expected lifetime costs, or total cost of ownership (TCO), of AEVs and ICE vehicles for County fleet Sedans and SUVs.

For each of the three vehicle classes (Sedans, Small SUVs, and Standard SUVs), representative AEV and ICE vehicles were chosen for TCO comparison in consultation with the County's Equipment Bureau. For Standard SUVs, there is currently a dearth of available market options, and a more luxury vehicle was chosen out of necessity.

Table 11. Vehicles Compared in County Fleet TCO Analysis

Vehicle Class	ICE Vehicle	All Electric Vehicle
Sedan	Nissan Versa	Nissan Leaf
Small SUV	Ford Escape	Chevy Bolt EUV
Standard SUV	Chevy Suburban	Rivian RS1

Methodology

The total cost of ownership model used for County fleet vehicles considers six (6) factors:

- Purchase Price
- Fuel/Energy Costs
- Maintenance and Repairs
- Incentives
- Fees
- Resale Value

Arlington County provided fleet data from 2021 to inform the estimates for purchase price, fuel/energy costs, and maintenance and repairs. For each vehicle, an 11-year useful life was assumed. In each category, costs were levelized over the 11-year time period.

To estimate fuel/energy costs, annual mileage was based on the 2021 County fleet median for each vehicle class and EPA fuel economy estimates for each comparison vehicle were applied[29]. To account for differences between city and highway vehicle efficiency, the proportion of miles in each category was based on 2021 data collected by the Virginia Department of Transportation in Arlington County. The Equipment Bureau provided the average price paid for gasoline in July 2022.

For AEV's, a standard overnight charging strategy was assumed, with electricity rates defined by the County's participation in the Virginia Energy Purchasing Governmental Association's (VEPGA) purchase agreement with Dominion Energy on behalf of Virginia municipalities and counties. The electricity rates offered to the County under the VEPGA agreement are substantially lower than for typical residential or commercial customers[30].

The County is taking advantage of another local jurisdiction's contract rider for Chargepoint EVSE. Chargepoint is a leading manufacturer of electric vehicle charging equipment. Base prices, before configurations, range from $1,100 per unit for the most basic Level 1 charger to $36,720 for a DC fast charger unit rated at 62.5 kW. EVSE costs were not included in the TCO analysis for the County fleet for the following reasons: the County hasn't yet decided on a preferred ratio of chargers and charger types to AEVs; costs for different equipment types vary; installation criteria and costs vary so much from location to location; and costs to the County are affected by a variety of programs and funding sources are available to cover their purchase and operation of EVSE.

Maintenance and repair costs were based on data provided by the Equipment Bureau, which specified annual per-vehicle costs for ICE vehicles in each vehicle class in 2019 and 2020. AEV costs were estimated by applying a model developed by the Argonne National Laboratory of the US Department of Energy, which is based on a systematic analysis of light-duty vehicle datasets

[29] US Environmental Protection Agency. FueEconomy.Gov. Accessed August 2022.
[30] VEPGA Master Agreement. 2019. https://vepga.org/wp-content/uploads/2019/10/2019-VEPGA-Master-Agreement-with-attachments-and-letter.pdf

in the U.S.[31]. The Argonne model considers variations in maintenance and repair costs due to vehicle class, powertrain, vehicle age, and original MSRP. Note that maintenance costs for AEV fleet vehicles are a projection or estimate, while the maintenance figures for ICE vehicles are based on actual maintenance average costs per vehicle class.

The TCO for County fleet vehicles here does not apply any federal, state, or local rebate or tax-credit incentives that would be available to non-governmental entities. While the County is responsible for standard registration fees to the Department of Motor Vehicles, which vary by vehicle class, they are exempt from the DMV's Electric Vehicle Fee for AEVs.

The expected resale value of vehicles at the end of their useful life is based on a standard depreciation forecast used by the Department of Energy's AFLEET tool[32].

See Appendix 2 for additional details on the data and assumptions used in the TCO analysis for County fleet vehicles.

Results

Tables 12, 13, and 14, below, show the results of the TCO analysis for County fleet Sedans, Small SUVs, and Standard SUVs over an expected 11-year ownership/lifetime period.

Table 12. Expected Total Cost of Ownership, County Fleet Sedans, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle
	Nissan Versa	Nissan Leaf
Purchase Price	$16,250	$25,000
Fuel/Energy	$3,414	$906
Maintenance and Repairs	$11,967	$8,319
Incentives	$0	$0
Fees	$338	$338
Resale Value	-$3,598	-$5,535
TOTAL TCO	**$28,371**	**$29,028**

[31] Argonne National Laboratory, US Department of Energy. 2021. Comprehensive Total Cost of Ownership Quantifications for Vehicle with Different Size Classes and Powertrains. https://publications.anl.gov/anlpubs/2021/05/167399.pdf.
[32] US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Table 13. Expected Total Cost of Ownership, County Fleet Small SUVs, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle
	Ford Escape	Chevy Bolt EUV
Purchase Price	$25,758	$27,200
Fuel/Energy	$3,526	$725
Maintenance and Repairs	$14,015	$8,525
Incentives	$0	$0
Fees	$338	$338
Resale Value	-$5,703	-$6,022
TOTAL TCO	**$37,935**	**$30,767**

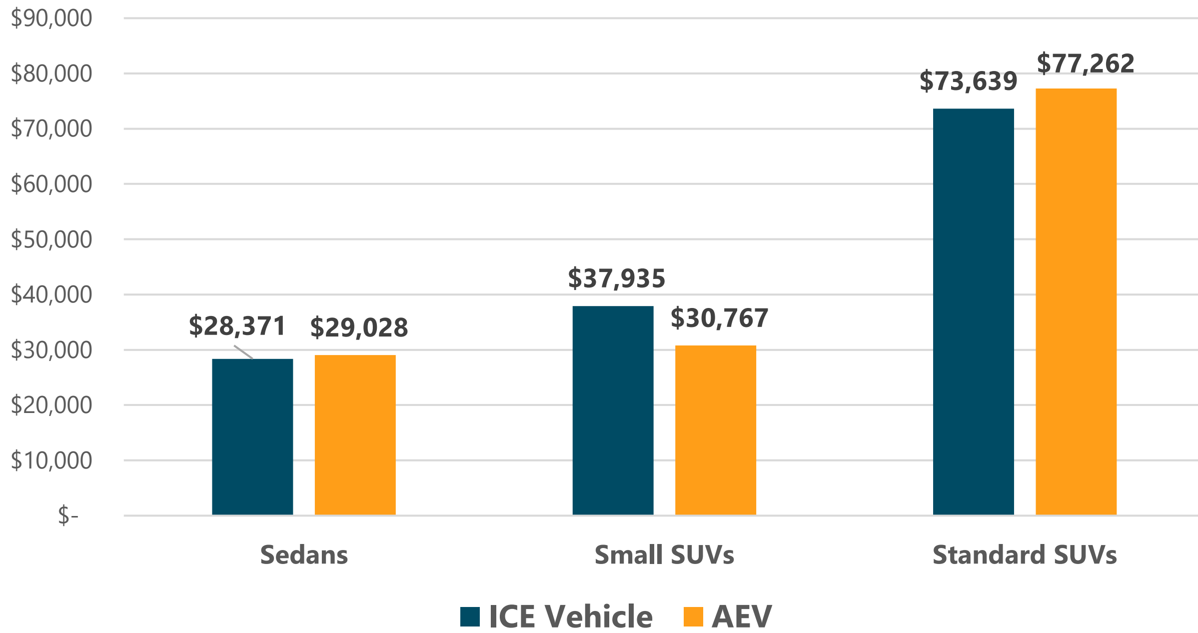
Table 14. Expected Total Cost of Ownership, County Fleet Standard SUVs, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle
	Chevy Suburban	Rivian R1S
Purchase Price	$46,626	$72,500
Fuel/Energy	$18,119	$3,638
Maintenance and Repairs	$21,397	$16,682
Incentives	$0	$0
Fees	$492	$492
Resale Value	-$12,994	-$16,051
TOTAL TCO	**$73,639**	**$77,262**

Summary

The results of the TCO analysis indicate that AEVs are expected to realize significant lifetime financial savings for Arlington County fleet vehicles in the Small SUV vehicle class (19% lower TCO) and to be essentially cost-neutral in the Sedan vehicle class (TCO within 2% of ICE vehicles). This is driven by significant savings of AEVs in two cost categories – fuel/energy, and maintenance and repairs. Per-mile savings in these categories is relatively consistent across all vehicle classes, with AEVs achieving 78% lower fuel/energy costs and 32% lower maintenance and repair costs. In the Sedan and Standard SUV classes, the savings by AEVs in these categories are not enough to completely offset their higher purchase price compared to ICE vehicles. This is partly due to the low purchase prices available to the County for ICE vehicles, and relatively low expected annual mileage.

Figure 9. Expected Total Cost of Ownership of County Fleet Sedans and SUVs, ICE vs AEV



The results indicate that savings from AEVs accumulate with usage over time, so that AEVs that are used more often have a greater potential for lifetime financial savings compared to ICE vehicles. As discussed in the Market Assessment, the range of commercially available AEV vehicles will continue to expand in the future, especially at lower price points in comparison to ICE vehicles. This is expected to expand future opportunities for cost savings in the Sedan and Standard SUV categories.

As shown in the Table 6, the County fleet currently includes 206 ICE Sedans, Small SUVs, and Standard SUVs. Replacing each of these vehicles with an AEV is expected to result in a total savings of at least $592,992 over the life of the vehicles.

Private Vehicles

EV Market Share in Arlington County

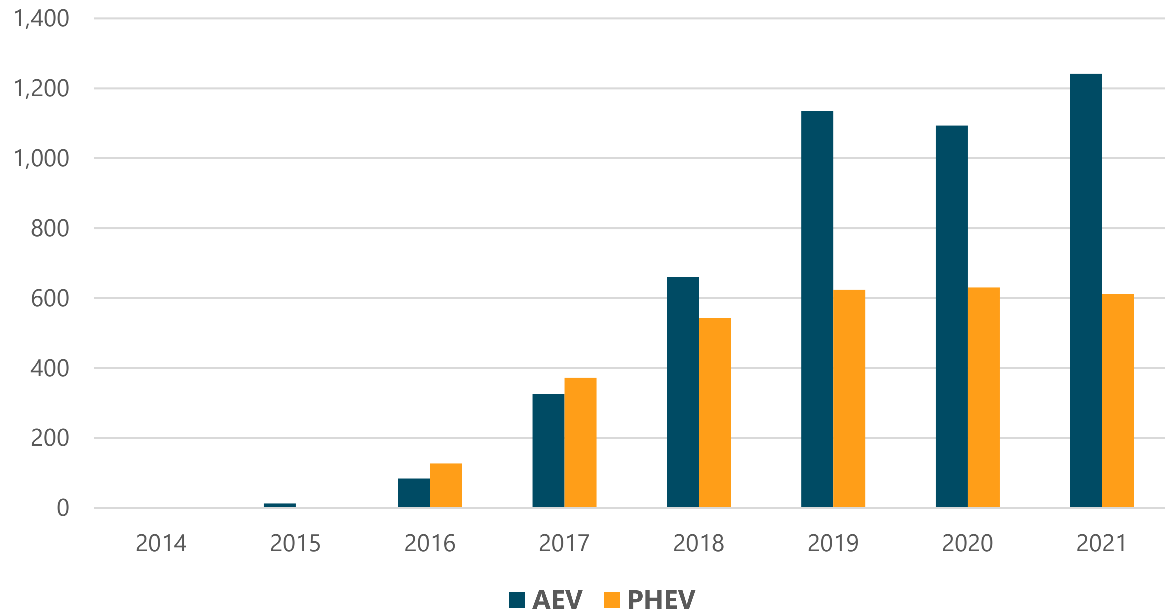
Arlington County's Community Energy Plan (CEP) establishes the goal of reducing GHG emissions from transportation sources by 81% between 2020 and 2050[33]. To support this goal, the plan suggests that vehicles need to drive less, be more fuel efficient, and be predominantly electric vehicles. The Carbon Neutral Transportation Master Plan (now in-progress) is more direct, with a first-in-loading order priority for the optimization of resident and business use of multimodal transportation and micro-mobility options, reduction of car ownership per household, reduction of single-occupancy trips, and a market/ownership shift to alternative fuel vehicles. Notwithstanding prioritization, all strategies (driving multi-modalism and micro-mobility, reducing average number of household vehicles, and market transition to low- to zero-emissions vehicles) will be deployed concurrently (not in sequence).

This section provides a simple benchmark on progress towards this goal by reviewing the recent trends in Arlington County EV registrations.

Figure 10 shows new EV registrations recorded by the Department of Motor Vehicles (DMV) in Arlington County from 2014 to 2021.[34] While EVs have been registered in Arlington County as far back as 2003, in 2014 there was just a single AEV registration recorded by DMV. Since that time, EV registrations have grown exponentially. In the early period of growth, PHEV registrations outpaced AEVs by a small margin. However, PHEV registrations began to level-off in 2019, while the growth in AEV registrations accelerated. In 2021, there were 1,855 new EV registrations in Arlington County, with 2/3 of them for AEVs.

[33] Arlington, Virginia. Community Energy Plan. An Element of Arlington County's Comprehensive Plan. September 2019. https://arlingtonva.s3.amazonaws.com/wp-content/uploads/sites/13/2019/10/Final-CEP-CLEAN-003.pdf
[34] Atlas EV Hub. State EV Registration Data. 12/31/21 Dataset from Virginia Clean Cities. https://www.atlasevhub.com/materials/state-ev-registration-data/.

Figure 10: New EV Registrations in Arlington County by Year, 2014 to 2021[35]



Since vehicle registrations in Virginia need to be renewed every few years, it is useful to examine the composition of EV vehicles that have active (unexpired) registrations in Arlington County. Table 15 shows the distribution of active EV registrations in Arlington by vehicle class. Sedans and compact cars predominate, with 66% of all active registrations, followed by SUVs and Midsize/Crossover/Wagons which each make up about 15% of all active registrations.

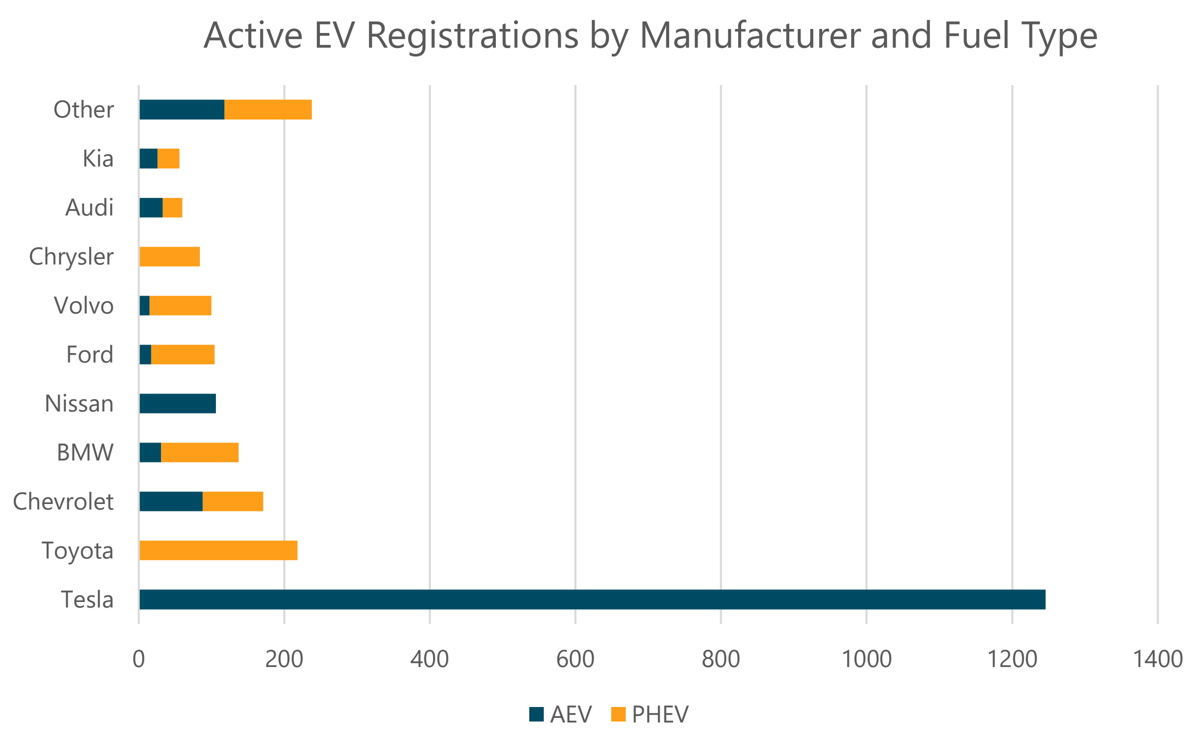
Table 15: Active EV Registrations in Arlington County by Vehicle Class, as of 12/31/21[36]

Vehicle Class	AEV	PHEV	Total
Sedan	1,537	629	2,166
SUV	243	298	541
Midsize/Crossover/Wagon	423	119	542
Compact	190	83	273
Minivan	3	149	152
Neighborhood EV (NEV)	2	0	2
All Vehicle Classes	**2,398**	**1,278**	**3,676**

[35] Atlas EV Hub. State EV Registration Data. 12/31/21 Dataset from Virginia Clean Cities. https://www.atlasevhub.com/materials/state-ev-registration-data/.
[36] Ibid.

Figure 11 shows the distribution of active EV registrations in Arlington County by vehicle manufacturer. Consistent with national trends, Tesla vehicles makeup the vast majority (74%) of active AEV registrations, and just under 50% of all active EV registrations. The next leading manufacturer, Toyota, accounts for just 9% of all active EV registrations.

Figure 11: Active EV Registrations in Arlington County by Manufacturer, as of July 2022



The composition of active EV registrations in Arlington County is largely a reflection of the current market offerings for EVs. As the number of AEV registrations increases and the EV market matures, there will be an increasing diversity in the range of vehicle types and shifting market share amongst manufacturers.

EV Charging Locations in Arlington County

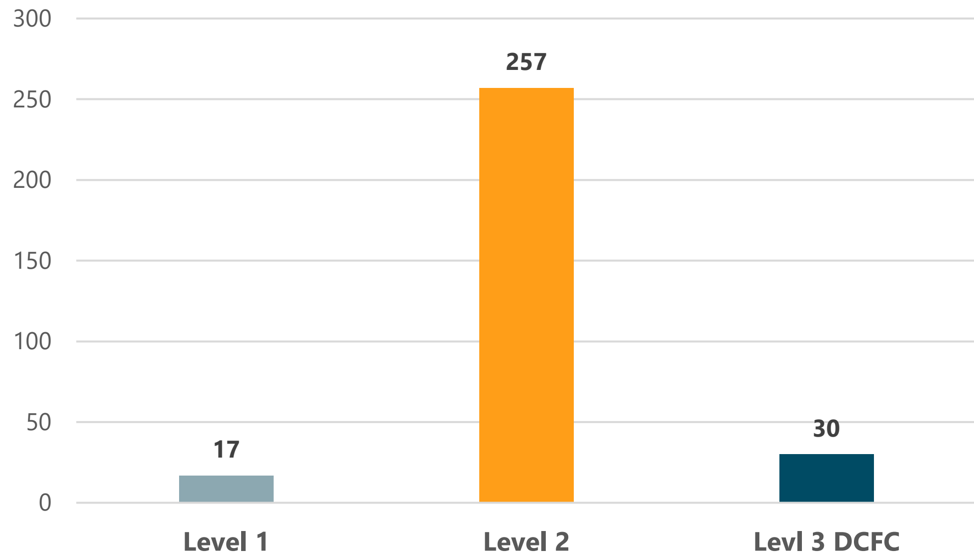
Presently, EV drivers do 80% or more of their charging at home and/or workplaces, which offer greater convenience and lower pricing than most public charging options.[37] However, as EV market share grows in Arlington, and penetrates new markets, the need for publicly accessible EV charging infrastructure will become increasingly important. The availability of public charging infrastructure provides options for people who may not be able to charge at home and is critical to enable longer distance travel. In particular, residential charging can be a challenge for those living in multifamily housing, those in urban neighborhoods without a dedicated parking space,

[37] NREL. National Plug-in Electric Vehicle Infrastructure Analysis. Sept 2017. https://www.nrel.gov/docs/fy17osti/69031.pdf

and renters, who may be reluctant (or not permitted) to install equipment at a home they do not own.

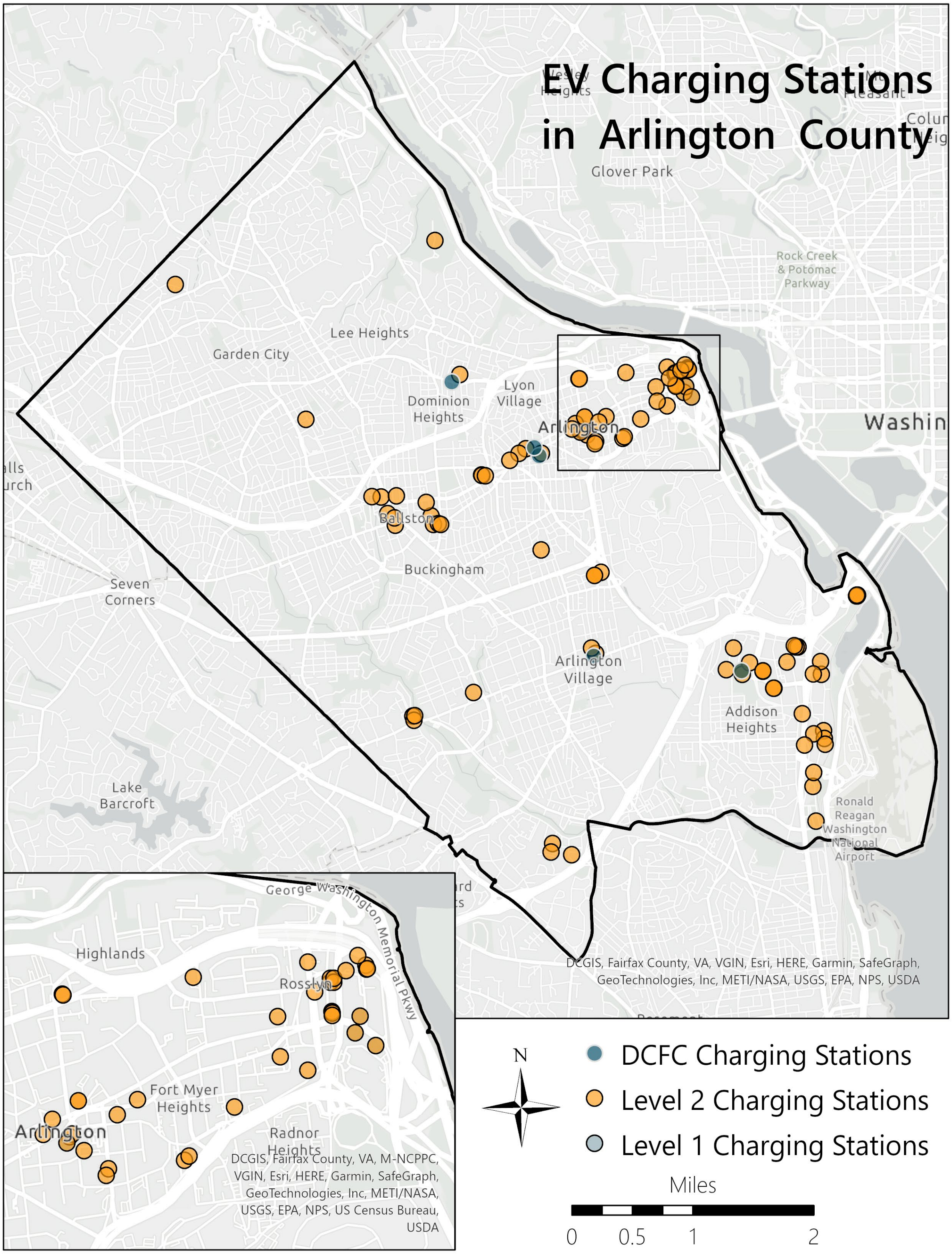
As of July 2022, there are 304 publicly available EV charging stations in Arlington County at 109 sites[38]. The median number of stations per site is 3. Figures 12 and 13 show the location and type of EV charging stations in Arlington County.

Figure 12. EV Charging Station Types, Arlington County, July 2022



[38] US Department of Energy. Electric Vehicle Charging Station Locations. Accessed July 2022. https://afdc.energy.gov/fuels/electricity_locations.html.

Figure 13. EV Charging Station Locations in Arlington County, July 2022



The vast majority of publicly available EV charging stations in Arlington County are Level 2 chargers (85%). While Level 2 chargers are relatively inexpensive to purchase and install, and compatible with a wide range of EVs, they deliver relatively slow charging speeds. As described in the Market Assessment, Level 2 chargers usually offer 10-20 miles of range per hour of charging and can take up to 10 hours to fully charge an AEV. DC Fast Charging stations, on the other hand, deliver an 80% charge to most AEVs in 30 to 60 minutes. However, because DCFC chargers are more expensive to install and operate, they generally have higher prices for EV consumers. Nonetheless, significant growth in the number of DC Fast Charging stations in Arlington County will be needed in order to meet growing charging demands[39].

Table 13 lists the public EV charging networks that are currently present in Arlington County. While some EV networks, such as Tesla, are proprietary to certain vehicles, many of the networks offer broad compatibility with many EV types and manufacturers. However, not all electric vehicles have the same charging standards, and consumers must do their research to ensure compatibility of their vehicle with a particular charging network and station.

Table 16: Public EV Charging Networks in Arlington County, July 2022

EV Charging Network	Number of Charging Stations
ChargePoint Network	70
SemaConnect Network	60
Blink Network	50
Tesla Destination	25
Tesla	18
Volta	15
eVgo Network	13
Non-Networked	53
TOTAL	**304**

While public funding has been, and will continue to be, an important accelerant in the development of EV charging stations, there is a growing and important trend towards privately funded and privately owned EV charging infrastructure. Private retail businesses, as destinations for both customers and employees, present excellent opportunities to host public EV charging stations. At many locations, EV charging operators work in partnership with site hosts, providing benefits and streams of revenue beyond the sale of electricity. These kinds of partnerships will be important in facilitating the expansion of EV charging infrastructure that supports the growing demand for EVs in Arlington County.

[39] National Renewable Energy Laboratory. 2021. Electric Vehicle Charging Infrastructure Trends from Alternative Fueling Station Locator: Second Quarter 2020. https://www.nrel.gov/docs/fy21osti/78486.pdf.

Total Cost of Ownership Analysis for Private Vehicles

As indicated in the Market Assessment, the purchase price of new AEVs is often more than comparable ICE vehicles. However, AEVs tend to have lower annual operating and maintenance costs. This section compares the expected lifetime costs, or total cost of ownership (TCO), of AEVs and ICE vehicles for privately owned vehicles in Arlington County.

For each of three light-duty vehicle classes (Sedans, Small SUVs, and Standard SUVs), representative AEV and ICE vehicles were chosen for TCO comparison.

Table 17. Vehicles Compared in County Fleet TCO Analysis

Vehicle Class	ICE Vehicle	All Electric Vehicle
Sedan	Toyota Camry	Nissan Leaf
Small SUV	Hyundai Kona	Hyundai Kona EV
Standard SUV	Ford Explorer	Volkswagen ID.4

Methodology

The total cost of ownership model used for private vehicles in Arlington County considers six (6) factors:

- Purchase Price
- Fuel/Energy Costs
- Maintenance and Repairs
- Electric Vehicle Supply Equipment (EVSE)
- Incentives
- Fees
- Resale Value

Purchase prices were based on the Manufacturer's Suggested Retail Price for base-model vehicles as of July 2022. For each vehicle, a 10-year useful life was assumed, and costs were levelized over the 10-year time period.

To estimate fuel/energy costs, annual vehicle mileage was based on the average miles per driver in Virginia in 2019[40], and EPA fuel economy estimates for each comparison vehicle were applied[41]. To account for differences between city and highway vehicle efficiency, the proportion of miles in each category was based on 2021 data collected by the Virginia Department of Transportation in

[40] US Department of Transportation, Federal Highway Administration. Highway Statistics 2019. https://www.fhwa.dot.gov/policyinformation/statistics/2019/.
[41] US Environmental Protection Agency. FueEconomy.Gov. Accessed August 2022.

Arlington County. The price of gasoline used in the model reflects the monthly average in Virginia as of July 2022[42].

For AEV's, energy costs associated with both home charging and public charging were modelled, to account for the variety of charging scenarios expected to occur among Arlington County AEV owners. For home charging, a typical overnight charging strategy with Level 2 charging was assumed. Electricity costs were based on the average residential rate for Arlington County, from publicly available information reported to the Energy Information Administration[43]. For public charging, electricity costs were based on the actual rates charged in Virginia by a leading public EV charging network[44].

Maintenance and repair costs were estimated by applying a model developed by the Argonne National Laboratory of the US Department of Energy, which is based on a systematic analysis of light-duty vehicle datasets in the U.S.[45]. The Argonne model considers variations in maintenance and repair costs due to vehicle class, powertrain, vehicle age, and original MSRP.

For home charging, costs associated with the purchase, installation, and on-going maintenance of EVSE were included. These costs were based on pricing information collected in a study of 1,200 residential EVSE installations in the United States[46]. EVSE costs were not included in the public charging scenarios, since users in this scenario would not purchase and install EVSE equipment at their homes.

There were two types of incentives included in this analysis – clean vehicle federal tax credits and EV charger incentives offered by Dominion Energy. Eligibility requirements for clean vehicle federal tax credits were changed with the passage of the Inflation Reduction Act. Beginning on August 16, 2022, the tax credit is generally only available for qualifying vehicles with final assembly in North America[47]. Accordingly, this Study applies the federal tax credit only to the Nissan Leaf (Sedan) in this analysis[48] (although it is anticipated that the federal government will, in 2023, identify other eligible vehicles and potential buyers are encouraged to closely monitor these developments, **https://afdc.energy.gov/laws/electric-vehicles-for-tax-credit**. Dominion

[42] American Automobile Association (AAA). Gas Prices. https://gasprices.aaa.com/?state=VA.
[43] FindEnergy. Arlington County, Virginia Electricity Rates & Statistics. https://findenergy.com/va/arlington-county-electricity/.
[44] EVGo Fast Charging. https://www.evgo.com/pricing/.
[45] Argonne National Laboratory, US Department of Energy. 2021. Comprehensive Total Cost of Ownership Quantifications for Vehicle with Different Size Classes and Powertrains. https://publications.anl.gov/anlpubs/2021/05/167399.pdf.
[46] Borlauge, B., et al. Levelized Cost of Charging Electric Vehicles in the United States. Joule, Volume 4, Issue 7. July 2020. https://www.sciencedirect.com/science/article/pii/S2542435120302312#bib28
[47] See the IRS's website for specific details on the final assembly requirement, which is vehicle-specific. Many manufacturers are adjusting their production to meet this new requirement. https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d.
[48] US Department of Energy. Electric Vehicles with Final Assembly in North America. https://afdc.energy.gov/laws/electric-vehicles-for-tax-credit.

Energy offers modest cash incentives for qualifying Level 2 EV chargers, which were applied to AEVs in the home charging scenario.

Fees associated with each vehicle included Arlington County's Vehicle Personal Property Tax, DMV registration fees, and the DMV's Electric Vehicle Fee for AEVs. For AEV's, the calculation of annual Vehicle Personal Property Tax included the application of property tax relief for qualifying clean-fuel vehicles[49].

The expected resale value of vehicles at the end of their useful life is based on a standard depreciation forecast used by the Department of Energy's AFLEET tool[50].

See Appendix 2 for additional details on the data and assumptions used in the TCO analysis for private vehicles.

Results

Tables 18, 19, and 20, below, show the results of the TCO analysis for County fleet Sedans, Small SUVs, and Standard SUVs.

Table 18. Expected Total Cost of Ownership, Privately Owned Sedans, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle *(Home Charging)*	All Electric Vehicle *(Public Charging)*
	Toyota Camry	Nissan Leaf	Nissan Leaf
Purchase Price	$25,945	$27,800	$27,800
Fuel/Energy	$10,537	$2,587	$6,280
Maintenance and Repairs	$8,993	$5,607	$5,607
EVSE	$0	$2,786	$0
Incentives	$0	-$8,025	-$8,025
Fees	$6,613	$3,950	$3,950
Resale Value	-$6,454	-$6,915	-$6,915
TOTAL TCO	**$45,634**	**$27,790**	**$31,483**

49 Arlington Virginia. Vehicle Property Tax Relief (PPTRA). https://www.arlingtonva.us/Government/Programs/Taxes/Vehicles/Vehicle-Tax-Relief

50 US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Table 19. Expected Total Cost of Ownership, Privately Owned Small SUVs, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle *(Home Charging)*	All Electric Vehicle (*Public Charging*)
	Hyundai Kona	Hyundai Kona EV	Hyundai Kona EV
Purchase Price	$21,300	$34,000	$34,000
Fuel/Energy	$12,913	$2,463	$5,978
Maintenance and Repairs	$8,664	$5,647	$5,647
EVSE	$0	$2,786	$0
Incentives	$0	-$525	-$525
Fees	$5,484	$4,844	$4,844
Resale Value	-$5,298	-$8,458	-$8,458
TOTAL TCO	**$43,063**	**$40,758**	**$44,273**

Table 20. Expected Total Cost of Ownership, Privately Owned Standard SUVs, ICE vs AEV

TCO Factor	ICE Vehicle	All Electric Vehicle *(Home Charging)*	All Electric Vehicle (*Public Charging*)
	Ford Explorer	Volkswagen ID4	Volkswagen ID4
Purchase Price	$35,510	$44,910	$44,910
Fuel/Energy	$14,739	$2,681	$6,508
Maintenance and Repairs	$9,189	$5,983	$5,983
EVSE	$0	$2,786	$0
Incentives	$0	-$525	-$525
Fees	$9,077	$6,870	$6,870
Resale Value	-$8,833	-$13,756	-$13,756
TOTAL TCO	**$59,681**	**$48,949**	**$52,775**

Summary

The results of the TCO analysis indicate that despite higher purchase prices, AEVs are expected to realize significant lifetime financial savings for most privately owned vehicles in Arlington County. AEVs had a lower TCO than ICE vehicles in 5 of the 6 comparisons, and on average, AEVs reduced TCO by 17% compared to ICE vehicles. This ranges from a TCO savings of 39% for an AEV Sedan produced in North America that utilizes home charging, to a TCO premium of 3% for an AEV Small SUV produced internationally that utilizes public charging.

AEV savings are driven by four factors that reduce the lifetime cost of AEVs compared to ICE vehicles - fuel/energy costs, maintenance and repairs, fees, and incentives. Fuel/energy cost savings are realized by AEVs compared to ICE vehicles in every scenario, with a reduction of 80% and 51% for home charging and public charging, respectively. Similarly, maintenance and repairs for AEVs are lower than those for ICE vehicles in every category, on average by 29%. The personal property tax relief for clean fuel vehicles produces an average reduction in fees of 26% for AEVs. When applicable, the federal clean vehicle tax credit is a significant portion of total AEV savings, but in every case the total savings from other factors are greater than the value of this incentive.

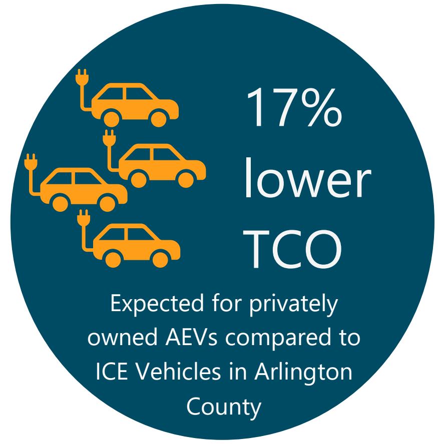


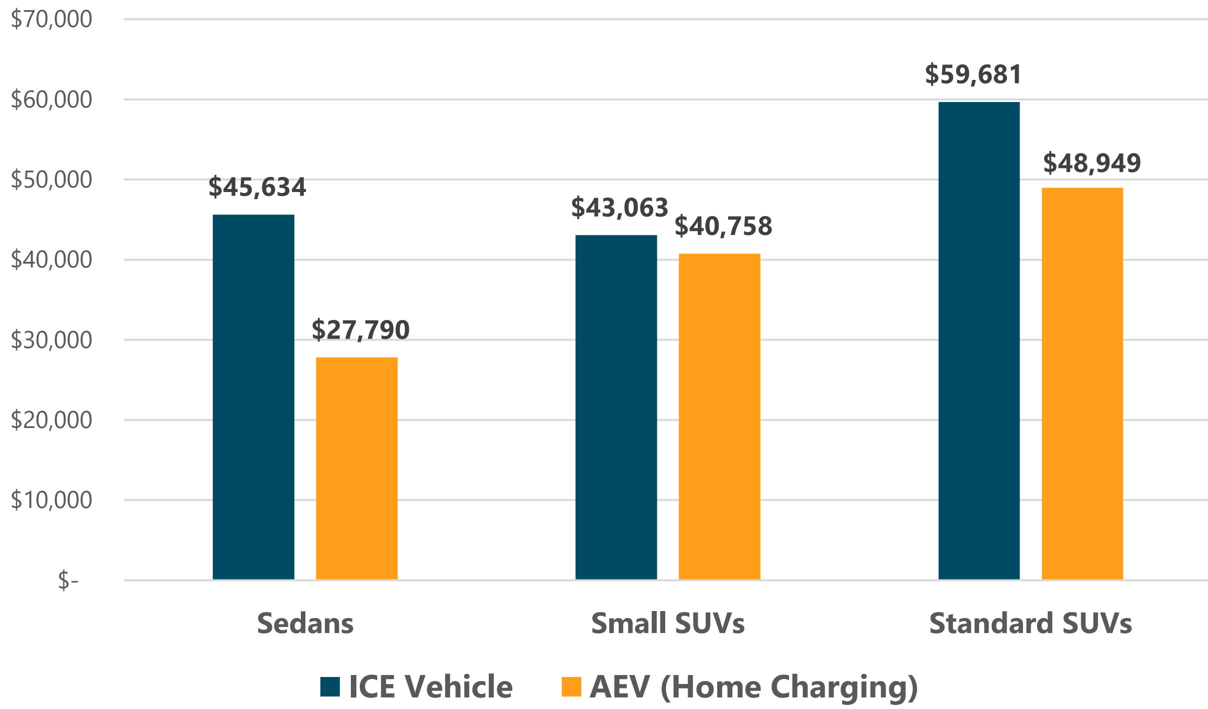
Table 21. Average Lifetime Savings of AEVs Compared to ICE Vehicles in Selected Categories, All Privately Owned Vehicle Types in Arlington County

TCO Factor	Average Lifetime Savings from AEVs (All Vehicle Types)	
	Home Charging	Public Charging
Fuel/Energy Costs	$10,153	$6,474
Maintenance and Repairs	$3,203	$3,203
Fees	$1,836	$1,836
Incentives	$525 to $8,025	$525 to $8,025

Figure 14, below, summarizes the results of the TCO analysis for each vehicle class utilizing home charging in Arlington County. Currently, most AEV charging is conducted at home, and this is expected to continue to be the case even as AEVs are adopted more widely[51].

[51] National Renewable Energy Laboratory. There's No Place Like Home: Residential Parking, Electrical Access, and Implications for the Future of Electric Vehicle Charging Infrastructure. 2021. https://www.nrel.gov/docs/fy22osti/81065.pdf

Figure 14. Expected Total Cost of Ownership of Privately Owned Sedans and SUVs, ICE vs AEV (Home Charging)



The results indicate that consumers in Arlington can expect TCO savings from AEVs in most scenarios. However, the greatest TCO savings are realized by:

- **Choosing an AEV with a lower purchase price.** While some AEVs, particularly in the Sedan vehicle class, have purchase prices that are close to parity with comparable ICE vehicles, many AEVs are still significantly more expensive to purchase than comparable ICE vehicles.
- **Taking advantage of the federal clean vehicle tax credit.** With the recent change in the federal clean vehicle tax credit eligibility, many popular AEV models that are produced outside of the United States are no longer eligible for this significant financial benefit[52], so expected savings can vary significantly depending on vehicle eligibility.
- **Charging at home.** Public charging was found to be more than twice as expensive as charging at home, reducing the expected financial savings from AEVs. However, public charging was still found to result in fuel/energy costs that are 51% less than for a comparable ICE vehicle.
- **Utilizing the AEV more often and over a longer period of time.** The greatest potential savings from AEVs come from reduced fuel/energy costs and maintenance and repairs, which reduce per-mile costs compared to ICE vehicles by 80% and 36%, respectively (with home charging). Savings in these categories accumulate with usage over time, so AEVs that are used more often have a greater potential for lifetime financial savings.

[52] See 'Policies and Incentives' for more information on the federal clean vehicle tax credit.

As discussed in the Market Assessment, the range of commercially available AEV vehicles will continue to expand in the future, especially at lower price points in comparison to ICE vehicles. Thus, the potential TCO savings from AEVs is expected to improve over time. As always, a consideration of lifetime vehicle costs, or TCO, will enable consumers in Arlington County to maximize the financial benefits that are possible from AEVs.

Policies and Incentives

Rebates and Incentives

Federal Clean Vehicle Tax Credits

Federal tax credits for EV purchases ranging from $2,500-$7,500 are available depending on the vehicle. Many changes to this incentive occurred with the passage of the Inflation Reduction Act in August 2022[53]. Some of the changes to the credit eligibility requirements took effect on passage while others will be phased in over a period of years; many of the changes take effect after December 31, 2022. The following is summary of the important provisions of the new federal clean vehicle tax credit program:

- ***Manufacturing Origin*** - Effective on passage, vehicles must have final assembly completed in North America to be eligible. This eliminated many popular EV models from the tax credit, although some may return in a few years if their manufacturing moves to North America[54]. To identify the manufacture location for a specific vehicle, the Internal Revenue Service recommends using the VIN Decoder website for the National Highway Traffic Safety Administration (NHTSA), accessible at **https://www.nhtsa.gov/vin-decoder**.
- ***Extension of Caps*** - The Inflation Reduction Act eliminated the 200,000 USA EV sales phase-out trigger for vehicles put into service starting January 1, 2023. Instead, all EV purchases meeting eligibility requirements will be eligible for a tax credit through December 31, 2032. This means Tesla and General Motors vehicles that are currently ineligible may return to eligibility for purchases made starting in 2023 (provided all the other eligibility requirements are met).
- ***Transferable to Dealers*** - Starting January 2024, purchasers will be able to work through a participating dealership to have the value of the credit passed through at the point of sale. This could be especially helpful for EV purchasers with limited tax liability who previously may have been unable to take full advantage of the incentive previously.
- ***Income Eligibility*** - Non-commercial purchasers must meet Adjusted Gross Income (AGI) eligibility requirements of $150,000 or less for individual filers or $300,000 or less for joint filers.

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[53] Internal Revenue Service. Plug-In Electric Drive Vehicle Credit (IRC 30D). https://www.irs.gov/businesses/plug-in-electric-vehicle-credit-irc-30-and-irc-30d

[54] US Department of Energy. Electric Vehicle With Final Assembly in North America. https://afdc.energy.gov/laws/electric-vehicles-for-tax-credit.

- ***Price Caps*** - EVs must have a Manufacturer's Suggested Retail Price (MSRP) of $55,000 or less for passenger cars or $85,000 for SUVs, pick-up trucks and vans to be eligible.
- ***Amount of the Credit*** - Rather than basing the value of the credit on the amount of energy the EV battery can store as was previously done, the new provisions will require a minimum battery size of 7 kWh and then $3,750 of the credit will be determined by whether enough of the minerals used in the battery were sourced from the USA or a free trade partner, and another $3,750 will be based on whether the value of the battery components meets requirements for North American sourcing. Additional rules detailing how the IRS will phase in these requirements are expected by the end of 2022.
- ***Used EV Credit*** - The bill also included a new incentive that would offer 30%, up to $4,000 toward a used EV priced at $25,000 or less that has not previously received a federal tax credit for a used EV purchase. The income requirement for this for individual filers is an AGI of $75,000 or $150,000 for joint filers and there is a limit of one used EV credit every three years. This will take effect on January 1, 2023.
- ***Commercial EVs*** - Businesses using EVs could be eligible for a 30% tax credit, up to $7,500 for vehicles less than 14,000 pounds or up to $40,000 for vehicles over 14,000 pounds. Rules are still being written that will determine which organizations will be eligible. This is scheduled to take effect January 1, 2023.
- ***Charging Infrastructure Tax Credit*** - The bill restored a tax credit for charging infrastructure installation that previously ended on December 31, 2021. The amount of the credit is 30% of the actual equipment and installation costs, up to $100,000 per property. Starting in January 2023, the credit will be limited to property located in qualifying census tracts in low-income communities and non-urban areas.

Personal Property Tax Relief for Qualifying Clean Vehicles

All cities and counties in Virginia have a personal property tax which helps fund local government. For Arlington County residents, the tax is assessed on all motor vehicles that are regularly parked overnight in Arlington County. For 2022, the tax rate is set at $5.00 per $100 of assessed value[55]. However, pursuant to the Personal Property Tax Relief Act of 1998 (PPTRA), qualifying clean-fuel vehicles receive the following relief:

- A 100 percent tax relief on the first $3,000 of the vehicle’s value
- A 50 percent tax relief on the next $17,000 of the vehicle’s value, from $3,001-$20,000
- No tax exemption for the portion of a vehicle’s assessed value over $20,000

Qualifying clean fuel vehicles are defined as those that result in lower emissions of specific air pollutants than conventional gasoline vehicles, and specifically includes AEVs. All AEV and PHEV models should expect to qualify for property tax relief under this program.

[55] Arlington, Virginia. Vehicle Personal Property Tax Assessments. https://www.arlingtonva.us/Government/Programs/Taxes/Vehicles/Vehicle-Personal-Property-Tax-Assessments.

Dominion Energy EV Charger Rewards Program

Dominion Energy, the primary electricity provider in Arlington County, offers a rewards program for residential customers with qualifying Level 2 chargers installed at their home[56]. Customers enrolled in the program agree to demand response events called by the Dominion during times of peak system demand, up to 15 times per month or 45 times per year. These events reduce the electric vehicle charging load while encouraging customers to charge their vehicles during off-peak hours. Customers can opt-out of individual demand response events.
For participation in this program, Dominion provides EV owners with a one-time payment of $125 after the EV charger has been installed, in addition to $40 annually.

State Policies and Planning

Alternative Fuel and Hybrid Electric Vehicle (HEV) Emissions Testing Exemption

AEVs are exempt from the Virginia emissions inspection program[57]. Qualifying PHEVs and other hybrids with EPA fuel economy ratings of at least 50 miles per gallon (city) are also exempt from the emissions inspection program, unless there are indications they may not meet current emissions standards. A list of qualifying vehicles can be found at **https://www.dmv.virginia.gov/vehicles/#emissions.asp**.

High Occupancy Vehicle (HOV) Lane Exemption

Alternative fuel vehicles (AFVs) displaying the Virginia Clean Special Fuel license plate may use Virginia HOV lanes on specified areas of I-64, I-264, the Dulles Toll Road, and in the City of Alexandria, regardless of the number of occupants[58]. For HOV lanes serving the I-66 corridor, only registered vehicles displaying Clean Special Fuel license plates issued before July 1, 2011, are exempt from HOV lane requirements. A complete list of qualifying vehicles can be found at **http://www.dmv.state.va.us/webdoc/citizen/vehicles/cleanspecialfuel.asp**.

Low-Emission Vehicle (LEV) and Clean Car Standards

HB 1965 was enacted in March 2021, establishing a low-emission vehicle (LEV) and zero-emissions vehicle (ZEV) program in Virginia. The bill directs the State Air Pollution Control Board to implement a LEV program for criteria pollutants and greenhouse gas emissions and a zero-emission vehicle program only for motor vehicles with a gross vehicle weight of 14,000 pounds or less, beginning with the 2025 model year. The percentage of ZEVs required to be delivered for sale under the program is roughly equal to the percentage required under California's ZEV program. Note that this program has been a target for sunsetting in recent legislative sessions.

[56] Dominion Energy. EV Charger Rewards. https://www.dominionenergy.com/virginia/save-energy/ev-charger-rewards.
[57] US Department of Energy. Virginia Laws and Incentives. https://afdc.energy.gov/laws/all?state=VA
[58] Ibid.

Virginia’s NEVI Planning

With funding provided to the National Electric Vehicle Infrastructure (NEVI) Program through the 2021 Infrastructure Investment and Jobs Act, the Commonwealth of Virginia planning to deploy approximately $100 million over the next five years to install public electric vehicle (EV) charging stations across Virginia[59]. Initially, public charging stations will be located within one mile of Virginia's federally designated Alternative Fuel Corridors (I-64, I-66, I-77, I-81, I-85, I-95, I-295, and I-495).

[59] Virginia Department of Transportation. Virginia Electric Vehicle Infrastructure Deployment Plan. https://publicinput.com/VirginiaNEVI

Appendix 1: County Fleet Emissions Analysis Data and Assumptions

Table A1-1. County Fleet Non-Public Safety Vehicles, Mileage, and Fuel Economy, 2021

Make	Model	Model Year	# of Vehicles	Vehicle Class	2021 Miles	Fuel Type	MPGGE	MPGGE Source
CHEVROLET	COBALT	2009	2	Sedan	2538	Gasoline	27	https://www.fueleconomy.gov/feg/noframes/25409.shtml
CHEVROLET	IMPALA	2007	1	Sedan	505	Gasoline	22	https://fueleconomy.gov/feg/noframes/23287.shtml
CHEVROLET	IMPALA	2009	1	Sedan	663	Gasoline	22	https://www.fueleconomy.gov/feg/noframes/25524.shtml
CHEVROLET	IMPALA	2012	1	Sedan	4513	Gasoline	22	https://www.fueleconomy.gov/feg/noframes/31407.shtml
CHEVROLET	IMPALA	2013	4	Sedan	9661	Gasoline	22	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=32724
CHEVROLET	IMPALA	2014	4	Sedan	5662	Gasoline	24	https://www.fueleconomy.gov/feg/noframes/33584.shtml
CHEVROLET	SUBURB-AN	2008	1	Standard SUV	1809	Gasoline	16	https://www.fueleconomy.gov/feg/noframes/24569.shtml
CHEVROLET	SUBURB-AN	2019	1	Standard SUV	8539	Gasoline	18	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=40293
CHEVROLET	VOLT	2011	1	Sedan	4787	Plug In Hybrid	60	https://www.caranddriver.com/news/a18734558/chevrolet-volt-epa-numbers-revealed-dissected/
FORD	ESCAPE	2008	2	Small SUV	2014	Gasoline	22	https://www.fueleconomy.gov/feg/noframes/24083.shtml
FORD	ESCAPE	2009	9	Small SUV	23684	Gasoline	21	https://www.fueleconomy.gov/feg/noframes/25669.shtml
FORD	ESCAPE	2010	2	Small SUV	3086	Gasoline	23	https://www.fueleconomy.gov/feg/noframes/29439.shtml
FORD	ESCAPE	2011	1	Small SUV	781	Gasoline	25	https://www.fueleconomy.gov/feg/bymodel/2011_ford_escape.shtml
FORD	ESCAPE	2012	3	Small SUV	7351	Gasoline	23	https://www.fueleconomy.gov/feg/noframes/31481.shtml
FORD	ESCAPE	2013	10	Small SUV	19424	Gasoline	25	https://www.fueleconomy.gov/feg/noframes/32367.shtml
FORD	ESCAPE	2014	7	Small SUV	24882	Gasoline	25	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=33722
FORD	ESCAPE	2015	8	Small SUV	14595	Gasoline	26	https://www.fueleconomy.gov/feg/noframes/35688.shtml
FORD	ESCAPE	2016	9	Small SUV	22022	Gasoline	26	https://www.fueleconomy.gov/feg/noframes/36496.shtml
FORD	ESCAPE	2017	11	Small SUV	24497	Gasoline	24	https://www.fueleconomy.gov/feg/noframes/37357.shtml
FORD	ESCAPE	2018	7	Small SUV	22664	Gasoline	26	https://www.fueleconomy.gov/feg/noframes/39463.shtml
FORD	ESCAPE	2019	20	Small SUV	47801	Gasoline	26	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=40911
FORD	ESCAPE	2020	9	Small SUV	23894	Gasoline	28	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=42257
FORD	EXPEDIT-ION XL	2015	1	Standard SUV	4299	Gasoline	18	https://www.fueleconomy.gov/feg/noframes/35702.shtml

Make	Model	Model Year	# of Vehicles	Vehicle Class	2021 Miles	Fuel Type	MPGGE	MPGGE Source
FORD	EXPLOR-ER	2011	1	Standard SUV	416	Gasoline	20	https://fueleconomy.gov/feg/noframes/31052.shtml
FORD	EXPLOR-ER	2014	2	Standard SUV	18539	Gasoline	23	https://www.fueleconomy.gov/feg/noframes/33719.shtml
FORD	EXPLOR-ER	2016	3	Standard SUV	19086	Gasoline	20	https://www.fueleconomy.gov/feg/noframes/36300.shtml
FORD	EXPLOR-ER	2020	2	Standard SUV	22630	Gasoline	24	https://www.fueleconomy.gov/feg/noframes/41485.shtml
FORD	FOCUS	2012	11	Sedan	21710	Gasoline	31	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=31182
FORD	FOCUS	2013	5	Sedan	9226	Gasoline	30	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=32916
FORD	FOCUS	2014	10	Sedan	15499	Gasoline	30	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=33999
FORD	FOCUS	2015	1	Sedan	631	Gasoline	31	https://www.fueleconomy.gov/feg/noframes/35962.shtml
FORD	FUSION	2010	19	Sedan	38502	Gasoline	25	https://www.fueleconomy.gov/feg/noframes/26401.shtml
FORD	FUSION	2016	1	Sedan	542	Gasoline	26	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=36159
FORD	FUSION	2017	1	Sedan	1545	Gasoline	25	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=37429
FORD	FUSION	2019	2	Sedan	9242	Gasoline	25	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=40699
FORD	INTERC-EPTOR	2016	1	Standard SUV	2639	Gasoline	13	https://www.fuelly.com/car/ford/police_interceptor_utility/2016
FORD	INTERC-EPTOR UT	2021	1	Standard SUV	117	Gasoline	24	https://www.ford.com/cmslibs/content/dam/brand_ford/en_us/brand/resources/general/pdf/brochures/21_Police_Brochure_MR.pdf
NISSAN	LEAF	2017	2	Sedan	908	AEV	112	https://www.fueleconomy.gov/feg/noframes/38428.shtml
NISSAN	LEAF	2018	3	Sedan	2795	AEV	112	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=39860
NISSAN	LEAF	2022	5	Sedan	111	AEV	111	https://www.fueleconomy.gov/feg/noframes/44446.shtml
TOYOTA	CAMRY	2009	2	Sedan	3336	Gasoline	23	https://www.fueleconomy.gov/feg/noframes/25275.shtml
TOYOTA	CAMRY	2010	2	Sedan	3576	Gasoline	26	https://www.fueleconomy.gov/feg/noframes/26422.shtml
TOYOTA	CAMRY	2011	2	Sedan	3536	Gasoline	25	https://www.fueleconomy.gov/feg/noframes/30087.shtml
TOYOTA	CAMRY	2012	1	Sedan	335	Gasoline	28	https://www.fueleconomy.gov/feg/noframes/31765.shtml
TOYOTA	PRIUS	2008	3	Sedan	6967	Gasoline HEV	46	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=24882
TOYOTA	PRIUS	2010	4	Sedan	9177	Gasoline HEV	50	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=26425
TOYOTA	PRIUS C	2013	3	Sedan	7559	Gasoline HEV	50	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=33315
TOYOTA	PRIUS C	2014	5	Sedan	7290	Gasoline HEV	50	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=34639
TOYOTA	PRIUS C	2015	4	Sedan	8077	Gasoline HEV	50	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=35775
TOYOTA	PRIUS C	2018	5	Sedan	9386	Gasoline HEV	46	https://www.fueleconomy.gov/feg/noframes/39037.shtml
TOYOTA	PRIUS C	2019	1	Sedan	1369	Gasoline HEV	46	https://www.fueleconomy.gov/feg/bymodel/2019_Toyota_Prius_c.shtml

Table A1-2. Electricity Generation Mix, SERC Reliability Corporation[60]

Source	Percent
Residual oil	0.3%
Natural gas	38.0%
Coal	23.2%
Nuclear power	31.9%
Biomass	0.4%
Others (Wind, Solar, Hydro, etc)	6.3%

Table A1-3. AEVs Used in Emissions Forecasts

Class	AEV Vehicle	MPGGE	MPGGE Source
Sedans	Nissan Leaf	112	https://www.fueleconomy.gov/feg/noframes/38428.shtml
Small SUV	Chevy Bolt EUV	115	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43954
Standard SUV	Rivian R1S	69	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44461

Table A1-4. Annual Criteria Air Pollutant Estimates

Pollutant	Annual Emissions (lbs)					
	Sedans		Small SUVs		Standard SUVs	
	Existing Fleet (2021)	100% AEV Fleet	Existing Fleet (2021)	100% AEV Fleet	Existing Fleet (2021)	100% AEV Fleet
CO	511.2	0.0	658.6	0.0	217.2	0.0
NOx	6.8	0.0	9.2	0.0	3.0	0.0
PM10	12.9	12.1	16.2	15.1	5.3	5.0
PM2.5	2.5	1.7	3.1	2.1	1.0	0.7
VOC	62.4	0.0	83.5	0.0	27.6	0.0
SOx	0.7	0.0	1.1	0.0	0.4	0.0
Total	596.5	13.8	771.7	17.2	254.6	5.7
Percent Reduction	-	97.7%	-	97.8%	-	97.8%

60 US Department of Energy. 2022. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Appendix 2: Total Cost of Ownership Analysis Data and Assumptions

County Fleet

Purchase Price

Table A2-1. Vehicle Purchase Prices, County Fleet TCO

Vehicle	Vehicle Class	Type	MSRP	Source
Nissan Versa	Sedan	ICE	$16,250	https://www.carsdirect.com/nissan/versa
Nissan Leaf	Sedan	AEV	$25,000	Equipment Bureau Replacement Costs
Ford Escape	Small SUV	ICE	$25,758	Equipment Bureau Replacement Costs
Chevy Bolt EUV	Small SUV	AEV	$26,595	https://www.chevrolet.com/electric/bolt-euv
Chevy Suburban	Standard SUV	ICE	$58,695	https://www.chevrolet.com/suvs/suburban/build-and-price/trims
Rivian RS1	Standard SUV	AEV	$72,500	https://www.kbb.com/rivian/r1s/2022/

Fuel/Energy Costs

Table A2-2. Inputs to Fuel/Energy Cost Calculations, County Fleet TCO

Input	Value	Source	Discussion
Gasoline Price	$3.59 / gal	Arlington Equipment Bureau	Average price paid in July 2022
Electricity Price	$0.0901 per kWh	Arlington DES	Virginia Energy Purchasing Governmental Association (VEPGA) Rate
Annual Miles - Sedans	1,1733 city/1,292 hwy	Equipment Bureau, VDOT Report ID VMT 1236	Average annual mileage for vehicle class from 2019 to 2021; City/Hwy miles based on 2020 VMT
Annual Miles - Small SUVs	1,444 city/1,077 hwy	Equipment Bureau, VDOT Report ID VMT 1236	Average annual mileage for vehicle class from 2019 to 2021; City/Hwy miles based on 2020 VMT
Annual Miles - Standard SUVs	4,333 city/3,230 hwy	Equipment Bureau, VDOT Report ID VMT 1236	Average annual mileage for vehicle class from 2019 to 2021; City/Hwy miles based on 2020 VMT
Fuel Economy - Nissan Versa	32 mpg/40 mpg (city/hwy)	https://www.fueleconomy.gov/feg/noframes/43432.shtml	

Input	Value	Source	Discussion
Fuel Economy - Nissan Leaf	123 mpgge/99 mpgge (city/hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44446	
Fuel Economy - Ford Escape	26 mpg/31 mpg (city/hwy)	https://www.fueleconomy.gov/feg/noframes/44814.shtml	
Fuel Economy - Chevy Bolt EUV	125 mpgge/104 mpgge (city/hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43954	
Fuel Economy - Chevy Suburban	15 mpg/19 mpg (city/hwy)	https://www.fueleconomy.gov/feg/noframes/44971.shtml	
Fuel Economy - Rivian RS1	73 mpgge/65 mpgge (city/hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44461	

Maintenance and Repairs

Estimates of maintenance and repair (M&R) costs for County vehicles were made by combining actual costs from the Equipment Bureau (Table A2-3) with a model based on a systematic analysis of light-duty vehicle sets in the U.S[61].

The Equipment Bureau provided combined maintenance and repair costs for each vehicle class in 2019 and 2020 (not including overhead), each of which was comprised of vehicles of different ages and MSRPs. The proportion of maintenance to repair costs was assumed to be 50/50. For repairs, the results of the Argonne model were scaled to match the Equipment Bureau's costs, and the scaled model was used to make estimates for each of the vehicles under consideration. This method accounts for differences in powertrain and MSRP, reflecting real-world data that indicates AEVs have lower M&R costs and that more expensive vehicles tend to cost more to repair.

Table A2-3. Arlington County Fleet Combined Maintenance and Repair Costs, Average 2019 to 2020

Vehicle Category	Annual M&R (without overhead)
Small Sedan	$ 1,078
Medium Sedan	$ 1,230
SUV	$ 1,441

[61] Argonne National Laboratory, US Department of Energy. 2021. Comprehensive Total Cost of Ownership Quantifications for Vehicle with Different Size Classes and Powertrains.

Table A2-4. Maintenance and Repair (M&R) Cost Estimates, County Fleet TCO

Vehicle	Vehicle Class	Powertrain	Estimated Annual Maintenance	Estimated Annual Repairs	Total Annual M&R
Nissan Versa	Sedan	ICE	$577	$511	$1,088
Nissan Leaf	Sedan	AEV	$348	$408	$756
Ford Escape	Small SUV	ICE	$721	$554	$1,274
Chevy Bolt EUV	Small SUV	AEV	$435	$340	$775
Chevy Suburban	Standard SUV	ICE	$721	$1,225	$1,945
Rivian R1S	Standard SUV	AEV	$435	$1,081	$1,517

Fees

Table A2-5. Fees, County Fleet TCO

Fee	Amount	Source
Annual Registration Fee - Sedans	$30.75	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf
Annual Registration Fee - Small SUVs	$30.74	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf
Annual Registration Fee - Standard SUVs	$44.75	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf

Resale Value

The expected resale value of vehicles at the end of their useful life is based on a standard depreciation forecast used by the Department of Energy's AFLEET tool[62]. All vehicles are assumed to lose 29% of their value after the first year, and 11% each subsequent year.

[62] US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Private Vehicles

Purchase Price

Table A2-6. Vehicle Purchase Prices, Private Vehicles TCO

Vehicle	Vehicle Class	Powertrain	MSRP	Source
Toyota Camry	Sedan	ICE	$25,945	https://www.toyota.com/camry/
Nissan Leaf	Sedan	AEV	$27,800	https://www.kbb.com/nissan/leaf/
Hyundai Kona	Small SUV	ICE	$21,300	https://www.edmunds.com/hyundai/kona/2022/
Hyundai Kona EV	Small SUV	AEV	$34,000	https://www.edmunds.com/hyundai/kona-electric/
Ford Explorer	Standard SUV	ICE	$35,510	https://www.ford.com/suvs/explorer/models/
Volkswagen ID.4	Standard SUV	AEV	$44,910	https://media.vw.com/en-us/releases/1661

Fuel/Energy Costs

Table A2-7. Inputs to Fuel/Energy Cost Calculations, Private Vehicles TCO

Input	Value	Source	Discussion
Gasoline Price	$4.243 / gal	https://gasprices.aaa.com/?state=VA	Monthly avg. on 7/20/22
Electricity Price	$0.1236 / kWh	https://findenergy.com/va/arlington-county-electricity/	Based on data reported to the Energy Information Administration
Annual Miles - Sedans	4,010 city / 2,990 hwy	https://www.thezebra.com/resources/driving/average-miles-driven-per-year/#average-miles-driven-per-year-by-state; VDOT Report ID VMT 1236	Average annual mileage for Virginia; City/Hwy miles based on 2020 VMT data for Arlington County
Annual Miles - Small SUVs	4,010 city / 2,990 hwy	https://www.thezebra.com/resources/driving/average-miles-driven-per-year/#average-miles-driven-per-year-by-state; VDOT Report ID VMT 1236	Average annual mileage for Virginia; City/Hwy miles based on 2020 VMT data for Arlington County

Input	Value	Source	Discussion
Annual Miles - Standard SUVs	4,010 city / 2,990 hwy	https://www.thezebra.com/resources/driving/average-miles-driven-per-year/#average-miles-driven-per-year-by-state; VDOT Report ID VMT 1236	Average annual mileage for Virginia; City/Hwy miles based on 2020 VMT data for Arlington County
Fuel Economy – Toyota Camry	28 mpg/39 mpg (City/Hwy)	https://www.fueleconomy.gov/feg/noframes/44348.shtml	
Fuel Economy - Nissan Leaf	99 mpgge / 123 mpgge (City/Hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44446	
Fuel Economy – Hyundai Kona	29 mpg/35 mpg (City/Hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=43763	
Fuel Economy – Hyundai Kona EV	108 mpgge/132 mpgge (City/Hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=44444	
Fuel Economy – Ford Explorer	18 mpg/24 mpg (City/Hwy)	https://www.fueleconomy.gov/feg/noframes/43289.shtml	
Fuel Economy – Volkswagen ID.4	98 mpgge / 116 mpgge (City/Hwy)	https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=45259	

Maintenance and Repairs

Estimates of maintenance and repair (M&R) costs for privately owned vehicles were made utilizing a model based on a systematic analysis of light-duty vehicle sets in the U.S[63]. The model reflects that maintenance and repair expenditures are influenced by annual vehicle usage, as more driving requires more scheduled maintenance and increases the likelihood of repairs. For maintenance costs, AEVs have 41% lower costs on a per-mile basis, and no difference was found between Sedan and SUV vehicle classes. For repairs, the model estimates annual repairs (exceeding warranty coverage) based on vehicle class, powertrain, and MSRP. This method accounts for differences in powertrain, MSRP, and vehicle usage, reflecting real-world data that indicates AEVs have lower M&R costs and that more expensive vehicles tend to cost more to repair.

[63] Argonne National Laboratory, US Department of Energy. 2021. Comprehensive Total Cost of Ownership Quantifications for Vehicle with Different Size Classes and Powertrains.

Table A2-8. Maintenance and Repair (M&R) Cost Estimates, Private Vehicles TCO

Vehicle	Vehicle Class	Powertrain	Estimated Annual Maintenance	Estimated Annual Repairs	Total Annual M&R
Toyota Camry	Sedan	ICE	$707	$192	$899
Nissan Leaf	Sedan	AEV	$4,27	$134	$561
Hyundai Kona	Small SUV	ICE	$707	$159	$866
Hyundai Kona EV	Small SUV	AEV	$4,27	$138	$565
Ford Explorer	Standard SUV	ICE	$707	$212	$919
Volkswagen ID.4	Standard SUV	AEV	$427	$171	$598

Fees

Personal property tax was calculated for each vehicle based on Arlington County's 2022 set tax rate of $5 on every $100 of assessed value[64]. The assessed value in each year was based on a standard depreciation forecast used by the Department of Energy's AFLEET tool[65]. All vehicles were assumed to lose 29% of their value after the first year, and 11% each subsequent year. ICE vehicles were assumed to pay the full tax rate in each year with no exemptions. The qualifying clean-fuel vehicles tax relief was applied to AEVs, which provides:

- 100% relief on the first $3,000 of assessed value;
- 50% relief on next $17,000 of assessed value, from $3,001 to $20,000;
- no exemption on value over $20,000

[64] Arlington County, Virginia. Vehicle Personal Property Tax Assessments. https://www.arlingtonva.us/Government/Programs/Taxes/Vehicles/Vehicle-Personal-Property-Tax-Assessments.
[65] US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Table A2-9. Personal Property Tax Estimates, Private Vehicles TCO

Vehicle	Vehicle Class	Powertrain	Total Personal Property Taxes, Years 1 - 10
Toyota Camry	Sedan	ICE	$6,305
Nissan Leaf	Sedan	AEV	$2,478
Hyundai Kona	Small SUV	ICE	$5,176
Hyundai Kona EV	Small SUV	AEV	$3,372
Ford Explorer	Standard SUV	ICE	$8,630
Volkswagen ID.4	Standard SUV	AEV	$5,257

Table A2-10. Annual Registration Fees

Item	Amount	Source
Annual Registration Fee – Sedans	$30.75	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf
Annual Registration Fee – Small SUVs	$30.74	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf
Annual Registration Fee – Standard SUVs	$44.75	https://www.dmv.virginia.gov/webdoc/pdf/dmv201.pdf

Resale Value

The expected resale value of vehicles at the end of their useful life is based on a standard depreciation forecast used by the Department of Energy's AFLEET tool[66]. All vehicles are assumed to lose 29% of their value after the first year, and 11% each subsequent year.

[66] US Department of Energy. Alternative Fuel Life-Cycle Environmental and Economic Transportation (AFLEET) Tool. https://greet.es.anl.gov/afleet_tool.

Appendix 3: Listing of Commercially Available EVs

The following tables are based on information from **http://www.evadoption.com**.

Table A3-1. Commercially Available New PHEVs in the US, September 2022

Make/Model	EPA Range	MSRP	Battery (kWh)	Miles/kWh
Kia Niro PHEV	26	$25,590.00	8.9	2.92
Toyota Prius Prime	25	$28,670.00	8.8	2.84
Hyundai Tuscon Plug-In Hybrid	33	$35,400.00	13.8	2.39
Ford Escape PHEV	37	$35,455.00	14.4	2.57
Subaru Crosstrek PHEV	17	$36,345.00	8.8	1.93
Mitsubishi Outlander PHEV	24	$36,995.00	13.8	1.74
Kia Sportage PHEV	32	$38,490.00	13.8	2.32
Hyundai Santa Fe PHEV	30	$40,000.00	12.4	2.42
Toyota RAV4 Prime	42	$40,300.00	18	2.33
Mini Countryman SE PHEV	18	$41,500.00	10	1.8
BMW 330e	23	$42,950.00	12	1.92
Kia Sorento Plug-in Hybrid SX	32	$45,190.00	13.8	2.32
Chrysler Pacifica Hybrid	32	$46,978.00	16	2
Volvo S60 T8 Recharge PHEV	40	$47,650.00	18.8	2.13
Jeep Wrangler 4xe	22	$47,995.00	17	1.29
Lincoln Corsair Grand Touring	28	$50,390.00	14.4	1.94
BMW 530e	20	$52,395.00	12	1.67
Volvo XC60 T8 PHEV	36	$53,895.00	18.8	1.91
Audi Q5 TFSI e PHEV	23	$55,400.00	17.9	1.28
Lexus NX 450h+	37	$55,650.00	18.1	2.04
Jeep Grand Cherokee 4xe	26	$60,695.00	17	1.53
Volvo S90 T8 PHEV	38	$64,645.00	18.8	2.02

Make/Model	EPA Range	MSRP	Battery (kWh)	Miles/kWh
BMW X5 xDrive 45e	31	$65,400.00	17	1.82
Volvo V60 Recharge	40	$67,300.00	18.8	2.13
Volvo XC90 T8 PHEV	35	$67,800.00	18.8	1.86
Lincoln Aviator Grand Touring	21	$68,680.00	14.4	1.46
Audi A7 TFSI e	26	$75,895.00	14.1	1.84
Porsche Cayenne S E-Hybrid	17	$79,900.00	11	1.55
Land Rover Range Rover Sport PHEV	19	$83,000.00	13	1.46
BMW 745e xDrive	17	$95,900.00	12	1.42
Land Rover Range Rover PHEV	19	$97,000.00	13	1.46
Porsche Panamera E-Hybrid	17	$99,600.00	11	1.55
Karma Revero GT	61	$144,800.00	28	2.18
Bentley Bentagya Hybrid	18	$156,900.00	13	1.38
Ferrari SF90 Stradale	9	$625,000.00	8	1.13

Table A3-2. Commercially Available New AEVs in the US, September 2022

Make/Model	EPA Range	MSRP	Battery (kWh)	Miles/kWh
Nissan LEAF	149	$27,800.00	40	3.73
Chevrolet Bolt EV	259	$31,500.00	60	4.32
Mazda MX-30	100	$33,470.00	35.5	2.82
Chevrolet Bolt EUV	247	$33,500.00	60	4.12
Hyundai Kona Electric	258	$34,000.00	64	4.03
Mini Cooper Electric SE Hardtop 2 door	115	$34,225.00	33	3.48
Ford F-150 Lightning	320	$39,947.00	98	3.27
Hyundai IONIQ 5	303	$39,950.00	77.4	3.91
Kia Niro EV	239	$39,990.00	64	3.73
Kia EV6	310	$40,900.00	77.4	4.01
Volkswagen ID.4	260	$41,230.00	77	3.38

Make/Model	EPA Range	MSRP	Battery (kWh)	Miles/kWh
Toyota bZ4X	252	$42,000.00	75	3.36
Ford Mustang Mach-E	300	$43,895.00	70	4.29
Tesla Model 3	267	$46,990.00	60.5	4.41
Polestar 2	233	$48,000.00	78	2.99
Audi Q4 e-tron	265	$48,800.00	82	3.23
Ford E-Transit	126	$49,575.00	68	1.85
Volvo XC40 Recharge	208	$53,990.00	78	2.67
Mercedes-Benz EQB	250	$54,500.00	66.5	3.76
BMW i4	301	$56,395.00	83.9	3.59
Audi Q4 e-tron Sportback	241	$56,800.00	82	2.94
Volvo C40	225	$58,750.00	78	2.88
Audi e-tron	222	$65,900.00	95	2.34
Tesla Model Y	318	$65,990.00	75	4.24
Audi e-tron Sportback	218	$69,100.00	95	2.29
Jaguar I-PACE	234	$69,500.00	90	2.6
Rivian R1S	295	$72,500.00	135	2.19
Rivian R1T	314	$73,000.00	135	2.33
Genesis Electrified G80	282	$79,825.00	80	3.53
BMW iX xDrive45	324	$84,010.00	105	3.09
Mercedes-Benz EQS	427	$102,310.00	107.8	3.96
Audi e-tron GT	238	$102,400.00	93	2.56
Porsche Taycan	201	$103,800.00	79	2.54
Tesla Model S	375	$104,990.00	100	3.75
GMC Hummer EV	320	$110,295.00	205	1.56
BMW i7	296	$119,300.00	100	2.96
Tesla Model X	332	$120,990.00	100	3.32
Lucid Motors Air	516	$154,000.00	118	4.37