ELECTRIFICATION ASSESSMENT OF PUBLIC VEHICLES IN WASHINGTON

A vehicle-by-vehicle assessment of the electrification potential for publicly-owned vehicles

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Washington state is positioned to cost effectively electrify nearly all public vehicle procurements by the year 2035. With near-term policy action and targeted investments in infrastructure, the state can accelerate ongoing efforts to advance electric vehicles and solidify its leadership position in the electric vehicle market in the United States.

The study team, led by Atlas Public Policy, along with the Washington State University Energy Program and the National Renewable Energy Laboratory (NREL) evaluated the electrification potential for all publicly-owned vehicles in the state of Washington for the Washington Joint Transportation Committee (JTC). The goal of this report was to assess the potential of accelerating the conversion of Washington's public fleets to electric vehicles. This report provides Washington with comprehensive, vehicle-specific electrification cost estimates both today and in the future along with actionable information on how to efficiently move forward with fleet electrification.

EXECUTIVE SUMMARY

The case for cost effectively electrifying nearly all public vehicle procurements in Washington state looks very favorable over the timeline extending through 2035. Over time, it is expected that the cost savings from increased EV use will substantially reduce the overall costs of operating the state's public vehicle fleet. Public fleets throughout the state have already made progress toward electrifying both passenger vehicles and transit buses and technology advances in the medium- and heavy-duty vehicle sector are expanding the range of use cases where EV options are available. The cost of vehicle batteries is declining rapidly, resulting in more competitive vehicle options and lifetime cost savings in many cases. An increasing number of EVs on the road will require a similar increase in EV charging infrastructure deployment, but savings are still possible when including the full cost of charging infrastructure. By leveraging existing funds through the Volkswagen Settlement and state programs like the Clean Energy Fund, fleets around Washington can reduce the upfront costs associated with vehicle electrification and charging station deployment. The state is well positioned to cement its leaderships position in the EV market in the United States with swift near-term policy action that establishes clear goals and policy priorities along with a timeline for widescale fleet electrification by the end of this decade.

BACKGROUND ON THE EV MARKET IN THE UNITED STATES

The EV market in the United States is rapidly expanding with the light-duty passenger vehicle and transit bus markets already approaching maturity. EVs have become an attractive alternative to conventional vehicles because they operate at three to four times the efficiency of a conventional vehicle, can have zero tailpipe emissions and very low lifecycle emissions, are fueled by a locally-generated, low-cost energy source, and offer exceptional performance and a quiet driving experience.

A substantial expansion in the number of EV models available across all vehicle types is coming soon. This expansion of models will include options across all light-duty vehicle segments including ones where there is currently no EV alternative, such as pickup trucks. The expansion of the light-duty EV and EV charging market has been facilitated by EV sales requirements through California's Zero Emission Vehicle (ZEV) Program, which was adopted in Washington in March 2020. Washington has long been an EV leader and as of August 6, 2020, the state had 58,619 registered EVs, making it the third-largest EV market in the country behind California and Florida [1]. In addition, EVs made up over seven percent of new light-duty vehicle registrations in July 2020 in Washington, more than three times the national average [2].

Growth in the passenger EV market has influenced efforts to electrify medium- and heavy-duty vehicles. Transit bus electrification, in particular, is rapidly accelerating both across the United States and in Washington where King County Metro alone has committed to purchasing 120 electric transit buses worth $130 million, with other Transit agencies such as Link Transit, Everett Transit, and Spokane Transit among others all planning to expand existing electric bus operations through the end of 2020 [3, 4, 5, 6]. School bus model offerings have risen as well with increasing government funding being allocated for electrifying these vehicles. School districts in Washington are dedicated to furthering electrification efforts with at least 40 buses planned for deployment across the state. While other medium- and heavy-duty vehicles such as trucks have less well-develop markets, here too the potential for electrification is increasing as manufacturing costs continue to drop and new models and manufacturers enter the market.

An additional area of consideration for Washington is hydrogen vehicles due to the potential to leverage low-cost renewable energy to generate low-cost hydrogen (see Box ES-1).

Box ES-1: Consideration of Hydrogen Vehicles

Due to the limitations present in the hydrogen sector including limited model availability, lack of sufficient refueling infrastructure, and high upfront and fuel costs, the study team did not consider hydrogen fuel cell vehicles as viable alternatives to internal combustion vehicles currently owned by the state and did not include them in comparisons of total cost of ownership. Hydrogen vehicles do offer some advantages compared to battery electric vehicles, particularly regarding vehicle range and refueling times, but costs for light-duty and heavy-duty vehicles are not projected to be competitive with EVs in the near future in the absence of technological breakthroughs.

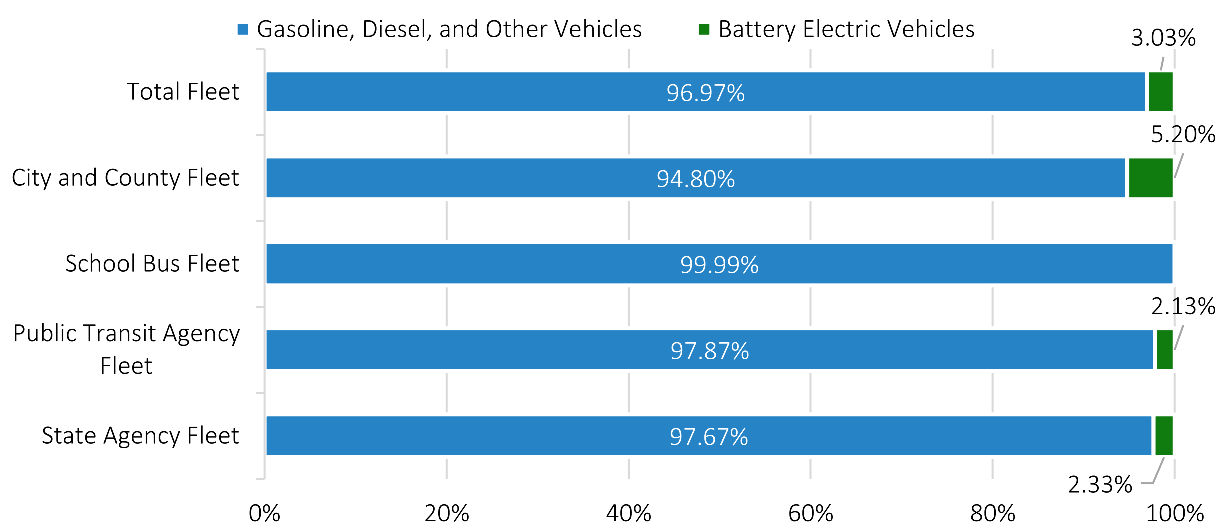
WASHINGTON HAS MORE THAN 56,000 PUBLIC VEHICLES

Recommendation: The study team recommends the state consider standardized tracking of key data fields, such as fuel type, across state and/or local government entities, and establish requirements for public agencies to notify the Department of Licensing about all vehicles removed from public fleets or exempt plates that are transferred to other vehicles. The study team also recommends Washington consider standardizing data collection related to duty cycles or operations, including typical average and peak miles traveled and miles traveled per year by vehicles, via telematics systems or otherwise.

This study sought to establish a baseline for the size and current electrification status of the public vehicle fleet in Washington state. To accomplish this, the study team collected data from multiple sources across Washington to create an inventory that includes 56,080 vehicles belonging to the public fleets studied including 12,987 stage agency vehicles, 9,222 public transit agency vehicles, 10,838 school buses, and an estimated 23,033 city and county vehicles. These vehicles were separated by their weight class as light-, medium-, or heavy-duty with each weight class representing approximately one-third of the total fleet. To ensure a comprehensive inventory and collect sufficient data for a total cost of ownership analysis, the study team requested data on vehicle make, model, year, fuel type, weight class designation (1-8), odometer readings, duty cycles, location, daily use range, maintenance costs, replacement plans, and Vehicle Identification Number (VIN). These data were not available for cities and counties and the study team relied on less detailed information from alternative fuels reporting data and a fleet questionnaire from a representative set of cities and counties across varying population sizes and locations. In total, detailed vehicle data was collected for 28,913 vehicles, including all types of light-duty vehicles and a wide range of medium- and heavy-duty vehicles, which were included in the total cost of ownership (TCO) analysis. A lack of detailed data for city and county fleets prevented their inclusion in the analysis, though the makeup and electrification potential of these fleets is likely similar to that of state agencies.

The results of the inventory show that the baseline electrification level of the fleet as of 2020 is low relative to targets already established by Washington, with electric vehicles accounting for approximately three percent of the overall fleet. The share of electric vehicles was considerably higher for light-duty vehicles at more than seven percent. Figure ES-1 provides a breakdown of the electrification status across the total inventory by fleet.

FIGURE ES-1: CURRENT ELECTRIFICATION STATUS OF PUBLIC FLEETS IN WASHINGTON



This figure shows the current electrification status for all fleets included in the study as a percentage of vehicles that are either battery electric or plug-in hybrids.

The study team collected and compiled disparate vehicle inventories from multiple sources, many of which followed different conventions for recording data. These inconsistencies across data sources presented challenges for creating a single, standardized inventory of public vehicles. Furthermore, the timeline of the data varied across sources, resulting in an inventory that reflects data from similar, but not precisely the same time period for all vehicles.

1,650+ OF THE VEHICLES ANALYZED CAN BE ELECTRIFIED COST EFFECTIVELY TODAY

Recommendation: To maximize EV deployment and savings, the state should consider prioritizing:

- Medium- and heavy- duty transit buses as these vehicles offered both the highest share of vehicles that qualified for electrification and the greatest savings.
- Light-duty vehicles for state agencies as these vehicles offered the potential for large scale electrification at a cost savings.

Recommendation: When electrifying vehicles, the state should consider pursuing:

- Right-sizing or selecting the least expensive EV alternative that meets the operational needs of a given vehicle, which could double the share of EVs deployed.
- Electrifying vehicles with high annual mileage.
- Smart charging systems or other means to avoid high electricity costs.
- Low-cost Level 2 charging solutions for light-duty vehicles.

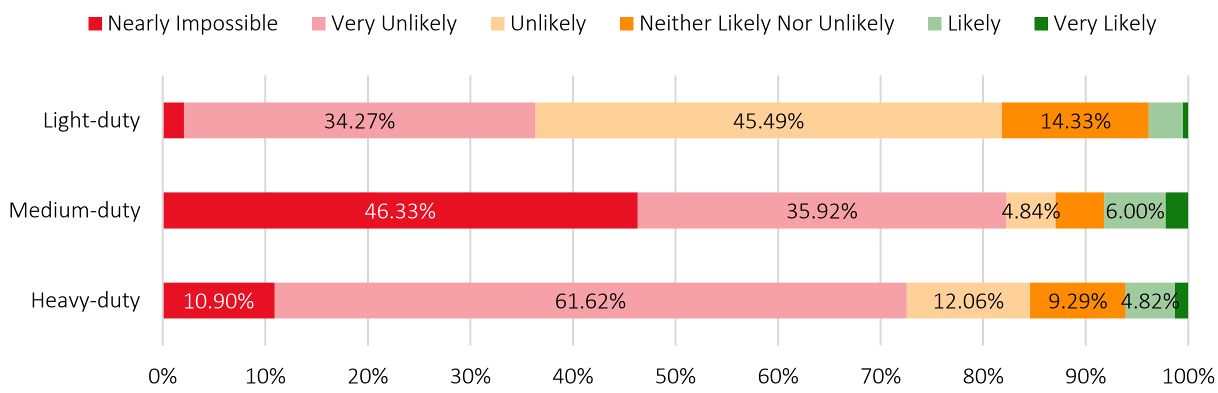
Overall, the vehicles share that had an EV within five percent of the conventional counterpart's total cost of ownership in the present day analysis was approximately six percent, or 1,650 vehicles out of the nearly 29,000 state agency, school district, and transit agency vehicles considered (see Box ES-3). The city and county fleets lacked sufficient detailed vehicle data and were excluded from the analysis, though insights can still be gained based on the results of this analysis (see Box ES-2). The cumulative savings from electrifying these vehicles was more than $72 million, primarily accounted for by substantial savings from transit bus electrification. However, these results varied widely across the fleets and scenarios included in the analysis ranging from more than 21 percent of the public fleet (6,175 vehicles) in the best case to two percent in the worst case.

Of the vehicles included in the analysis, medium-duty vehicles had the highest proportion that met the electrification threshold at more than eight percent. This was due to the high number of medium-duty transit buses which could be electrified cost effectively; almost no other medium-duty vehicles met the threshold. These were followed by heavy-duty vehicles and light-duty vehicles at six and four percent, respectively. Figure ES-2 shows the likelihood results in an initial deployment of EVs for all vehicles included in the analysis separated by weight class.

Box ES-2: City and County Fleets

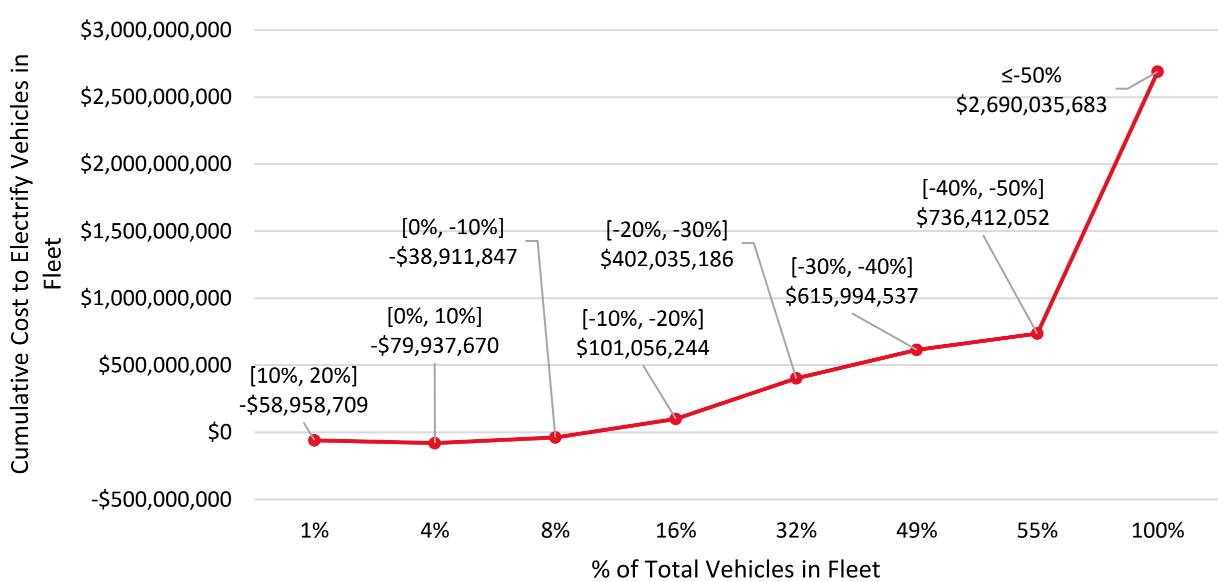
Due to lack of available detailed vehicle data for city and county fleets, these vehicles were not included in the TCO analysis. However, the makeup and electrification potential of these local government fleets is likely similar to that of state agencies; primarily light-duty vehicles serving in similar functions. One key difference between state agency and city and county fleets is access to resources necessary to properly plan for, procure, and install charging infrastructure. Smaller local governments in particular may need technical assistance for cost-effective electrification which could be provided by the state or local electric utility.

FIGURE ES-2: LIKELIHOOD RESULTS FOR ALL VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the likelihood results for all vehicles included in the analysis broken down by weight class.

FIGURE ES-3: CUMULATIVE COST TO ELECTRIFY ALL VEHICLES IN AN INITIAL EV DEPLOYMENT

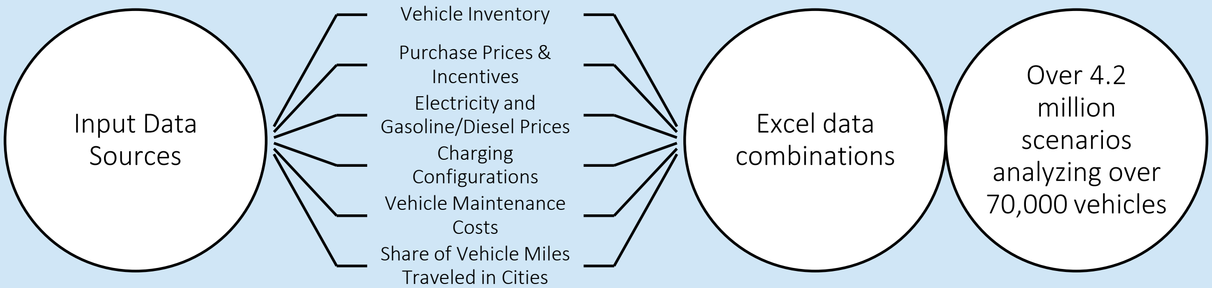


This figure shows the cumulative cost or savings to electrify all vehicles included in the analysis in an initial deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $2.7 billion on average to electrify all vehicles included in the analysis, though it could electrify nearly 10 percent of vehicles at an average savings of more than $38.9 million.

Box ES-3: A Comprehensive Approach to Analyzing Public Vehicles in Washington

To accurately assess the electrification potential of public vehicles in Washington state, the project team performed a vehicle-by-vehicle total cost of ownership (TCO) analysis on all vehicles for which sufficient data was available and for which at least one EV alternative existed. This analysis compared the TCO of existing internal combustion vehicles in the public fleet with up to three electric alternatives under a wide array of scenarios both in the present day and in the years 2025, 2030, and 2035. In total the study team analyzed the electrification potential of nearly 29,000 vehicles under a wide range of scenarios including variations in electricity prices, EV models, charging configurations, and public policies. Figure ES-4 depicts the process of data aggregation and transformation performed to create the TCO analysis.

FIGURE ES-4: DATA MODEL FOR TCO ANALYSIS



The results of this analysis were used to determine whether vehicles qualified for electrification based on the criteria established in WAC 194-28 where any internal combustion vehicle for which an EV alternative was within five percent of the TCO met the threshold for electrification. To further quantify the electrification potential of vehicles, the study team assigned a likelihood of electrification to each vehicle. Likelihood of vehicle electrification was separated into six categories: Very Likely, Likely, Neither Likely nor Unlikely, Unlikely, Very Unlikely and Nearly Impossible. These likelihood categories were defined based on the percentage difference in average TCO across all scenarios between an EV and an equivalent internal combustion vehicle. Table ES -1 provides a breakdown of Likelihood categories used in the study.

TABLE ES-1: LIKELIHOOD CATEGORIES FOR ELECTRIFICATION

Likelihood Category	TCO Percentage Difference from Internal Combustion Equivalent
Very Likely	At least 10% lower
Likely	Between 10% lower and 5% higher
Neither Likely nor Unlikely	Between 5% and 20% higher
Unlikely	Between 20% and 35% higher
Very Unlikely	Between 35% and 100% higher
Nearly Impossible	More than 100% higher

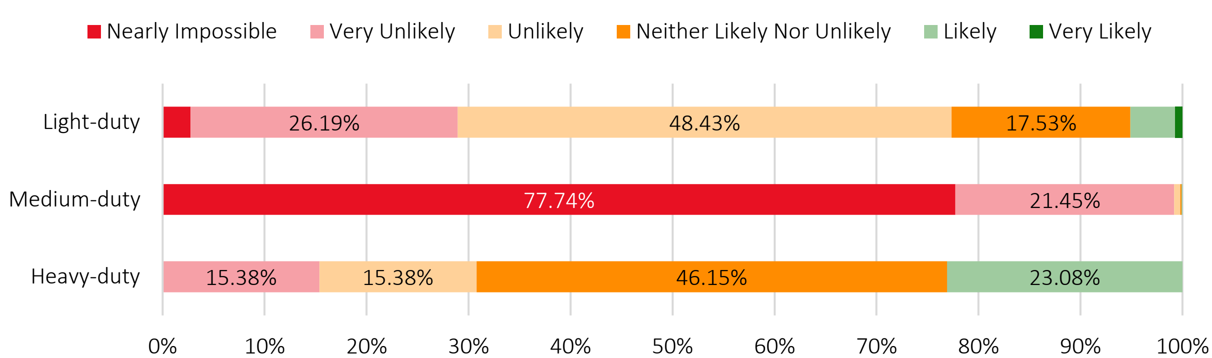
In addition, the study team evaluated the electrification potential of vehicles when EVs are first deployed and upon subsequent EV deployments. For the case when EVs are first deployed, the study team averaged the TCO results for EVs across all scenarios under consideration, including various charging configurations, EV models, and electricity rates. For subsequent EV deployments, the study team limited the scenarios under consideration to just those that modeled the cost of charging infrastructure for a subsequent EV purchase; in these cases, the analysis assumed there would be no cost for construction and electrical grid upgrades. The subsequent scenario is intended to reflect the long-term savings potential of EVs once the upfront investments in charging infrastructure have already been made.

From a cost perspective, government can electrify many thousands of vehicles today at a net savings. As mentioned above, using a TCO threshold of 5 percent yields 1,650 vehicles but government can electrify nearly 2,500 vehicles at a net savings of more than $38 million on average. Figure ES-3 shows the net cost of electrification as the TCO threshold is increased. As shown in the figure, it is infeasible to electrify all public vehicles in Washington today.

STATE AGENCY ANALYSIS RESULTS

Aside from the small number of heavy-duty vehicles analyzed, light-duty state agency vehicles offered the most compelling case for electrification with more than five percent of vehicles meeting the threshold for electrification. Crucially, nearly a quarter of vehicles fell within 20 percent of the TCO of an internal combustion equivalent and could easily meet the five percent threshold for electrification with only slight shifts in the factors such as vehicle selection, charging configuration, or electricity price. This was true even in a market where EV alternatives for several common use cases like pickup trucks are currently limited to expensive luxury models. The results for medium-duty vehicles indicated that the market for these vehicles is still in its infancy and will need to further develop before large-scale electrification is financially feasible. Figure ES-5 shows the likelihood results for all state agency vehicles by weight class in an initial EV deployment.

FIGURE ES-5: LIKELIHOOD RESULTS FOR ALL STATE AGENCY VEHICLES



This figure shows the likelihood results for all state agency vehicles included in the analysis separated by weight class

FINDING: LIGHT-DUTY VEHICLES NEAR THE TIPPING POINT FOR LARGE-SCALE ELECTRIFICATION

Government can electrify a large number of passenger vehicles in the current market and any savings the state can achieve from incentives, vehicle selection, price reductions, or charging infrastructure planning can cause large shifts in the number of vehicles that can be electrified cost effectively. This finding applies across both the initial and subsequent deployment scenarios and is true for a market in which pickups, the second most common type of vehicle owned by the state, and large SUVs only have luxury options available as EV alternatives. The cumulative savings from fleet electrification exceeds the cost for over 20 percent of the light-duty fleet when modeling an average savings of just $3,700, or approximately half of the currently available federal incentive for light-duty EVs. This represented a near doubling of the number of vehicles that could be electrified in the absence of that discount. Slight shifts in the TCO analysis can mean the difference between cost-effective electrification of thousands of vehicles.

FINDING: EXPENSIVE EV OPTIONS REDUCE ELECTRIFICATION LIKELIHOOD OF MEDIUM-DUTY VEHICLES IN THE PRESENT DAY

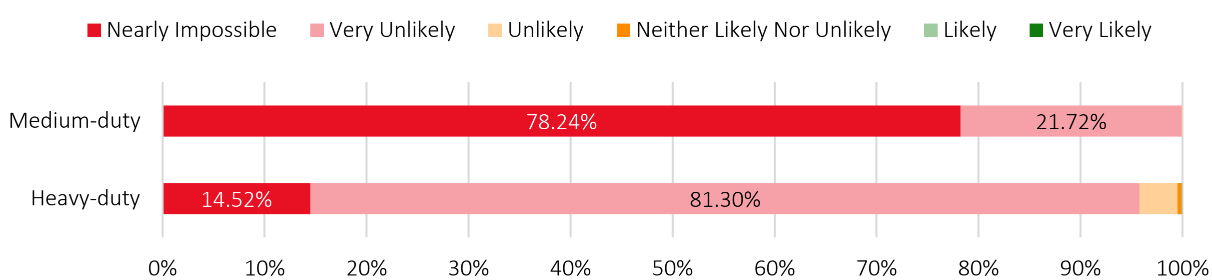
Electrifying medium-duty vehicles in the state agency fleets was considerably less cost-effective than light-duty vehicles with many EV alternatives having a TCO more than 100 percent higher than their internal combustion counterparts. Before attempting wide-scale electrification, this market segment will need to develop beyond offerings from small manufacturers.

By contrast, the heavy-duty EVs included in the state agency analysis had smaller upfront price premiums than medium-duty EVs. The lower price premium for these vehicles along with high annual mileage meant that heavy-duty EVs could often accumulate enough operational cost savings to meet the five percent threshold for electrification. Refuse trucks, in particular, offered substantial potential savings with over 35 percent of trucks meeting the five percent threshold for electrification even when burdened by the full cost of charging infrastructure installation.

SCHOOL BUS FLEET ANALYSIS RESULTS

The analysis results demonstrated that school buses were not cost-effective targets for electrification for all but a handful of vehicles. Electrifying even one percent of the fleet could come at substantial additional cost in the absence of policy interventions. Figure ES-6 shows the likelihood results for all school buses by weight class in an initial EV deployment.

FIGURE ES-6: LIKELIHOOD RESULTS FOR ALL SCHOOL BUSES



This figure shows the likelihood results for all school buses included in the analysis separated by weight class

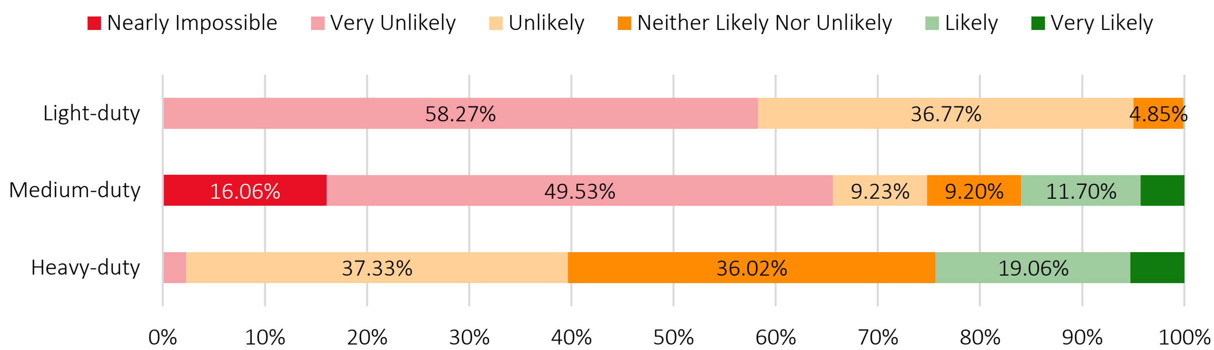
FINDING: GRANT FUNDING IS ESSENTIAL FOR COST EFFECTIVE SCHOOL BUS ELECTRIFICATION IN THE NEAR TERM

School buses had the lowest share of vehicles that met the five percent threshold for electrification across all fleets. These vehicles had low annual mileage and any operational cost savings from lower maintenance costs, greater fuel economy, or cheaper fuel did not accumulate enough to bring electric school buses within five percent of their internal combustion counterparts for all but a handful of vehicles. Although Washington already has at least one electric school bus in operation with plans to deploy 40 more, school districts have relied on grant funding from the Department of Ecology (resulting from the Volkswagen Settlement) to help defray the incremental costs for electric buses. Grant funding along with other incentives will remain a critical component for the electrification of school buses in the near future.

TRANSIT FLEET ANALYSIS RESULTS

Outside of light-duty vehicles, transit vehicles were the most cost-effective to electrify across all vehicles included in the analysis and should be a priority for future electrification efforts. Electrifying all vehicles that met the five percent threshold would result in a cumulative savings of more than $70 million. If the state were to apply these savings toward vehicles with less compelling cases for electrification, it could electrify more than 20 percent of all transit agency vehicles before incurring additional costs. Figure ES-7 shows the likelihood results for all transit agency vehicles by weight class in an initial EV deployment.

FIGURE ES-7: LIKELIHOOD RESULTS FOR ALL TRANSIT AGENCY VEHICLES



This figure shows the likelihood results for all transit vehicles included in the analysis separated by weight class

FINDING: 30% OF MEDIUM-DUTY TRANSIT BUSES COULD BE ELECTRIFIED FOR $400,000

In comparison to the medium-duty trucks and vans included in the state agency analysis, medium-duty shuttle buses were substantially more cost effective to electrify due to lower average price premiums and high annual mileage. The cumulative cost to electrify all medium-duty vehicles for which an EV was within 30 percent of the TCO of an internal combustion equivalent, representing 30 percent of the total fleet included in the analysis, was less than $400,000. To electrify an additional ten percent of the medium-duty bus fleet, or 1,276 vehicles in total, would result in a cumulative cost of just $14.3 million, which is $2.3 million more than the most recently approved funding for the Green Transportation Capital Grant program. When discounting the cost of charging infrastructure under a subsequent EV deployment, these figures improve markedly with electrification of 46 percent of fleet achieving a cumulative savings of more than $1.2 million. As the market continues to mature and the upfront price premium for these vehicles falls, electrification for most medium-duty vehicles owned by transit agencies should come within reach.

FINDING: HEAVY-DUTY TRANSIT BUSES WERE THE MOST COST-EFFECTIVE VEHICLE TYPES TO ELECTRIFY

The results of the TCO analysis indicate that heavy-duty transit buses were the most cost-effective vehicles to electrify across the entire public fleet in Washington state. In the initial EV deployment scenario which includes the full cost of charging infrastructure equipment and installation, more than 24 percent of buses, or 706 vehicles, met the threshold for electrification. Transit buses are typified by both high upfront and operational costs with buses typically costing in excess of $500,000 and traveling more than 30,000 miles per year. Given the high costs associated with these vehicles, even small percentage savings in the total cost of ownership can represent large sums of money. Electrifying the 706 vehicles that met the five percent threshold for electrification would result in a savings of $61.6 million on average.

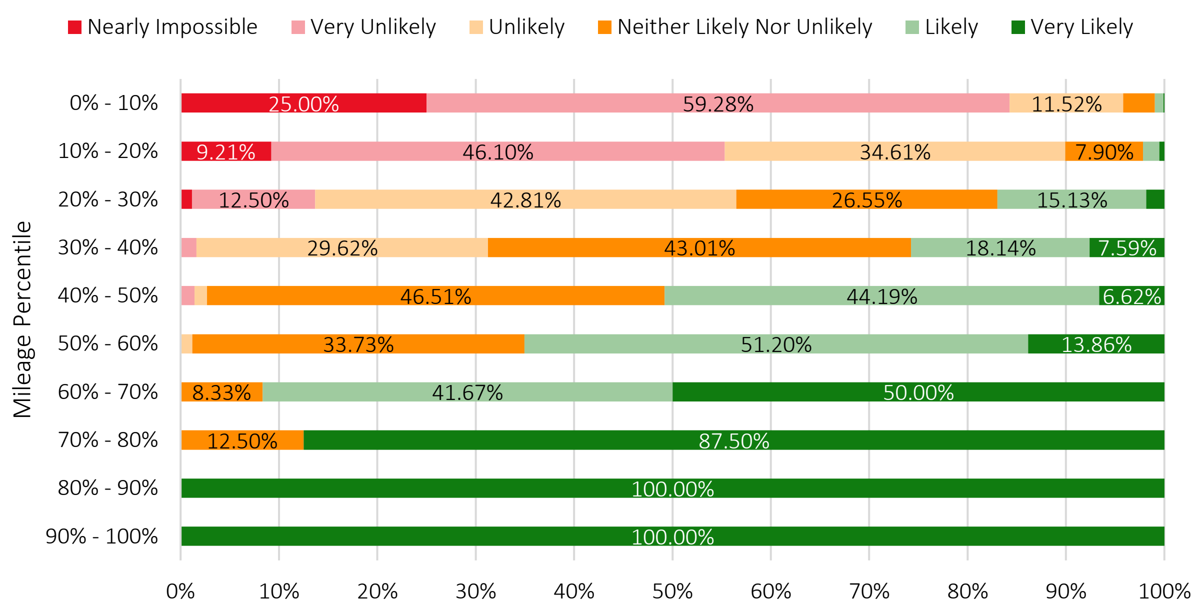
Increasing the TCO threshold from within five to 20 percent of internal combustion buses adds 1,045 vehicles, bringing the total number of electrified vehicles to 1,751 or nearly 60 percent of the fleet. However, electrification of these vehicles would come at a substantial additional expense resulting in an average incremental cost for transit agencies of $155.1 million.

VEHICLE CHARACTERISTICS

FINDING: OTHER THAN VEHICLE PRICE, VMT INFLUENCED EV COST COMPETITIVENESS THE MOST

The higher the annual mileage for an EV, the more operational cost savings from reduced fuel and maintenance costs it accumulates. Not only were vehicles with high annual mileages more likely to meet the five percent TCO threshold for electrification, they also offered considerable additional savings. The average per-vehicle savings from electrifying vehicles in the 10th percentile of annual mileage was just under $1,600. The average per-vehicle savings from electrifying vehicles in the 90th percentile of annual mileage was more than $620,000. On average, per-vehicle savings increased by 134 percent for each of the percentile bands. Figure ES-8 highlights the different likelihood of electrification at different mileage percentiles.

FIGURE ES-8: LIKELIHOOD RESULTS FOR ALL VEHICLES BY ANNUAL MILEAGE



This figure shows the likelihood results for all 28,913 vehicles included in the analysis by their annual mileage percentile where 0-10% are vehicles that traveled 10,460 or less miles per year and 90%-100% are vehicles that traveled 94,000 or more miles per year.

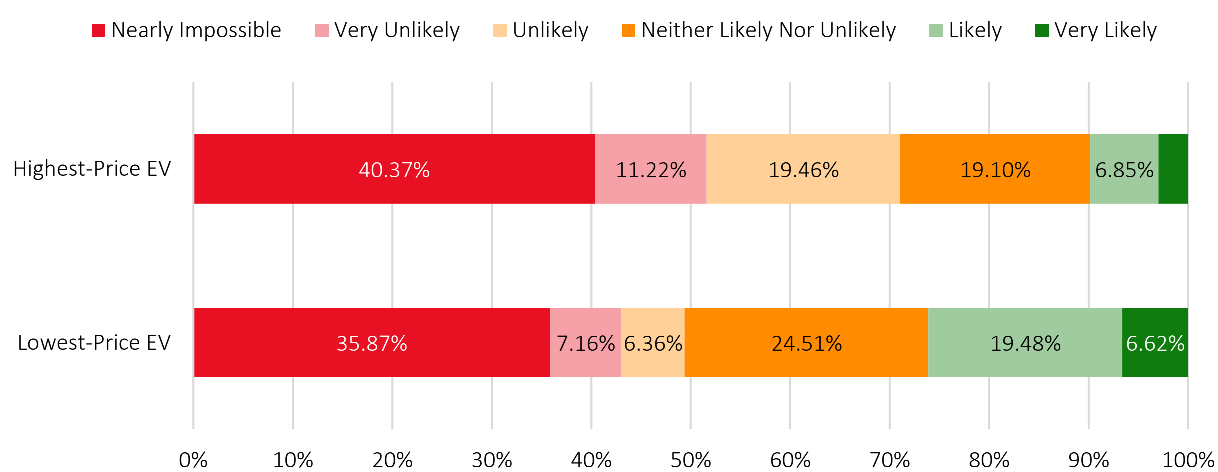
FINDING: SMART CHARGING CAN MITIGATE ELECTRICITY DEMAND CHARGES

Electricity demand charges, costs resulting from high electricity draw which were estimated to double the electricity price, decreased the number of vehicles that met the five percent threshold for electrification by more than 50 percent. Demand charges can be mitigated by smart charging software which can limit the total electricity draw across multiple charging stations and was shown to reduce the costs associated with demand charges by 50 percent in a study by the National Renewable Energy Laboratory [7].

FINDING: RIGHT-SIZING EV MODEL SELECTION HAD THE MOST SIGNIFICANT EFFECT ON ELECTRIFICATION POTENTIAL OVERALL

Of all procurement aspects considered in this analysis, vehicle selection had the largest effect on the electrification potential of public vehicles in Washington state. The study team included several EV alternatives, which offered slight variations in capability and price, for most vehicles. For example, school buses with a lower range that still met the minimum operational requirements offered an upfront savings of more than $50,000 on average. Optimizing the vehicle selection increased the number of vehicles that met the five percent threshold by 160 percent from 2,846 to 7,547 (see Figure ES-9). Electrifying these vehicles would result in an additional savings of $61.8 million and bring the total cumulative savings to more than $164.3 million. Without changing any state policy or allocation of additional funds, fleet managers could generate substantial additional savings and electrify more vehicles by only targeting lower priced EVs when replacing internal combustion vehicles. King County Metro has recognized the benefits of right-sizing vehicle procurements to meet the needs of a use case using the least expensive EV alternative. For their MetroPool commuter program, King County is purchasing Nissan Leaf vehicles which offer an upfront savings of over 11 percent compared to the least expensive electric van option while still providing comparable service in many cases.

FIGURE ES-9: LIKELIHOOD RESULTS FOR ALL VEHICLES WHEN SELECTING THE LOWEST AND HIGHEST-PRICE EV ALTERNATIVES



This figure shows the likelihood results for all vehicles when choosing the highest- and lowest-price EV alternative.

FINDING: LOW-COST CHARGING CONFIGURATIONS HAD GREATEST INFLUENCE ON LIGHT-DUTY ELECTRIFICATION POTENTIAL

Variations in charging infrastructure cost could have significant impacts on the electrification potential of light-duty vehicles. Costs for charging configurations for light-duty vehicles ranged from $6,105 for the most expensive configuration to $1,520 for the least expensive configuration. Moving from the highest- to lowest-cost charging configuration resulted in an additional 548 vehicles meeting the threshold for electrification in an initial EV deployment, more than tripling from 226 to 774.

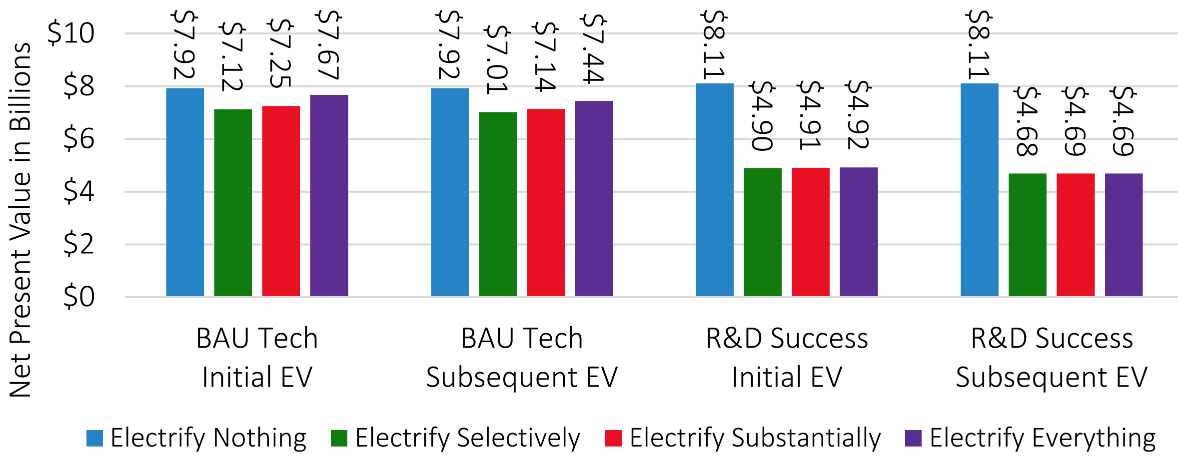
The overall results for medium-duty and heavy-duty vehicles indicate that choice of charging configuration was unimportant for determining a vehicle's electrification potential, largely due to the high average price premiums for many of these vehicles and the low share of TCO accounted for by charging infrastructure. However, this was not true for medium- and heavy-duty transit vehicles which were already largely cost competitive with their internal combustion counterparts, demonstrating the importance of charging configuration optimization for competitively priced vehicles.

WASHINGTON CAN REALIZE BILLIONS IN SAVINGS FROM ELECTRIFICATION BY 2035

Recommendation: The state should consider developing a roadmap to swiftly increase the share of EVs in the public fleet between 2020 and 2035 to achieve billions in fleet cost savings.

Washington can realize billions in savings by pursuing a strategy of rapid electrification of the public fleet. The results of this analysis show that even under the worst case assumptions for technology advancement and EV deployment considered in this study, more than 50 percent of the nearly 29,000 vehicles analyzed would have an EV alternative within five percent of the TCO of an internal combustion equivalent by the year 2035 and could achieve an average cumulative cost savings of nearly $800 million from electrification. If the electrification threshold were increased to 20 percent of the TCO of an internal combustion vehicle, then 75 percent of vehicles could be electrified by 2035 while still achieving a cumulative cost savings of nearly $670 million. Even 100 percent electrification of the vehicles included in the analysis would result in a cumulative savings of more than $250 million by 2035. When assuming cost-saving innovations in technology and reduced charging infrastructure costs, 100 percent fleet electrifications results in considerably more savings, totaling more than $3.4 billion (see Figure ES-10)

FIGURE ES-10: LIFETIME FLEET COSTS IN 2035 UNDER VARIOUS TECHNOLOGY, INFRASTRUCTURE, AND POLICY SCENARIOS



This chart shows the total lifetime fleet costs (in billions of U.S. dollars) for all vehicles under different policy scenarios in year 2035. The results presented are for an initial EV deployment under a BAU Tech scenario. As technology improves and EV costs come down, the cost of the Electrify Everything scenario decreases considerably over time.

In order to achieve these savings, the state would need to pursue a strategy of rapid electrification between 2020 and 2035. By 2035, nearly all vehicles analyzed in the study will likely meet the TCO threshold for electrification, but many will likely achieve that threshold well before then; the state would need to prioritize electrifying those vehicles to achieve operational savings as soon as possible. Under a business-as-usual assumption for technology advancement and EV deployment, the state could still cost-effectively electrify 17 percent of the total fleet by 2025 and 34 percent by 2030. If cost saving innovations in technology are achieved, that figure could be as high as 79 percent by 2030. With more than 90 percent of the vehicles included in the analysis set to exceed their useful lives within the next ten years, there is a significant opportunity for the state to both advance electrification and achieve substantial cost savings by pursuing a strategy of rapid electrification.

To ensure the state realizes the maximum savings from fleet electrification Washington's strategy for fleet electrification should consider requiring periodic fleet evaluations and frequent monitoring of vehicle availability. To ensure vehicles with large, expected savings are prioritized for electrification the state should consider conducting periodic reviews of the TCO for EVs and conventional vehicles. The state should also consider the aggregated TCO for all vehicles to be purchased and invest the higher savings from electrification for some vehicles into the electrification of additional vehicles with lower savings potential. This strategy would allow both for accelerated pace of electrification and the opportunity to realize additional savings from subsequent EV purchases that can rely on existing charging infrastructure.

Box ES-4: Approach to TCO Analysis for the Future

A future analysis of the TCO of electrification considered the four policy scenarios included in Table ES-2.

TABLE ES-2: ELECTRIFICATION POLICY SCENARIOS

Scenario Name	Electrification Criteria
Electrify Nothing	None of the vehicles in the public fleet are electrified.
Electrify Selectively	Vehicles that meet the "Likely" or "Very Likely" TCO criteria are electrified.
Electrify Substantially	Vehicles that meet the "Neither Likely nor Unlikely", "Likely", or "Very Likely" TCO criteria are electrified.
Electrify Everything	All the vehicles in the public fleet are electrified.

In addition to these scenarios, electrification potential was analyzed for several combinations of deployment and technology scenarios. This inspection will carry forward the previously described scenarios: EV Deployment (Initial EV and Subsequent EV) and Technology Development (BAU Tech and R&D Success). The combination of these two dimensions represent a total of four scenarios as shown in Table ES-3.

TABLE ES-3: PROJECTED TCO SCENARIO MATRIX

		Technology Scenario	
		Business as Usual Technology	R&D Success
Deployment Scenario	Initial EV	BAU Tech + Initial EV	R&D Success + Initial EV
	Subsequent EV	BAU Tech + Subsequent EV	R&D Success + Subsequent EV

The subsequent EV deployment scenario differs from the initial in that charging costs are reduced to reflect the long-term savings potential of EVs once the upfront investments in charging infrastructure have already been made. The R&D Success technology scenario differs from the Business as Usual scenario in that it considers a future where aspirational technology targets are met.

While the projected TCO analysis provides a positive outlook for the economic viability of EVs in the public fleet, it should be noted that this analysis did not consider vehicle- or route-specific driving requirements or the distribution of daily vehicles miles necessary to accommodate substantial levels of electrification. Based on the data available, EV alternatives were selected based on average, or typical, daily range requirements. Right sizing electric range for agency-specific applications could likely require larger or smaller vehicle battery packs than considered in this analysis (along with corresponding charging infrastructure) and could affect the study findings.

STATE AGENCY TCO ANALYSIS RESULTS

FINDING: UP TO 97% OF STATE AGENCY LIGHT-DUTY VEHICLES CAN BE ELECTRIFIED AT A CUMULATIVE SAVINGS BY 2025

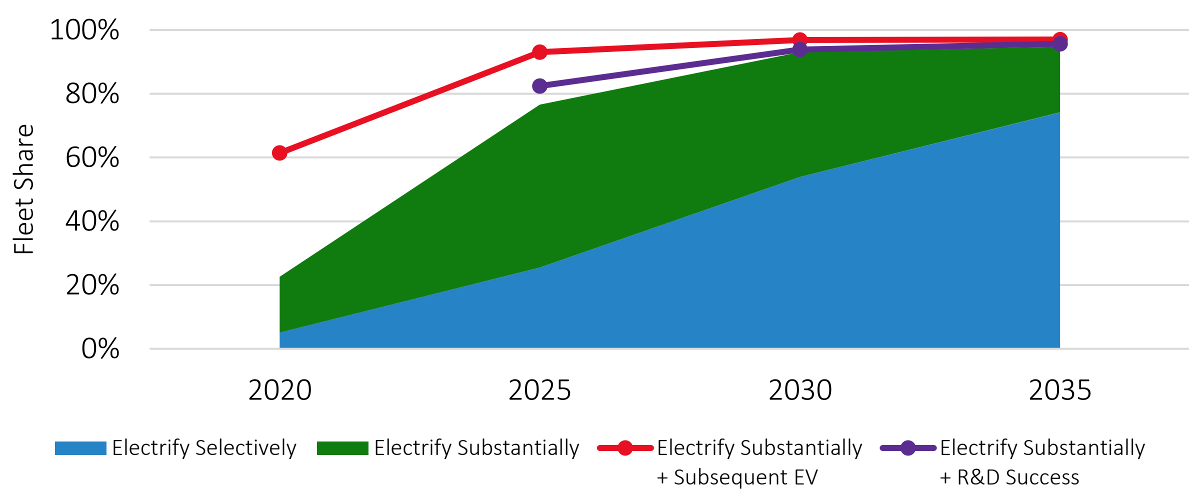
Less than 10 percent of light-duty vehicles in 2020 met the threshold for electrification in an initial EV deployment. As automotive technology costs decline, EVs become a competitive alternative for over 66 percent of this fleet segment by 2025 when discounting the cost of charging infrastructure. The more aggressive policy approach of electrifying all vehicles for which an EV is within 20 percent of the TCO of an internal combustion equivalent results in over 90 percent of the fleet meeting the threshold for electrification by 2025 when discounting charging infrastructure (see Figure ES-11). This figure can be further expanded to 97 percent of vehicles while still achieving a cumulative cost savings of more than $2.2 million. Technology cost evolution is less impactful in the light-duty sector and Washington will not need to rely on technological breakthroughs before pursuing large-scale electrification of these vehicles. These general trends were also seen for light-duty vehicles operated by transit agencies.

SCHOOL BUS TCO ANALYSIS RESULTS

FINDING: R&D SUCCESS HAS MOST PROFOUND IMPACT ON LIKELIHOOD OF SCHOOL BUS ELECTRIFICATION BY 2030

As is the case with other medium- and heavy-duty vehicles, school bus TCO projections were not impacted significantly by the installation cost of infrastructure. However, the share of electric buses that were within 20 percent of the TCO of their internal combustion equivalents is projected to reach nearly 100 percent by 2030 under the R&D Success scenario. This result reflects projections for the manufacturing cost of heavy-duty electric school buses to decrease significantly over the next decade as a result of innovations in battery technology and manufacturing volumes.

FIGURE ES-11: PERCENT OF LIGHT-DUTY VEHICLES IN STATE AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (BAU TECH SCENARIO)



This figure shows the share of light-duty fleet vehicles that would be electrified when the TCO threshold for electrification is met.

TRANSIT AGENCY TCO ANALYSIS RESULTS

FINDING: AT LEAST 90% ELECTRIFICATION OF HEAVY-DUTY TRANSIT BUSES ARE LIKELY COST EFFECTIVE BY 2030

Heavy-duty transit buses become cost competitive at high levels of electrification faster than any other technology in the most unfavorable policy, technology, and deployment scenarios. For heavy-duty vehicles, the share of vehicles meeting the TCO electrification threshold is projected to increase steadily this decade under the business-as-usual technology scenario and exceed 90 percent of the fleet by 2030 and 95 percent of the fleet by 2035. Wide scale electrification is feasible for these vehicles as soon as 2025 with 64 percent of vehicles projected to meet the threshold for electrification by 2025 even under the business-as-usual technology scenario.

CHARGING INFRASTRUCTURE

FINDING: CHARGING INFRASTRUCTURE REPRESENTS A SMALL BUT CRITICAL PORTION OF TOTAL ELECTRIFICATION COSTS

At the highest level of fleet electrification considered in this study, nearly 28,000 vehicles met the threshold for electrification by 2035. In this scenario, the fleet is supported by just under 10,000 charging stations of which nearly 53 percent are DC fast chargers. The cumulative cost for the purchase and installation of these charging stations would be approximately $311 million or just over five percent of the total cost of the fleet. Despite the relatively small costs, the installation of charging infrastructure is potentially the most critical component of fleet electrification and proactively installing charging infrastructure well in advance of vehicle procurement may be necessary to ensure that fleet managers can take advantage of volumes of scale when installing new charging infrastructure. Scale to decrease charging equipment and installation costs and scale to reduce the cost of upgrades to the depot's electrical infrastructure could all prove efficient in the long run.

FINDING: LARGE-SCALE ELECTRIFICATION OF THE PUBLIC FLEET WOULD LIKELY HAVE MINIMAL IMPACT ON THE ELECTRICAL GRID

While not the primary focus of this analysis, the electrical grid's ability to serve new load brought on by transportation electrification is a critical question. Washington has committed to 100 percent of electricity generation being greenhouse gas neutral by 2030 as required by the Clean Energy Transformation Act [8]. At the bulk system level, the study team has estimated that full electrification of the more than 56,000 public fleet vehicles would result in approximately 0.69 terawatt-hours (TWh) of new annual electric load from EV charging, or just 0.6 percent of total electricity demand as of 2018.

EMISSIONS REDUCTION BENEFITS

Electrifying all 28,913 vehicles included in the analysis could lead to an annual carbon dioxide (CO_2) reduction of nearly 750,000 tons, representing approximately two percent of total CO_2 emissions from the entire transportation sector in Washington in 2017 [9].

FINDING: HEAVY-DUTY VEHICLES ACCOUNT FOR MORE THAN 75% OF CO_2 AND PARTICULATE MATTER EMISSIONS

The electrification of heavy-duty vehicles accounted for the bulk of savings for both carbon emissions and particulate matter emissions, one of the primary determinants of air quality. Heavy-duty vehicle electrification represented 77 percent of CO_2 emission savings and 80 percent of particulate matter emissions savings, despite these vehicles accounting for only 40 percent of all vehicles analyzed. While electrification of the heavy-duty fleet is more costly, it also provides significantly greater marginal emissions savings across most emissions categories.

FINDING: EMISSION REDUCTION BENEFITS PRIMARILY CONCENTRATED ALONG MAJOR HIGHWAY CORRIDORS AND DENSE URBANIZED AREAS

Emissions benefits from public fleet electrification are not distributed evenly across the state. Areas with relatively large existing public fleets are expected to see the greatest emissions savings from fleet electrification. Specifically, Snohomish and King Counties had the highest levels of emissions savings from fleet electrification, followed closely by Pierce and Thurston Counties. The study team further broke down county-level emissions to reflect localized particulate matter emissions savings and found that emissions savings were concentrated along a few major corridors and urbanized areas with significant vehicle activity, such as along I-5, I-90, I-82, the greater Seattle region, Olympia, Tacoma, and Spokane.

FINANCING MECHANISMS AND PUBLIC POLICIES

Recommendation: To accelerate the pace of electrification in Washington, the state should:

- Prioritize low- or no-cost policies of bundled procurements, right-to-charge legislation, and proper fleet management.
- Expand existing grant funding programs to accelerate medium- and heavy-duty electrification in the near term.
- Encourage utilities to enact or expand charging infrastructure programs.

Fleet electrification is expected to provide considerable benefits to the electrical grid as well as savings for operators [10]. Washington faces a unique set of challenges and opportunities that can be addressed both by leveraging the state's existing policy framework and exploring new interventions. Table ES-4 lists the incremental number of vehicles that could be electrified under each policy intervention modeled assuming a 10 percent threshold for electrification.

TABLE ES-4: EFFECT OF POLICY OPTIONS ON FLEET ELECTRIFICATION

Policy Modeled	Number of Additional Vehicles to Electrify	Percent of Fleet	Additional Operational Cost Savings from Electrification
Vehicle-grid Integration	468	2%	$17,326,753

Policy Modeled	Number of Additional Vehicles to Electrify	Percent of Fleet	Additional Operational Cost Savings from Electrification
Carbon Price	1,725	6%	$84,032,302
Level 2 Infrastructure Grant	1,828	6%	$1,114,852
DC Charging Grant	813	3%	$18,707,575
Truck and Bus Grant Funding Program	12,065	42%	$510,153,977
Bundled Procurements	1,149	4%	$671,420

FINDING: REVOLVING LOAN PROGRAMS FOR STATE AGENCIES CAN OVERCOME ELECTRIFICATION FUNDING BARRIERS

Implementing a loan program is considered a key opportunity for Washington by the Department of Commerce, especially if expanded to include state agencies. A direct lending program or a program that reduces the cost of borrowing from a private institution (e.g., a loan loss reserve) could have meaningful impact on fleet electrification by providing access to capital for the purchase of EVs and charging equipment in cases where EVs are deemed cost effective. This can be useful for inflexible public budgets that have more funds allocated for operating expenses than capital expenses as is common for conventional fleet operations.

FINDING: RIGHT TO CHARGE LEGISLATION CAN ADDRESS CHARGING INSTALLATION CHALLENGES AT LEASED PROPERTIES

The state leases around 90 percent of facilities and these agreements rarely cover the installation of charging infrastructure. Resistance by property owners towards the installation of charging infrastructure was a primary barrier cited by officials at the Department of Commerce. Right to charge legislation could address this issue by providing tenants or property residents the right to install charging infrastructure assuming the tenant will cover the associated costs.

FINDING: REDUCED EV CHARGING RATES HAVE A SUBSTANTIAL POSITIVE IMPACT ON TCO

A vehicle-grid-integration (VGI) program had a noticeable, positive effect on the electrification potential of all vehicle classes, increasing the number of EVs by nearly 20 percent. The presence of a VGI program was particularly effective for medium- and heavy-duty EVs which saw an increase of in average savings from electrification of more than $17 million. As the EV market advances, the ability of electrical grid operators to manage this new power load will increasingly depend on successful VGI programs.

FINDING: ACCOUNTING FOR THE SOCIAL COST OF CARBON TRIPLES THE NUMBER OF LIGHT-DUTY VEHICLES MEETING THE CRITERIA FOR ELECTRIFICATION

The study team used a social cost of carbon of $74 per ton established in Washington regulatory code. Implemented via a clean fuel standard or credit-based system, this price on carbon would have a significantly positive effect on the electrification potential of all vehicle classes. For light-duty vehicles, accounting for the social cost of carbon in the TCO analysis nearly tripled the number of vehicles that met the electrification TCO threshold. For medium- and heavy-duty vehicles, it resulted in a smaller increase in the vehicles that met the threshold, but with more savings totaling $120 million. In all, accounting for the social cost of carbon can result in the electrification of between 1,725 and 3,774 additional vehicles in the present day beyond what would be done otherwise.

FINDING: A LEVEL 2 CHARGING STATION GRANT COULD MORE THAN DOUBLE THE SHARE OF VEHICLES THAT MEET THE THRESHOLD FOR ELECTRIFICATION

A grant covering the full cost of Level 2 charging infrastructure equipment and installation could more than double the share of vehicles that meet the electrification threshold, reaching 13 percent, or 3,451 vehicles. The number of electrified light-duty vehicles could be tripled.

FINDING: A DC FAST CHARGING STATION GRANT COULD INCREASE THE SAVINGS POTENTIAL OF MEDIUM- AND HEAVY-DUTY ELECTRIFICATION BY 50%

Based on input from the Department of Commerce and examples from around the country, the study team selected to model utility grant programs covering up to 50 percent of the cost of DC fast charging stations. The effects of adding these grants could have significant effects for medium- and heavy-duty vehicles, potentially increasing the proportion of the fleet that could be electrified by two percent in both cases but at an additional savings of nearly $19 million.

FINDING: GRANT FUNDING FOR MEDIUM- AND HEAVY-DUTY VEHICLES COULD MAKE ALL VEHICLE TYPES COST COMPETITIVE NOW

Instituting a truck and bus program similar to California's Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) program makes all publicly-owned trucks and buses cost effective to electrify now. The grant program brings in the timeline for cost reductions for vehicles to the present day. As these EVs are less expensive to operate than their conventional counterparts and tend to have high mileage requirements, the savings are considerable. Washington could expand existing programs, such as the Green Transportation Capital Grant Program to provide regular funding opportunities for fleets to acquire medium- and heavy-duty EVs, though funding for large-scale electrification would be considerable.

FINDING: CAPTURING SOME OF THE FEDERAL TAX EV CREDIT HAS A SIGNIFICANT IMPACT ON LIGHT-DUTY ELECTRIFICATION POTENTIAL

Washington has historically been able to capture up to 50 percent of the light-duty EV federal tax credit in some cases. Increasing the share of the tax credit captured from 50 to 100 percent increases the share of the vehicles to electrify by nearly 200 percent. Overall, the benefits of capturing the full federal EV tax credit can make it possible to electrify an additional 1,149 vehicles above what would be electrified when capturing only 50 percent of the tax credit. Bundled procurements are a way to increase the likelihood of capturing the more of the tax credit's value in a procurement.

ACKNOWLEDGEMENTS

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- **Atlas Public Policy**: Lead report authors, Electric Vehicle Market Overview, Analysis Methodology, Present Day Total Cost of Ownership Analysis, Financing Mechanisms and Public Policies, Conclusions and Recommendations
- **Washington State University Energy Program**: Vehicle Inventory
- **National Renewable Energy Laboratory:** Projected Total Cost of Ownership Analyses, Charging Infrastructure, Quality Emission Savings

It is through collaborative efforts with organizations such as these that Atlas is able to pursue its mission to arm businesses and policymakers with the information necessary to make strategic, informed decisions and encourage the use of new technologies and products along with changes in consumer behavior. Atlas is an independent organization and is solely responsible for the thoughts and opinions expressed in this work.

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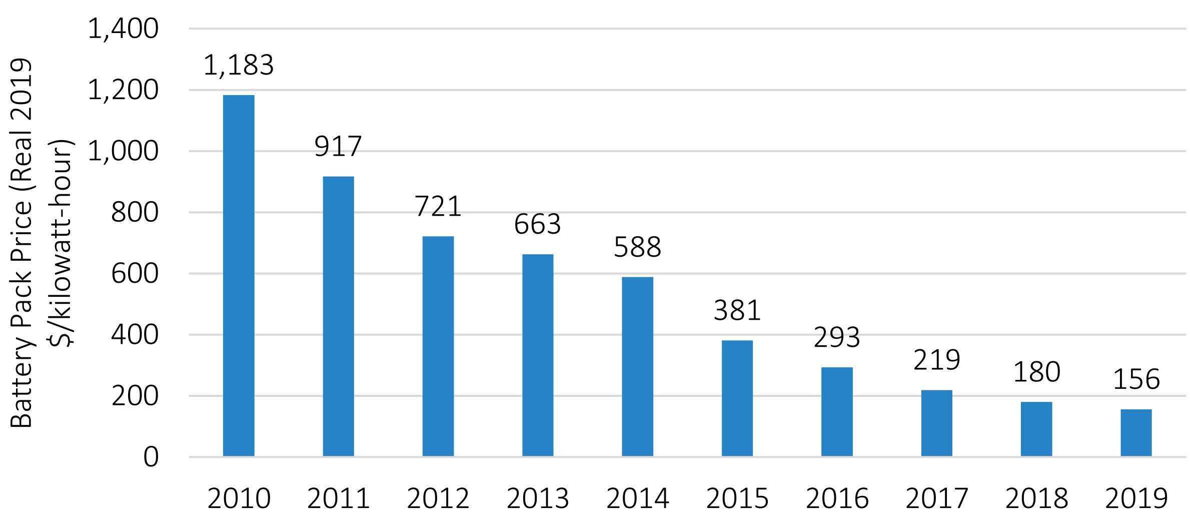
INTRODUCTION

Residents, businesses, and governments at all levels in Washington state are moving forward in a largescale effort to reduce transportation's impact on human health and the environment. The use of fossil fuels in transportation is the largest source of greenhouse gas emissions in Washington and a significant source of other criteria air pollutants, such as particulate matter and nitrogen oxides [11, 12]. Increasing the adoption of electric vehicles (EVs) is a critical step in meeting the climate and public health goals encapsulated in the Washington State Legislature's 2020 update to statewide greenhouse gas reduction targets seeking to achieve net zero emissions by 2050 [9].

Washington is already a national leader in transportation electrification and is the third-largest passenger EV market in the country both in terms of total number of registered EVs on the road and on EVs registered per capita. Deployment of medium- and heavy-duty EVs is also on the rise in Washington and the state has the second-largest electric transit bus fleet in the country [13]. The state is considered a high priority market for truck electrification as well, based on existing policy support, technology availability, and emissions reduction goals [14].

As is the case nationally, passenger EV adoption has increased significantly in Washington since 2018. More than half of the almost 60,000 passenger EV sales recorded in Washington between 2010 and July 2020 have occurred since the beginning of 2018 [2]. Increasing sales coincides with expanded EV range resulting from significant battery cost declines seen between 2010 and 2018 [2]. This trend is expected to continue with Bloomberg New Energy Finance predicting that the 2019 average price per kilowatt-hour will fall below $100 per kilowatt-hour by 2024 (see Figure) [15].

FIGURE 1: ESTIMATED BATTERY PACK PRICE (REAL 2019 $/KILOWATT-HOUR)



This chart shows the decline in average battery costs per kilowatt-hour from 2010 to 2018 with predicted future cost reductions.

Source: [15]

EV market growth in Washington has been accompanied by a large expansion of the EV models offered for sale. Washington offered 36 EV models for sale as of August 2020, 11 more than were offered in 2019. Nationwide, more than 62 new EVs are expected to reach the market by the end of 2022 including vehicles like pickup trucks that have no available EV alternative as of 2020 [2]. EV model offerings will be supported by the Washington's adoption of California's Zero Emission Vehicle (ZEV) Program in March 2020, which requires automakers to make available for sale an increasing proportion EVs every year [16].

Public fleet operators in Washington have an opportunity to lead electrification efforts and serve as an example for private fleets and individual drivers on the cost savings potential and air quality benefits associated with increased EV adoption. Washington has already taken steps to implement policy requiring fleets across the state to transition to EVs. In 2007, the legislature established deadlines for all state agencies and local governments, including transit agencies, to use electricity or biofuel for 100 percent of their fuel usage for operating publicly owned vessels, vehicles, and construction to the "extent determined practicable" by the Department of Commerce [17]. After extensive stakeholder consultation, Commerce enacted administrative rules under WAC Chapter 194-28 and 194-29 for state agencies and local governments effective May 23, 2013 and November 19, 2018, respectively [18]. In each case, the rules define practicability in terms of lifetime vehicle cost of ownership, availability of fuels and charging infrastructure and ability to meet governments' service needs.

State agencies in Washington have also endeavored to engage other stakeholders in their transportation planning. The State Electric Vehicle Task Force was first convened in 2011 and convened a group, including state and local governments, utilities, vehicle original equipment manufacturers, other private sector companies, and consumer advocates to work on transportation electrification planning. In September 2011, the group published the *Plug-In Electric Vehicle Readiness Plan for the State of Washington* to provide a clear and actionable roadmap for the widespread adoption of EVs across all sectors [19].

Governor Jay Inslee has also worked to promote adoption of EVs throughout his tenure. In 2015, the Governor announced the Washington State Electric Vehicle Fleets Initiative which set a target of having EVs comprise 20 percent of new passenger vehicle purchases each year for state agencies. This initiative was later updated with more aggressive electrification targets in 2018, increasing the target percentage to 35 by 2019 and 50 by 2020 [20, 21]. The initiative allows agencies to opt out of EV procurement if the available vehicles do not meet the operational needs of the agency. It also requires state agencies to demonstrate in their "Fleet Acquisition Plans" that they have sufficient EV charging to support their current and future EV purchases [20].

Although the annual new EV purchase goals set forth in the Washington State Electric Vehicle Fleets Initiative were not met in 2016, 2017, or 2018, the state has continued to make progress and in 2019 more than 30 percent of passenger vehicles purchased by state agencies were either all-electric or plug-in hybrid vehicles. Of these two vehicle types, plug-in hybrids were the more popular option, making up nearly 25 percent of new vehicle purchases with fully electric vehicles representing the remaining five percent of purchases.

In addition to the Electric Vehicle Fleets Initiative, Governor Inslee issued Executive Order 18-01 creating the State Efficiency and Environmental Performance (SEEP) office in 2018 [22]. SEEP works with state agency partners to achieve reductions in greenhouse gas emissions and eliminate toxic materials from state agency operations. These responsibilities include support for fleet electrification as well as efforts related to energy efficient and zero energy facilities, sustainable purchasing and clean electricity [23].

In an effort to advance progress on fleet electrification, the Washington Legislature in 2019 directed the Joint Transportation Committee (JTC) to conduct a comprehensive study to determine the benefits and costs of electrifying public fleets in the state. The JTC commissioned a study team led by Atlas Public Policy in partnership with the Washington State University Energy Program and the National Renewable Energy Laboratory (NREL) to conduct this analysis. The study team sought to provide fleet managers and policymakers in Washington with a report that encompassed comprehensive, vehicle-specific electrification cost estimates both today and in the future and actionable information on how to efficiently move forward with fleet electrification.

This report is broken out into seven chapters. *Chapter 1: Vehicle Inventory* provides a detailed inventory of public vehicles owned by the state, cities, counties, transit agencies and school districts in the state including information on fuel type, class, and usage.

Chapter 2: Electric Vehicle Market Overview provides a detailed review of the state of electrification across different segments of the EV market including light-duty vehicles, school buses, transit buses, and trucks.

Chapter 3: Analysis Methodology presents the methodology and results of the study teams' vehicle-by-vehicle total cost of ownership analysis which compares the total cost of ownership of available and soon-to-be available alternatives with the internal combustion vehicles currently owned by the fleet. Included in the chapter is a detailed breakdown of the elements such as charging infrastructure installation cost and electricity price and their effect on the electrification potential of vehicles in the public fleet.

Chapter 4: Total Cost of Ownership Analyses (Present Day) details the TCO analysis results for all vehicles in the present day. This chapter provides great detail by public agency and vehicle use case on the factors driving the TCO.

Chapter 5: Total Cost of Ownership Analyses (2020-2035) details the total cost of ownership of electric and internal combustion vehicles in 2025, 2030, and 2035 and the financial commitment necessary for the state to achieve substantial conversion of the fleet to alternative electric vehicles at these different times.

Following the identification of substantial electrification scenarios, study team member NREL compiled data on existing charging infrastructure and daily vehicle operations to determine the amount of charging infrastructure necessary to support a substantially electrified fleet. These recommendations are outlined in *Chapter 6: Charging Infrastructure*. In *Chapter 7: Quality Emissions Savings*, the study team quantified emissions savings potential under different electrification scenarios.

Finally, in *Chapter 8: Financing Mechanisms and Public Policies*, the study team reviewed potential financing strategies and policy options that Washington could employ to accelerate the adoption of electric vehicles and the effect of these strategies on the total cost of ownership of EVs.

CHAPTER 1: VEHICLE INVENTORY

Establishing an inventory of all public vehicles was the first step required in order to accurately assess the electrification potential of public fleets in Washington. All public fleets keep records of their vehicles and assets—some in more detail than others. The Department of Commerce regularly collects reports from state agencies, universities, and local governments that use more than 200,000 gallons of gasoline or diesel fuel per year. These reports cover roughly 90 percent of fuel use by public fleets and provide a record of fuel use and fleet developments by government entities around the state. Together, these records provide a snapshot in time of the size and makeup of the public fleets in Washington that allowed the study team to answer important questions about electrification. Over the course of the project, the study team gathered detailed vehicle data across state agency, transit agency, school district, and city and county fleets. This inventory establishes a baseline for the size and current electrification status of the public vehicle fleet in the state of Washington. This chapter discusses the process of collecting and organizing fleet data and details on the breakdown of vehicles across all types of fleets in the state.

Not all vehicles presented in the inventory were analyzed for this project. Details on which vehicles were analyzed and why are found in *Chapter 1*. Generally, vehicles were analyzed when the study team had access to detailed data on vehicle make, model, year, location, and mileage, and provided there was an available or soon-to-be available electric alternative for that vehicle.

FLEET INVENTORY COLLECTION METHODS

In this section, the study team provides details about the agencies and fleets included in the inventory and the methods used to gather data and document fleet vehicles and operations. Major public fleets included in this study included the following:

- State agencies
- Public transit agencies
- School districts
- Counties
- Cities

Examples of public fleets not included in this study, but that can benefit from the results, include ports, public utilities, and others.

The study team sought to collect detailed data about the existing fleet inventories to establish a baseline and ensure a comprehensive analysis for current, upcoming, and potential vehicle electrification of Washington's public fleet. Having detailed baseline data also informed the design and scope of the analysis, including assumptions on vehicle use and potential charging strategies. The study team thus reached out and requested the following detailed vehicle-related data whenever possible:

- Make, model, year, fuel type
- Class designation (1-8) representing all light-, medium-, and heavy-duty vehicles (see Table)
- Odometer readings
- Duty cycle(s): days per month, assignments, uses, special needs (cargo, AWD)
- Location: home base and location at night

- Daily use range: average miles per day, peak miles per day
- Maintenance costs: average cost per mile
- Replacement plans: typical years or miles of life, position in replacement cycle
- Vehicle Identification Number (VIN)

The study team gathered data from a wide variety of public records and resources. In addition to available lists of fleet vehicles, the study team made specific requests for data from many fleets. To gather data relevant to infrastructure analyses, the study team also requested data from county and city fleet operators about issues related to EV readiness and the needs for electric vehicle supply equipment (EVSE), also known as EV charging infrastructure.

TABLE 1: VEHICLE WEIGHT CLASS RATINGS

GVWR Class	Study Class	Example Vehicles
Class 1 (0–6,000 pounds)	Light	Passenger Sedans and SUVs
Class 2a (6,001–8,500 pounds)	Light	Light pickup trucks such as an F-150, small cargo vans
Class 2b (8,501–10,000 pounds)	Medium	Full-size trucks and cargo vans such as an F-250 or Mercedes Sprinter
Class 3 (10,001–14,000 pounds)	Medium	Walk-in vans, small box trucks and full-size picks such as an F-350
Class 4 (14,001–16,000 pounds)	Medium	Shuttle buses, small freight trucks
Class 5 (16,001–19,500 pounds)	Medium	Large Shuttle buses and specialty vehicles such as bucket trucks
Class 6 (19,501–26,000 pounds)	Medium	Large freight trucks, dump trucks, small buses
Class 7 (26,001–33,000 pounds)	Heavy	School and transit buses, large dump trucks
Class 8 (33,001+ pounds)	Heavy	Semi-tractors, school and transit buses, road construction vehicles, refuse vehicles

This table shows the division of vehicles into the categories of light, medium, and heavy based upon the vehicle Gross Vehicle Weight Rating.

STATE AGENCY DATA

The Department of Enterprise Services (DES) offers a large selection of administrative, personnel, printing, fleet, and information services to the Washington state government. DES was able to provide detailed vehicle specification and usage data for vehicles that they own and maintain across the 70 agencies, offices, colleges, and universities with which they work. Other agencies that own and maintain their own fleets were also able to provide detailed inventories of vehicles. Each agency keeps its own data records with some but not all of the records requested for this study. Record-keeping among the agencies was not consistent with regard to manufacturer, model, vehicle type or description, vehicle class, fuel type, or mileage data. For example, manufacturer names might be spelled out or abbreviated (e.g., Chevrolet, Chev, or Chevy). Model names were shown with more or less detail in the record. Vehicle descriptions might show pick-up, truck, or pick-up truck for the same vehicle. Fuels could be listed as gas, gasoline, or unleaded. Through detailed review, the study team was able to compare and standardize the key common elements of the data to develop a primary inventory of vehicles that could be sorted more effectively for later analyses.

TRANSIT DATA

The Public Transportation Division of Washington State Department of Transportation (WSDOT) provides support and planning assistance and maintains extensive databases of information about the various buses owned and operated by Washington's transit agencies. Though contained in a single source, the WSDOT transit data is self-reported by more than 30 transit agencies across the state. This results in various inconsistencies about manufacturers, models, type and class descriptions, fuel type, mileage and expected useful life. The study team worked to standardize data across agencies, sometimes using data supplied about vehicles by one agency to fill in data not supplied by others. This provided a consistent, comprehensive, more complete inventory of public transit vehicles in the state to enable the analysis of the electrification potential of these vehicles. One limitation of these data is that the most recent data available was from the end of 2018, so the inventory does not reflect vehicles purchased or retired in 2019 or 2020.

The study team collected information on each of these vehicles to understand the composition, fuel consumption, and usage patterns of transit vehicles across the state. For transit buses alone, the study team tracked buses across multiple variations in length, fuel type, functionality, and design including 30', 35', 40' and 60' buses and intercity coach buses. Similarly, shuttle buses and vans vary widely in size and build. Shuttle buses are particularly central to transit services in rural areas as well as providing service for workplace transportation, carpool programs, and demand response such as dial-a-ride type services for people who require special access.

SCHOOL DISTRICT DATA

The Office of the Superintendent of Public Instruction (OSPI) keeps detailed records about the school buses on the road in Washington across all school districts in the state of Washington. OSPI's records were used to develop the school bus inventory for the project. OSPI staff maintains and regularly updates these records. Metrics such as fuel type, bus type, mileage, and location are already standardized across all school districts and did not require further coordination.

COUNTY AND CITY DATA

With 39 counties and 281 cities in Washington, gathering data from every public fleet was not feasible for this study. The legislature requested sampling data from a wide variety of cities and all counties. The study team used several methods to compile these data. One source was the Department of Commerce, to which many larger cities and counties submit data about vehicles and fuel purchases to comply with the requirements for alternative fuels reporting outlined in WAC 194-29 [18]. To gather additional data, the study team developed a questionnaire for counties and cities, which was reviewed by the Joint Transportation Committee and Staff Workgroup. In February 2020, the questionnaire was distributed to fleet managers across all 39 counties and more than 30 cities to gather data about vehicles, operations, and EV readiness on the part of cities and counties. Cities were selected based upon population data and location, ensuring that data was collected from a representative cross section of cities of varying sizes from both the eastern and western part of the state. The population categories defined in this study are listed at the bottom of Table 2 and Table 3. Specific data requested included:

- Fuel use
- Average and peak miles driven
- Overnight parking – at fleet centers or at employees' residences
- Maintenance locations
- Locations of fleet charging stations

- Fleet EV readiness planning
- EV readiness goals
- Required facility upgrades
- Common obstacles
- Desired forms of state support
- Budgets for EVs or infrastructure

CITY DATA

The study team gathered inventory data for 12 western and five eastern Washington cities ranging across four population groups. Table 2 provides a list of cities included in the analysis by region and population.

TABLE 2: RESPONDENT CITY CHARACTERISTICS

City Name *Alphabetical	Eastern or Western WA City	Population
Auburn	Western	50,000-100,000
Bellevue	Western	100,000-200,000
Edmonds	Western	<50,000
Ellensburg	Eastern	<50,000
Everett	Western	100,000-200,000
Lacey	Western	50,000-100,000
Lynden	Western	<50,000
Lynnwood	Western	<50,000
Olympia	Western	50,000-100,000
Pullman	Eastern	<50,000
Renton	Western	100,000-200,000
Richland	Eastern	50,000-100,000
Seattle	Western	>200,000
Spokane	Eastern	>200,000
Spokane Valley	Eastern	50,000-100,000
Tacoma	Western	>200,000
Vancouver	Western	100,000-200,000
Summary	12 Western WA Cities 5 Eastern WA Cities	3 Cities (>200,000) 4 Cities (100,000-200,000) 5 Cities (50,000-100,000) 5 Cities (<50,000)

This table lists the cities that responded to the study team's questionnaire and captures each city's geographic and population characteristics.

COUNTY DATA

Though data was requested from all 39 counties in Washington, the study team was able to compile data for 11 western and five eastern Washington counties. The study team captured vehicle inventories for the largest and smallest counties in Washington. The other completed inventories represent a broad distribution of counties at all population levels with a near even split between counties that could be described as having significant urban or rural characteristics. Table 3 shows the breakdown of counties included in the analysis by regional classification and population size.

TABLE 3: RESPONDENT COUNTY CHARACTERISTICS

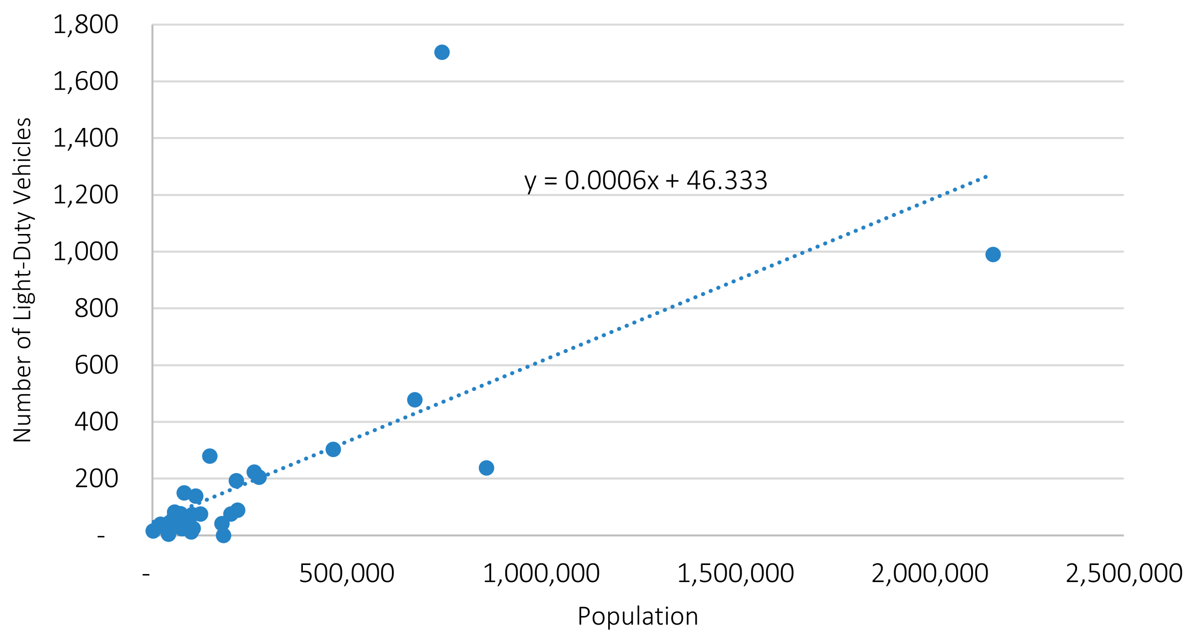
County Name *Alphabetical	Eastern or Western WA Counties	Urban or Rural Counties	Population
Chelan	Eastern	Rural	50,000-150,000
Clark	Western	Urban	400,000-600,000
Cowlitz	Western	Rural	50,000-150,000
Garfield	Eastern	Rural	<50,000
Grays Harbor	Western	Rural	50,000-150,000
King	Western	Urban	>2,000,000
Kitsap	Western	Urban	200,000-300,000
Lewis	Western	Rural	50,000-150,000
Okanagan	Eastern	Rural	<50,000
Pierce	Western	Urban	800,000-1,000,000
Skagit	Western	Rural	50,000-150,000
Snohomish	Western	Urban	800,000-1,000,000
Spokane	Eastern	Urban	400,000-600,000
Stevens	Eastern	Rural	<50,000
Thurston	Western	Urban	200,000-300,000
Whatcom	Western	Rural	200,000-300,000
Summary	11 Western WA Counties 5 Eastern WA Counties	7 Urban counties 9 Rural Counties	1 County (>2,000,000) 2 Counties (800,000-1,000,000) 2 Counties (400,000-600,000) 3 Counties (200,000-300,000) 5 Counties (50,000-150,000) 3 Counties (<50,000)

This table lists the counties that responded to the study team's questionnaire and captures each county's geographic and population characteristics.

ESTIMATED CITY AND COUNTY FLEET

As mentioned previously, collecting fleet data from all 39 counties and 281 cities was not feasible for this project. To establish a baseline for the size and electrification status of the entire city and county fleet, the study team used the city and county fleet data collected through the questionnaire to estimate the total number of vehicles in the city and county fleets that did not respond to the questionnaire or were not targeted when the questionnaire was sent out. First, the study team used data collected from cities and counties in the sample to make a linear regression equation for the number of light-duty vehicles compared to population. Where no detailed vehicle data was available, as was the case for city and county fleets, the classification of light-duty, medium-, and heavy-duty was determined by the reporting entity. Where detailed vehicle data was available, light-, medium-, and heavy-duty vehicles are defined based on the Gross Vehicle Weight Rating (GVWR). Using this regression, the team estimated the number of light-duty vehicles in the other cities and counties to be 4,423. Figure 2 shows the regression estimate for light-duty vehicles.

FIGURE 2: REGRESSION ESTIMATE FOR LIGHT-DUTY VEHICLES AND BREAKDOWN BY VEHICLE CLASS ACROSS RESPONDENT CITY AND COUNTY FLEETS



This chart shows the linear regression estimate for light-duty vehicles across Washington state based off data collected from City and County respondents.

For the medium- and heavy-duty vehicle calculations, the study team estimated ratios of additional city and county medium- and heavy-duty vehicles based on the overall ratio of medium- and heavy-duty vehicles to light-duty vehicles across cities and counties for which data was collected. Using this methodology, the additional medium- and heavy-duty vehicles were estimated and are shown in Table 4.

TABLE 4: RATIOS OF MEDIUM- AND HEAVY-DUTY VEHICLES

Vehicle Class and Type	Actual City/County inventory	Ratio to Light-duty Vehicles	Estimated City/County inventory	Total
Medium-duty Vehicles (excluding buses)	4,739	0.77	3,408	8,120
Heavy-duty Vehicles (excluding buses)	2,549	0.41	1,833	4,340
Medium-duty Buses	27	0.0057	19	46
Heavy-duty Buses	42	0.0165	30	72

This table lists the number of medium- and heavy- duty vehicles as reported by city and county questionnaire respondents, and the ratio metric used by the study team to estimate the total number of medium- and heavy-duty vehicles across every county and city governments in Washington.

FLEET INVENTORY RESULTS

The inventory created from the data collected includes 56,080 vehicles belonging to the public fleets studied. Throughout this report, the vehicle class, vehicle type, or gross vehicle weight rating (GVWR) will be referenced, at times in combination and is explained in Table 5.

TABLE 5: VEHICLE CLASS AND GVWR EXAMPLES

<table>
<tr><th>Vehicle Class and (GVWR)</th><th>GVWR Category</th><th>Vehicle Type Example(s)</th></tr>
<tr><td>Class 1 (<6,000 lbs)</td><td rowspan="2">Light-Duty
<8,500 lbs</td><td rowspan="2">• Sedan
• Full size Pickup
• Mini Pickup
• Minivan
• SUV
• Crew Size Pickup</td></tr>
<tr><td>Class 2a (6,001 - 8,500 lbs)</td></tr>
<tr><td>Class 2b (8,501 - 10,000 lbs)</td><td rowspan="5">Medium-Duty
8,501 lbs – 26,000 lbs</td><td rowspan="5">• Mini Bus
• Step Van
• Utility Van
• City Delivery
• Conventional Van
• Landscape Utility
• Large Walk In
• Bucket
• City Delivery
• Beverage Truck
• School Bus</td></tr>
<tr><td>Class 3 (10,001 - 14,000 lbs)</td></tr>
<tr><td>Class 4 (14,001 - 16,000 lbs)</td></tr>
<tr><td>Class 5 (16,001 - 19,500 lbs)</td></tr>
<tr><td>Class 6 (19,501 - 26,000 lbs)</td></tr>
</table>

Vehicle Class and (GVWR)	GVWR Category	Vehicle Type Example(s)
Class 7 (26,001 - 33,000 lbs)	Heavy-Duty	• City Transit Bus • Furniture Truck • High Profile Semi • Medium Semi Tractor • Refuse Truck • Tow Truck • Cement Mixer • Dump Truck • Fire Truck • Heavy Semi Tractor • Refrigerated Van
Class 8 (>33,001 lbs)	>26,000 lbs	

This chart outlines the classification of vehicles by vehicle classes, GVWR, and vehicle types.

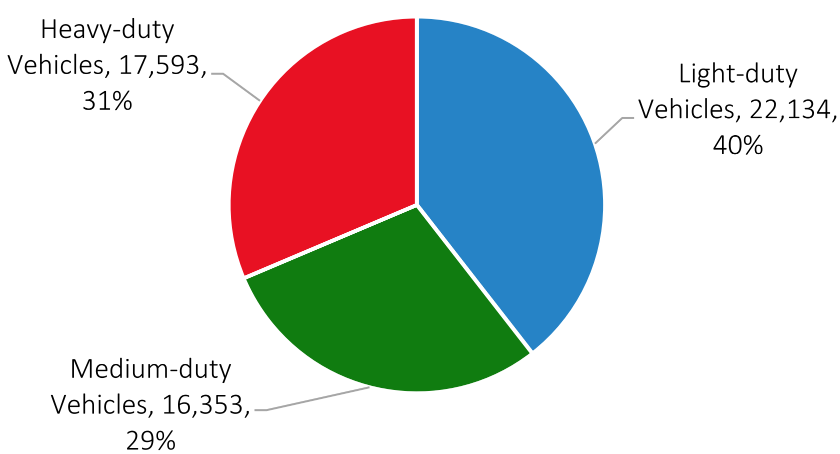
Source: [24]

Washington's fleet results are reported in Figure 3 as light-, medium-, and heavy-duty classes.

- 22,134 light-duty vehicles = 40%
- 16,353 medium-duty vehicles = 29%
- 17,593 heavy-duty vehicles = 31%

Included in the above counts are 10,838 school buses (2,063 medium-duty and 8,775 heavy-duty) and 3,196 transit buses.[1]

FIGURE 3: WASHINGTON FLEET VEHICLE INVENTORY BREAKDOWN BY CLASS



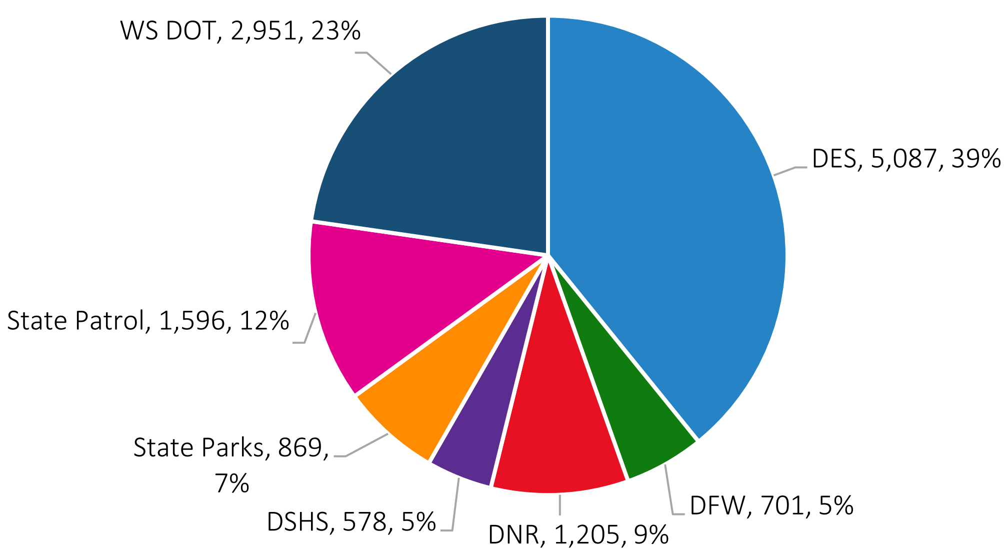
This chart shows Washington state's fleet inventory results for all reported vehicles by vehicle class.

[1] Transit bus figure includes 30', 35', 40', and 60' Transit buses, along with Coach and Double-Decker buses, along with identified and estimated transit buses from city and county fleets.

STATE AGENCY FLEETS

The inventory results here includes vehicle and other fleet-related data from all the key following state agencies, including DES, which owns and subsequently leases vehicles to many state agencies which do not have vehicles of their own, as well as the Departments of Fish & Wildlife (DFW), Natural Resources (DNS), Social and Health Services (DSHS), State Parks, State Patrol, and Transportation. The total includes 12,987 vehicles identified as part of the state government fleet. DES operates a majority of the state-owned vehicles with an approximately 40 percent share of the total. The data received from DES shows that the agency owns and manages through lease arrangements more than 5,000 vehicles for some 70 agencies, offices, colleges, and universities of state government. The WSDOT claims the second-largest share with 23 percent. Figure 4 shows the proportion of vehicles operated by each agency.

FIGURE 4: STATE GOVERNMENT FLEET BREAKDOWN BY AGENCY



This chart shows the Washington state's fleet inventory results for state agency that are owned or leased to each agency.

Light-duty sedans make up 18.3 percent of the state-owned vehicles included in the inventory. DES owns and manages 75 percent of these passenger cars. Combined, light-duty and medium-duty pick-up trucks and sport utility vehicles (SUVs) total more than 6,000, or nearly half of all state-owned vehicles. Combined, cargo and passenger vans make up approximately nine percent of the fleet inventory, while non-pickup trucks, such as dump trucks, bucket trucks, and box trucks, make up approximately 16 percent of the fleet inventory. The fleet of police pursuit vehicles at State Patrol make up 7.4 percent of all state vehicles. Table shows the breakdown of vehicles by class and type across all state government fleets.

WSDOT operates a majority of the state's Class 8 vehicles (heavy-duty vehicles that weigh more than 33,000 pounds), which are primarily used for road construction or repair. DES operates the largest fleet in terms of total number of vehicles, with the majority those vehicles being Class 3 or below. Figure 5 shows the breakdown of vehicles by weight across the Washington state agency fleets included in the inventory.

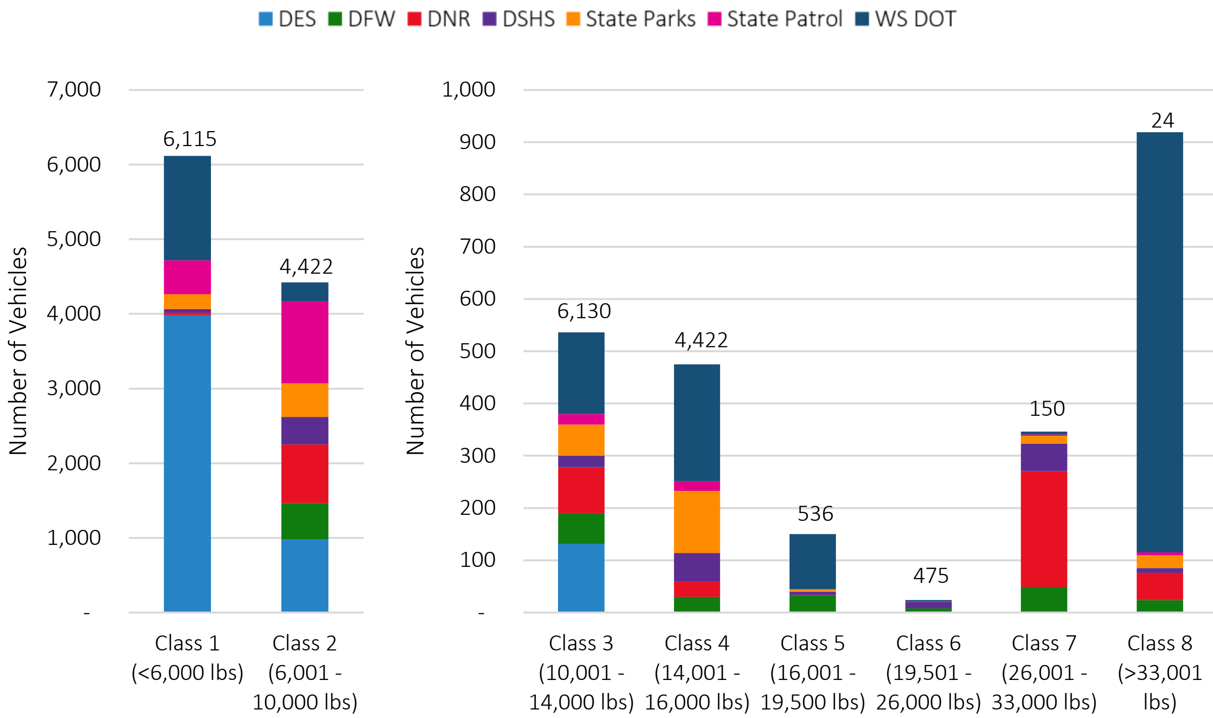
TABLE 6: STATE GOVERNMENT FLEET BREAK DOWN BY VEHICLE CLASS AND TYPE

Vehicle Class	Vehicle Type	DES	DFW	DNR	DSHS	State Parks	State Patrol	WS DOT	Total
Light-Duty Vehicle	Bus			5	4				9
	Fire Truck				1		4		5
	Other	5				3			8
	Pickup	836	432	629	87	316	93	924	3,317
	Police Pursuit						963		963
	Sedan	1,835	5	31	73	40	152	239	2,375
	SUV	1,689	37	119	43	74	238	82	2,282
	Truck		7		3		16	253	279
	Utility Vehicle		3			46			49
	Van	590	10	29	211	13	24	156	1,033
	Motorcycle		5				58		63
	ATV					154			154
	LDV Total	4,955	499	813	422	646	1,548	1,654	10,537
Medium-Duty Vehicle	Bus	7		16	2			25	16
	Fire Truck				1			1	
	Pickup	123		2	1	2		5	2
	SUV			31	175	24		448	31
	Truck	1	129			7		7	
	Van	1		16	2	3	431	605	16
	MDV Total	132	129	118	95	183	40	488	1,185
Heavy-Duty Vehicle	Bus			45	28				73
	Fire Truck				1				1
	Other			35	3	10	2	5	55
	Pickup			2	2				4
	Police						4		4
	Truck		73	192	27	30	1	798	1,121
	Van							6	6
	Other Fire						1		1
	HDV Total		73	274	61	40	8	809	1,265
Total by State Agency		**5,087**	**701**	**1,205**	**578**	**869**	**1,596**	**2,951**	**12,987**

This table summarizes Washington state's state agency fleet inventory results by vehicle class and vehicle type.

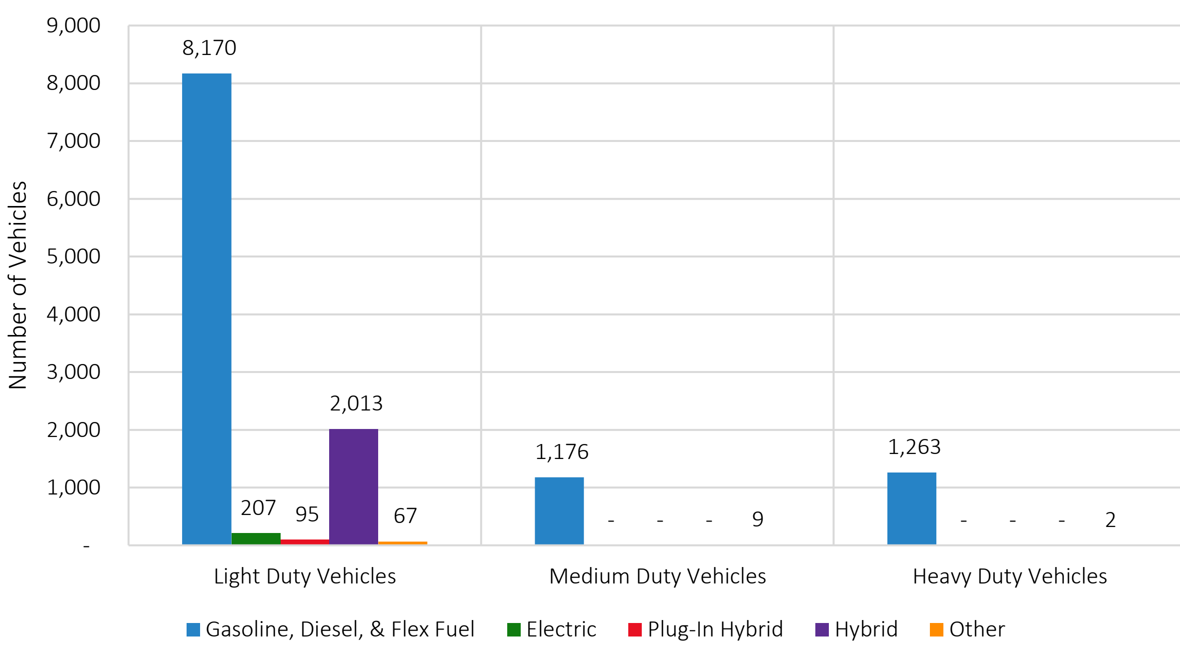
In terms of fuel type, gasoline vehicles are the primary fuel source for both light- and medium-duty state government vehicles while diesel powers a majority of the state's heavy-duty vehicles. The state does not currently operate any medium- or heavy-duty EVs and only 1.4 percent of the light-duty vehicles operated by the state are EVs, of which DES owns 75 percent. The breakdown of fuel used by state vehicles is shown in Figure 6.

FIGURE 5: STATE GOVERNMENT FLEET VEHICLE COUNT BY GVWR CLASS



These charts show Washington state's fleet inventory results for state agency vehicles by GVWR class.

FIGURE 6: NUMBER OF STATE GOVERNMENT VEHICLES BY FUEL TYPE AND CLASS

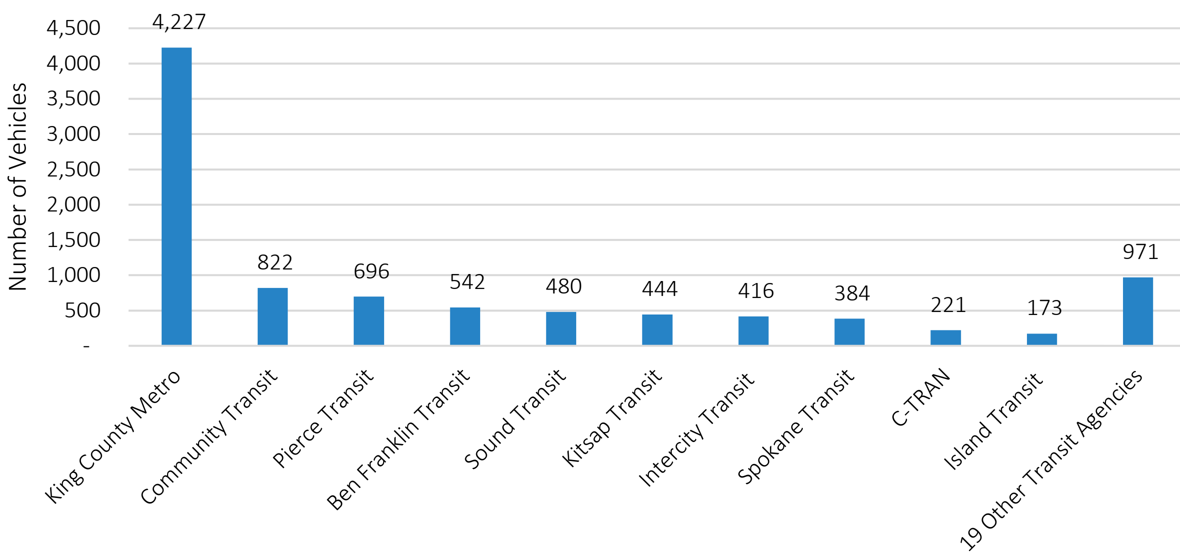


This chart shows Washington state's fleet inventory results for state agency vehicles by vehicle class and fuel type.

PUBLIC TRANSIT AGENCIES

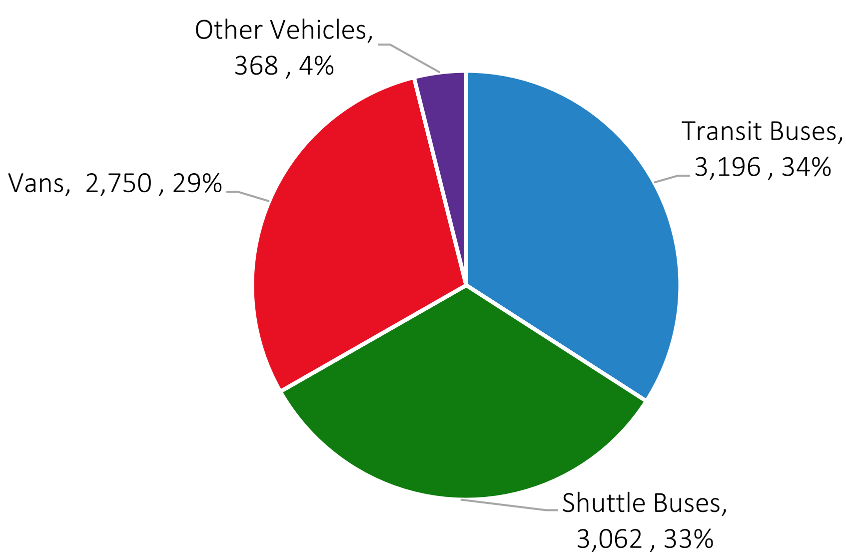
The study team identified 9,222 vehicles owned by 29 public transit agencies in Washington. Nearly half of these vehicles are operated by King County Metro. As shown in Figure 7, King County, Community, Pierce, Ben Franklin, Kitsap, Intercity, Spokane, Sound, C-Tran, and Island are the 10 largest transit agencies in terms of total fleet size.

FIGURE 7: NUMBER OF VEHICLES ACROSS TRANSIT AGENCIES IN WASHINGTON



This chart shows the total number of vehicles by transit agencies for the 10 largest transit agencies by vehicle count. The remaining 19 transit agencies are summarized together

FIGURE 8: BREAKDOWN OF TRANSIT VEHICLES IN WASHINGTON BY VEHICLE TYPE



This chart shows Washington state's fleet inventory results for transit agencies by vehicle types.

All the transit vehicles in Washington are split roughly in thirds among transit buses, shuttle buses, and vans. Shuttle buses refer primarily to vehicles with an aftermarket passenger body from manufacturers such as Eldorado, Champion, Startrans, and ARBOC. These vehicles are typically used in a paratransit or vanpool capacity. Roughly two percent of transit fleet vehicles in the fleet inventory are light-duty vehicles including sedans, SUVs, and pick-up trucks including vehicles used for administration or maintenance purposes. Figure 8 shows the breakdown of these vehicles throughout public transit fleets in Washington.

Based on the fleet inventory collected by the study team, Washington's transit bus vehicle fleet is split almost evenly across vehicle types. Specialty vehicles like trolleys are included in the transit bus category and are all powered by electricity. Electric transit in the form of wired electric trollies has been a part of King County Metro's transit services in urban areas of the Seattle-King County region since 1978. As of 2018, the agency was operating 174 electric trollies. In recent years, through the use of various state and federal grants, King County Metro and nine other transit agencies have begun adding battery electric buses into their fleets. The study team identified 196 electric transit buses to include in the fleet inventory. Of these 196 electric buses, 174 are electric trolleys which, while they have the capability of traveling outside of their wired routes, are only operated along routes that have the necessary overhead charging infrastructure installed.

While electric buses made up only six percent of the transit bus fleet as of 2018, transit agencies across the state are gaining critical experience for the future where EVs will constitute a higher proportion of these fleets. For some agencies, electric transit bus deployment has moved past the pilot phase toward adoption of goals for substantial electrification of their fleets in the years ahead.

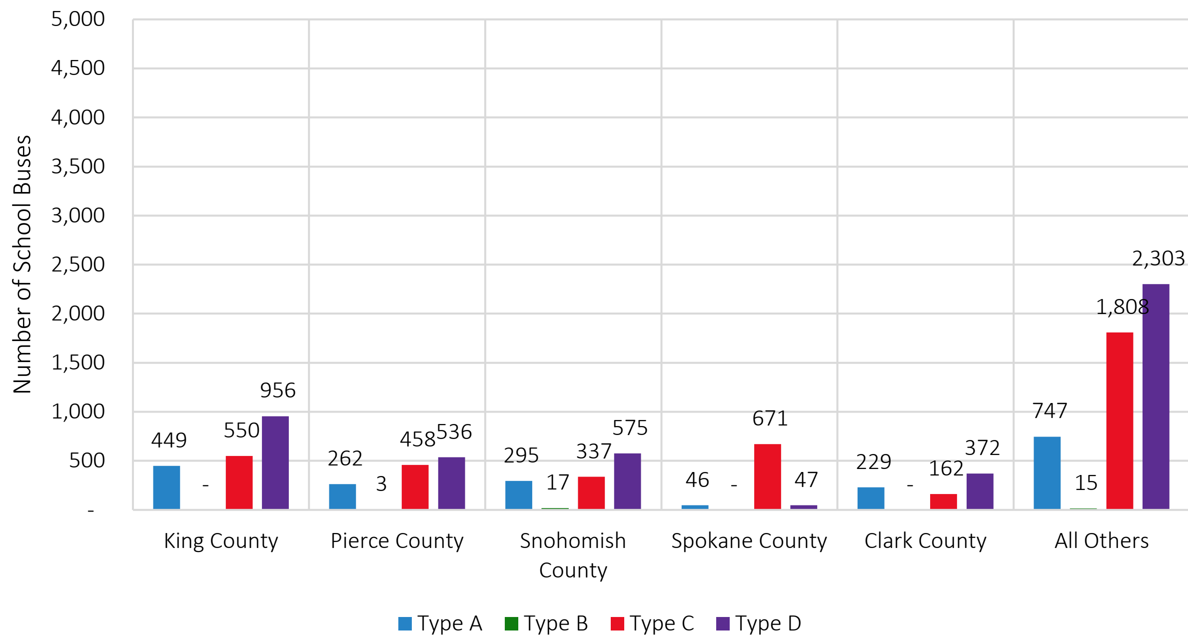
The state grant programs that have made these steps possible include the new Green Transportation Capital Program at WSDOT, as well as proceeds from state and federal settlement agreements with Volkswagen resulting from their past diesel emission scandal. These programs are covered in greater detail in *Chapter 8* of this report.

In addition to electric transit buses, King County Metro is exploring the electrification of its vanpool vehicles. The transit agency is currently piloting five plug-in hybrid minivans and had purchased 44 Nissan Leaf vehicles as of 2018 for its MetroPool program, which offers vehicles for commuting services in King County.

SCHOOL BUSES

The fleet inventory put together by the study team includes a total of 10,838 school buses used to transport students in the state. These are vehicles that the Office of the Superintendent of Public Instruction (OSPI) monitors for purposes of funding transportation services. Distribution of school buses somewhat correlates with the population around Washington, with the three largest counties having the largest numbers of school buses— King County (1,955 or 18 percent), Pierce County (1,250 or 12 percent), and Snohomish County (1,224 or 11 percent). They are followed by Spokane and Clark counties with 764 and 763 buses respectively, claiming seven percent of the total state fleet each. The other counties in Washington make up the remaining half of the school bus fleet.

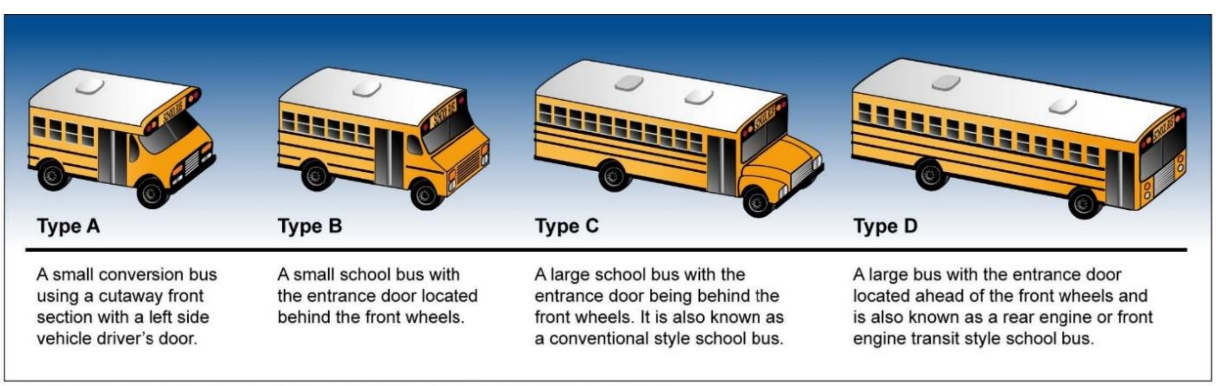
FIGURE 9: BREAKDOWN OF SCHOOL BUS COUNTS BY COUNTY



This chart shows Washington state's fleet inventory results for school buses, by school bus type in King, Pierce, Snohomish, Spokane, and Clark County, with the remaining counties being summarized under "all others".

School buses have their own classification system and fall under four different types— A, B, C, and D — as shown in Figure 10. All four of these class types are represented in the Washington fleets, and all have available EV models. Washington school districts operate the fewest number of Type B buses and the statewide fleet is made up primarily of larger Type C and Type D buses [25]. A summary of these different classes is shown in Figure 11.

FIGURE 10: SCHOOL BUS CLASS SUMMARIES



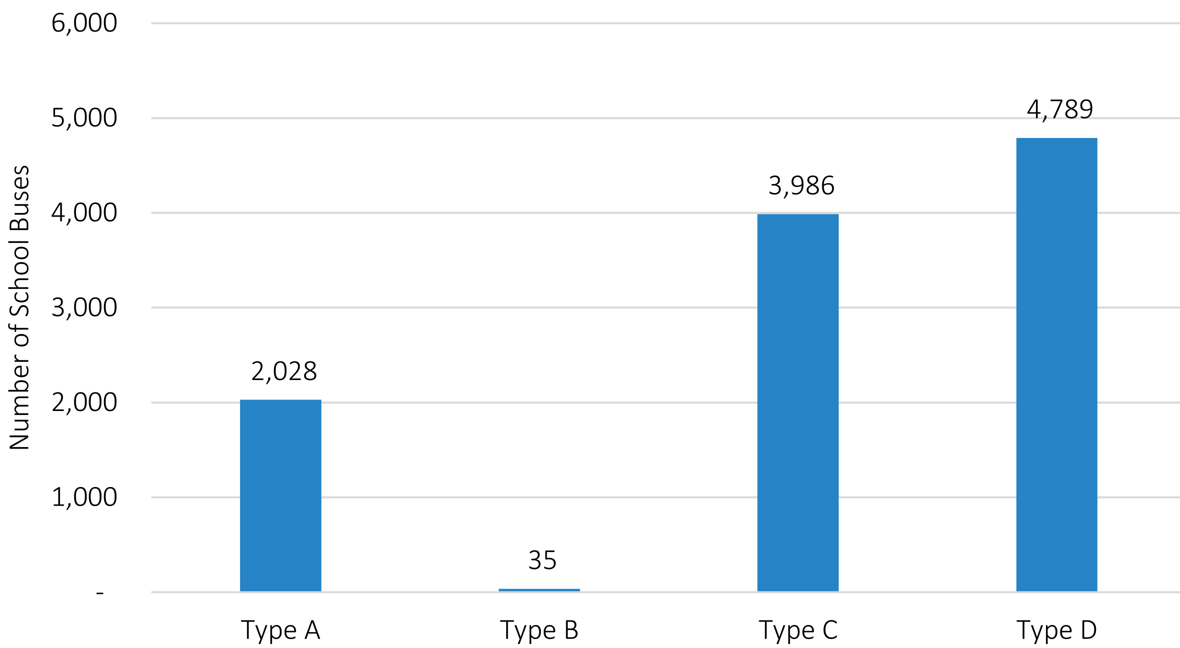
Source: GAO presentation of 2015 National School Transportation Specifications and Procedures. | GAO-17-209

This figure presents the different classifications for Buses under Type A, B, C, and D.

Source: [25]

The Washington fleet is made up mostly of Type C and Type D school buses, the two largest types. There are almost no Type B buses in the fleet inventory recorded in this analysis. Figure 11 provides a breakdown of the number of vehicles included in the inventory by school bus type.

FIGURE 11: WASHINGTON STATE SCHOOL BUS FLEET BY BUS TYPE



This chart shows Washington state's fleet inventory results for school buses by bus type A, B, C, and D.

In April 2020, the Department of Ecology awarded $12 million in Volkswagen Settlement grants to 22 school districts for the purchase of 41 electric school buses and related charging equipment [26]. These vehicles are not yet included in the most recent OSPI database used in this study. At less than half a percent of the statewide fleet, these acquisitions are just the first steps toward supporting increased adoption as the vehicle and charging technologies improve.

CITY AND COUNTY FLEETS

The study team identified and included in the fleet inventory at least 13,438 vehicles across all city and county fleets surveyed. Almost half of these, roughly 6,150 vehicles, were light-duty vehicles, with medium-duty and heavy-duty vehicles making up 35 percent and 19 percent of city and county fleets, respectively. This distribution among classes of vehicles in city and county fleets is similar to the breakdown in the state agency fleet inventory, described in the *State Agency Fleets* section.

The study team estimated that other cities and counties would have 3,427 medium-duty vehicles and 1,863 heavy-duty vehicles. When combined, the documented and estimated values for local government vehicles show a total inventory of 23,151 vehicles. Table 7 shows the estimated totals by vehicle class.

TABLE 7: FLEET INVENTORY FOR LOCAL GOVERNMENTS

Class	Documented	Estimated	Totals
Light-Duty	6,150	4,423	10,573
Medium-Duty	4,712	3,408	8,120
Heavy-Duty	2,507	1,833	4,340
Transit Buses	69	50	119
Totals	**13,438**	**9,714**	**23,152**

This table shows Washington state's fleet inventory results for city and county governments as documented from questionnaire respondents and estimated by the study team to determine a total number of vehicles by vehicle class across all city and county governments.

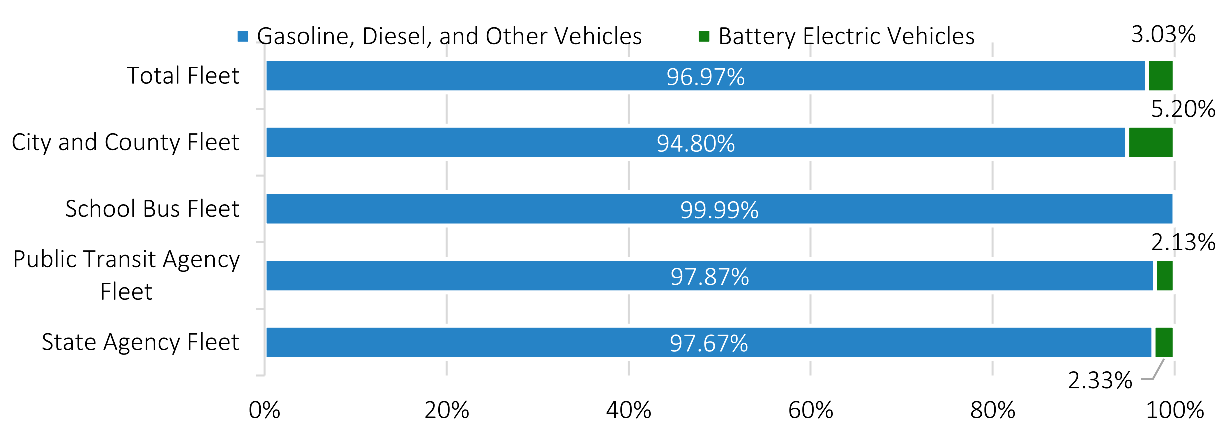
Electrification efforts among cities and counties are scattered, but they were expected to be well represented among those that provided information to the study team. In general, cities in Western Washington have deployed more EVs and have more advanced electrification strategies than those in the eastern part of the state.

Among the cities and counties that were selected for active data collection, battery electric vehicles made up 2.9 percent of their total fleets and 5.8 percent of their light-duty fleets. When plug-in hybrid vehicles are included, these electric vehicles make up 5.2 percent of all fleet vehicles and 10.3 percent of light-duty vehicles.

CURRENT ELECTRIFICATION STATUS

The current electrification status across the entire inventory was low at only three percent. Across the fleets, this ranged from a high of 5.2 percent for the city and county fleet to a low less than one percent for the school bus fleet. Despite initiatives to spur electrification at both the state and local level, the number of electric vehicles is only a small fraction of the total fleet. However, there is considerable room for growth and these figures do not reflect recently acquired EVs or planned purchases which could further increase these figures. Figure 12 shows the current electrification status by fleet.

FIGURE 12: CURRENT ELECTRIFICATION STATUS OF PUBLIC FLEETS IN WASHINGTON



FLEET DATA RECOMMENDATIONS

As described throughout this report, the study team collected and compiled disparate vehicle inventories from multiple sources, many of which followed different conventions for recording data. These inconsistencies across data sources presented challenges for creating a single, standardized inventory of public vehicles. Furthermore, the timeline of the data varied across sources, resulting in an inventory that reflects data from similar, but not precisely the same time period for all vehicles. Despite these inconsistencies, the study team was able draw conclusions and concluded that the data collected was a representative inventory of Washington state's public fleet. In addition to the recommendations that the study will make regarding electrification efforts, the project team felt it could be helpful to share recommendations about record-keeping for all fleets. Recommendations for how to improve record-keeping could allow policy makers to more readily compare costs between conventional and electric vehicles, track progress toward electrification, and share data between state and local governments.

To support better tracking of data that would support the state's efforts to transform public fleets, the study team urges consideration of the following:

- Support standardized tracking of key data fields across state and/or local government entities, especially vehicle fuel type across all fleets.
- Encourage collection of data related to duty cycles or operations, including typical average and peak miles traveled and miles traveled per year by vehicles. Other helpful data points include cost per mile calculations such as fuel and maintenance costs. Telematics systems could be supported for key agencies or fleets.
- Establish consistent definitions for vehicle attributes such as weight class or mileage tracking across all public agencies.
- Capture fleet information for tracking through data-sharing agreements among state agencies and local governments that report their alternative fuel data.
- Require public agencies to notify DOL about all vehicles removed from public fleets or exempt plates that are transferred to other vehicles.
- Share the results of this project and these recommendations for improved data tracking among state agencies and local governments that report their alternative fuel data.

Areas for further consideration include data currently developed and maintained by DES for many but not all state agencies. One pathway for data pooling and coordination of data collection lies in the reports prepared by state and local public fleets with the Department of Commerce for alternative fuel tracking.

CHAPTER 2: ELECTRIC VEHICLE MARKET OVERVIEW

In tandem with creating the fleet inventory, the study team gathered an extensive amount of data on existing and soon-to-be offered electric alternatives for light-, medium-, and heavy-duty vehicles. This chapter reviews the state of the market for light-, medium-, and heavy-duty EVs including details on the types of vehicles currently offered in the market, planned offerings in the near future, potential gaps in EV availability in some vehicle segments, and examples of the electrification strategies taken to date in both the public and private sphere. As more EVs across all vehicle classes are expected to reach the market in the coming years, decisionmakers will need to reassess the electrification potential of different vehicles and use cases frequently.

LIGHT-DUTY ELECTRIC VEHICLE MARKET OVERVIEW

The light-duty market is the most well-developed for electric vehicles with wide and soon-to-be-increasing range of offerings from multiple manufacturers across all light-duty vehicle segments. As the light-duty vehicle market has expanded, so too has the EV charging network necessary to support these vehicles throughout the country. Light-duty vehicles, here defined as any vehicle with a gross vehicle weight rating (GVWR) below 8,500 pounds, comprise the majority of the public vehicle fleet in Washington. These vehicles include passenger sedans, vans, SUVs, motorcycles, police vehicles, and pickup trucks. Electrification of the light-duty fleet, particularly sedans and small SUVs, is a primary focus for both governments and private entities across the nation. This section describes the current market progress of light-duty EVs in the United States, the EV charging network that has coincided with the expansion of the EV market and highlights supportive policies for EVs and charging infrastructure.

To date, light-duty vehicles have been a primary focus of electrification efforts in Washington and they were the target of Governor Jay Inslee's Electric Vehicle Fleets Initiative. These vehicles make up 39 percent of the public fleet in Washington, the highest share of any of the three class groupings (light-, medium-, and heavy-duty). The governor's initiative set a goal of having an increasing percentage of new passenger vehicle purchases be electric vehicles beginning in 2017 and reaching minimum of 50 percent by 2020 [27]. As of June 24, 2019DES, the department responsible for overseeing the initiative with the SEEP program, announced 113 of its long-range EVs had driven over one million miles. The 113 EVs is a fraction of the reported 5,000 vehicles that DES oversees, and DES still has a way to go to reach Governor Inslee's 50 percent electrification goal. Though their one million miles driven does mark a significant milestone and demonstration of EVs being driven in Washington's fleet [28].

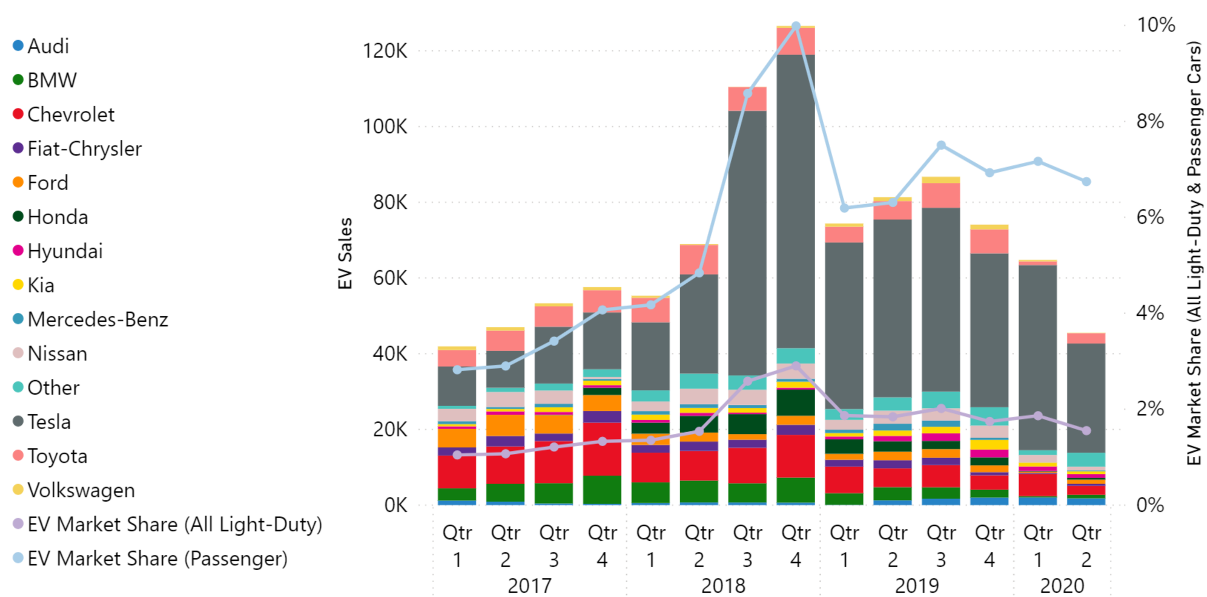
Since the first mass-market light-duty passenger EVs– the Nissan Leaf and Chevrolet Volt– were introduced in 2010 the market has matured considerably. Electrification of passenger vehicles saw a resurgence in the 1990s when General Motors (GM) brought the EV 1 to market to comply with California's first Zero Emission Vehicle (ZEV) program, although high production costs and a range of only 80 miles led to its discontinuation in 2001. This was around the same time that the Toyota Prius was released in the United States and became the first mass-produced hybrid electric vehicle. It was another nine years before Nissan released the Leaf and Chevrolet introduced the Volt in 2010. In that same year, Tesla received a $465 million loan from the U.S. Department of Energy to ramp up their operations. The release of these early EV models coincided with a significant expansion of the nation's charging infrastructure through the American Recovery and Reinvestment Act of 2009 which invested more than

$400 million in transportation electrification projects including funding for roughly 18,000 charging stations throughout the country [29, 30].

Since 2010, EV technology has advanced significantly and automakers have expanded their EV options for consumers. From 2010 to 2019, EV range rapidly increased as a result of innovation and the declining cost of batteries, which decreased by more than 85 percent [2]. Tesla rose to the top of the EV market during this time, offering vehicles with up to 300 miles of range and reaching one million vehicle deliveries in March 2020 [31]. Tesla's success has helped usher in a new era of EVs and, as of August 2020, there were 52 EVs on the market nationwide and more than 1.55 million EVs had been sold in the United States [1]. The market has also expanded beyond sedans and a variety of crossover and electric SUVs are available for sale.

EV passenger vehicle market share and EV sales have both shown steady growth from 2010 through 2019. EV sales and market share peaked during the second half of 2018 when Tesla introduced the Model 3 and then returned to more previously growth levels during the first half of 2019. Both metrics began to decline during the second half of 2019, in part due to the sharp increases from the Model 3 introduction, and then began a sharper decline at the onset of the COVID-19 pandemic in March 2020. EV sales during the first half of 2020 experienced similar declines to conventional vehicles. In the first quarter, EV sales were mostly flat while conventional vehicles sales declined by 12 percent [32]. In the second quarter, EV sales dropped 44 percent, while sales across the entire auto market fell by a similar level of 34 percent [33].

FIGURE 13: U.S. PASSENGER EV SALES 2017 THROUGH Q2 2020



This chart shows the fluctuation of passenger EV sales volumes over time in the United States. Sales peaked in 2018 with the introduction of the Tesla Model 3.

Source: Atlas EV Hub [34]

Although the long-term trend of EVs is positive, the market for passenger EVs has been flat or declining in the last two years. In 2018, total U.S. EV sales grew by 81 percent compared to 2017 while 2019 sales volumes were 10 percent lower than 2018 [34]. As a result of COVID-19, EV sales are down 29 percent in the first and second quarters of 2020 compared to 2019. Figure 13 shows the trend of passenger EV sales from 2017 through the second quarter of 2020.

Tesla has dominated the EV market since reaching full production of the Model 3 in the second half of 2018. In 2019, Tesla was responsible for 56 percent of all EV sales in the Unites States. This has contributed to a top-heavy market where only seven out of 55 offered EV models achieved sales volumes greater than 10,000 vehicles in 2019 [34]. Tesla's control of the EV market could be challenged as other automakers and startups are required to bring an increasing number of EV models to market in some states. California, in an effort to accelerate and widen the passenger EV market, implemented EV sales requirements for automakers through the ZEV Program which was first adopted in 1990 and was reconstituted in 2008. The standards require automakers to make available for sale a certain number of EVs each year based on total sales volumes. Washington adopted the ZEV program in March 2020, making it the 12th state to do so [35].

In addition to requiring manufacturers to make available for sale an increasing number of EVs to consumers, several states and cities are implementing policies to ensure that fleet vehicles are also electrified. In 2015, Washington adopted a commitment to make at least 20 percent, later increased to 50 percent, of all new passenger vehicles in government fleets electric by 2020 [36]. Seattle has taken these commitments a step further in the Drive Clean Seattle Initiative and has a goal of reaching carbon neutrality by 2050 [37]. These commitments are generating savings for fleet operators and helping the jurisdictions achieve environmental goals. In Washington, the Department of Enterprise Services (DES) deployed their first long-range EVs in 2017 and the combined fleet has travelled more than 1.7 million miles, saving an estimated 71,000 gallons of gasoline and replacing it with Washington's low-cost, clean electricity [38].

Cities around the country are also seeing savings by electrifying public vehicles. In Indiana, EVs should recoup their additional upfront costs in just two years according to a local police chief [39]. New York City, which operates the largest municipal EV fleet, is anticipating lifetime savings greater than $8,000 per EV compared to comparable conventional vehicles [40].

EV sales requirements and the cumulative growth in the EV market have led to a significant expansion of the passenger EV charging network throughout the country. Between the end of 2018 and 2019, the total number of charging ports grew by 38 percent and the cumulative number of EVs sold grew by 28 percent [34]. Through September 2020, there were more than 89,000 public charging ports deployed throughout the country. Roughly 20 percent of these ports are DC fast charging and of these stations, Tesla superchargers, which can only be used to charge Tesla vehicles, account for roughly half. As of September 2020, more than 2,600 Level 2 and 630 DC fast charging ports were deployed throughout Washington, roughly four percent of the country's total port count.

Electric utilities are also ramping up investment in the passenger EV charging sector. Since 2012, 45 utilities across 27 states have been approved to invest more than $2.6 billion in programs directly targeting EV charging expansion. These programs could support more than 143,000 Level 2 and 4,300 DC fast charging stations across the country. California and New York account for more than 85 percent of this investment. Washington utilities began filing EV-related programs in 2013 and have been approved to invest almost $23 million in EV charging through September 2020 [41]. Early efforts led to the adoption of HB 1512 in 2019 that gave utilities the express authority to file transportation electrification plans, advertise their EV services, and offer incentives or rebates to support EV and EV charging deployment [42]. See Box 1 for more information on action by the Washington State Legislature related to EV charging.

Box 1. Washington State Legislative highlights on Electric Vehicle Charging Infrastructure

A 2015 study commissioned by the Joint Transit Committee, “Business Models for Financially Sustainable EV Charging Networks” analyzed various financing models for public charging infrastructure and concluded a combination of public subsidies, incentives, and interventions were necessary for charging infrastructure to expand across Washington. These findings helped lay the foundation for the Electric Vehicle Charging Infrastructure Partnership Program (EVIPP), led by the Washington State Department of Transportation. Through EVIPP, $2.5 million in grant funding has been invested in deploying new charging locations along I-5, I-90, and I-82/US-395/I-182 [43] . Additional legislation from 2015, HB 1853, authorized “the Utilities and Transportation Commission to allow a rate of return on investment on capital expenditures for electric supply equipment that is deployed for the benefit of ratepayers [44]” to further encourage utility investment. And most recently, the 2019 passage of HB 1512, authorized “the governing body of a municipal electric utility or public utility district to adopt an electrification of transportation plan and to offer incentive programs in the electrification of transportation [45].”

Despite this growth in EV charging, research from organizations including the International Council on Clean Transportation, the Edison Electric Institute, and MJ Bradley & Associates conclude that gaps remain and the availability of charging, particularly public charging, will have to grow between four and 16 times over 2017 levels by 2025 to meet the anticipated growth in EV adoption in the United States [46]. Bloomberg New Energy Finance (BNEF) projects EVs to reach 60 percent of new passenger vehicles sales in the United States by 2040 [15]. EVs made up 2.2 percent of the entire light-duty vehicle market in July 2020, indicating that sales will have to increase considerably to reach this projected market share in 2040 [2].

Growth in the light-duty EV market is not likely to be evenly distributed around the country as states with supportive policies such as adoption of the ZEV program will likely account for a greater portion of EV sales in the near term. Through June 2020, more than 65 percent of EV sales in the United States have come in states that follow the ZEV program [2]. Washington has long been an EV leader and as of August 6, 2020, the state had 58,619 registered EVs, making it the third-largest EV market in the country behind California and Florida [1]. In addition, EVs made up over seven percent of new light-duty vehicle registrations in July 2020 in Washington, more than three times the national average [2].

Overall market growth will continue to be influenced by new EV offerings. More than 60 new passenger EV models are planned to be released over the next several years, with half coming before the end of 2022 [47]. There are currently no electric pickup trucks available for sale though automakers plan to unveil at least seven models through 2022. This includes an all-electric version of the Ford F-150, the nation’s highest-selling vehicle across all vehicle types [48]. In addition to Ford, other major automakers and EV startups like Rivian, Lordstown Motors, and Nikola are working to bring their first offerings to market with ranges as high as 400 miles [49]. While Rivian’s pickup starts at $69,000, Lordstown is aiming to release their Endurance at $52,000 to compete more closely with Ford and GM. Tesla hopes to hit an even lower price point for their Cybertruck, targeting a starting price of under $40,000 for 250 miles of range when it is introduced in late 2021 [50]. Pickup trucks account for only some of the new EVs expected in the coming years and in July 2020, GM announced plans for large, three-row SUV EVs based on the Hummer and Escalade platforms [51]. Rivian’s three-row SUV is also expected in August of 2021 [52]. The market is still rapidly evolving and as new models are released, the potential for electrification for a given vehicle should be reassessed.

MEDIUM-DUTY AND HEAVY-DUTY ELECTRIC TRUCK MARKET OVERVIEW

The medium- and heavy-duty electric truck market is expanding with a growing number of public agencies, electric utilities, and private companies investing in this technology [53]. Globally, BNEF predicts in their 2020 EV Outlook that zero emission trucks will account for a third of all new commercial vehicle sales by 2040 [15]. In Washington, medium- and heavy-duty trucks and cargo vans account for over 29 percent of the total medium- and heavy-duty public fleet, excluding transit and school buses.

The United States is poised to lead the market for electric trucks and in June 2020, California passed the landmark Advanced Clean Trucks Rule requiring all new truck sales in the state to be zero emission by 2045. The rule goes into effect in 2024 and requires manufacturers to sell an increasing proportion of zero emission vehicles each year. By 2035, 55 percent of Class 2b-3, 75 percent of Class 4-8, and 40 percent of tractor trailer vehicle sales must be zero emission [54]. Shortly after this landmark rule was enacted, Washington along with 13 additional states and the District of Columbia signed a multi-state MOU establishing a goal of 30 percent zero emission medium- and heavy-duty truck and bus sales by 2030 and 100 percent sales by 2050 [55].

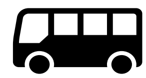
The business case for electric trucks is improving due to falling battery costs, improving technology, and production efficiencies. Public funding and leadership from public agencies will remain essential for increased deployment of these vehicles in the near term as new models enter the market and some vehicle use cases exit the pilot phase and reach higher levels of commercialization [56]. Limited model availability and high cost differentials between conventional trucks and EV alternatives has contributed an absence of publicly owned medium- or heavy-duty electric trucks or vans in Washington. Accounting for 29 percent the vehicles in the Washington fleet, trucks must be a priority for electrification if Washington is to meet greenhouse gas emissions reductions statutory goals. Figure 1 shows the commercial availability of different types of trucks, vans, and buses.

As of 2020, most medium- and heavy-duty truck applications are still in early testing phases and significant price decreases are expected throughout decade. Deployment is being led by California, which offers rebates between $50,000 and $150,000 depending on the use case of the truck through the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) [57]. Many of the vehicles currently available on the market are repowers of an existing vehicle in which the drivetrain of an internal combustion vehicle is replaced with an electric motor and battery pack. The cost to repower an existing vehicle is typically equivalent to, and in some cases higher than, the purchase price of an entirely new internal combustion vehicle. Many vehicle offerings from prominent manufacturers of medium- and heavy-duty electric trucks like Lightning Systems, Phoenix Motorcars, and Motiv Power are repowers of new vehicles from major vehicle manufacturers like Ford and GM. These repowers made up a majority of the EV alternative medium-duty vehicles used in the analysis.

Growth in the electric truck market has also led to several original models from major manufacturers. These vehicles are defined as first-party products where the manufacturer produces the vehicle with an electric drivetrain rather than repowering a vehicle from another manufacturer. A majority of these offerings fall in the Class 6 delivery truck and Class 8 freight truck categories. Leading manufacturers in the conventional short- and long-haul freight truck sectors including Volo, Freightliner, Peterbilt, and Kenworth all have EV models either available in limited production or planned for release by 2022. Daimler, the parent company of Freightliner, first unveiled plans for their eCascadia Class 8 electric freight truck in 2018 and has deployed at least 44 across the West Coast in demonstration projects through March 2020 [58]. Some of these have been deployed in Southern California with funding available through the California Climate Investments program which also supported the first deployment of Volvo's

VNR electric freight truck in June 2020 [59]. These established truck makers will face competition from Tesla, which unveiled a concept version of its Semi in 2017. Since then, the timeline for production of the Semi has been delayed from 2019 to 2021 [60].

FIGURE 14: COMMERCIALIZATION OF ELECTRIC TRUCKS AND BUSES BY VEHICLE TYPE

Use Cases	Weight Class	Commercial Availability	
Long Haul Heavy-Duty	Heavy-Duty Vehicles (Class 7-8)	Demonstration/ Prototype	
Short Haul Heavy-Duty	Heavy-Duty Vehicles (Class 7-8)	Demonstration/ Prototype	
School Bus	Heavy-Duty Vehicles (Class 7-8)	Full	
Transit Bus	Heavy-Duty Vehicles (Class 7-8)	Full	
Terminal Tractor	Heavy-Duty Vehicles (Class 7-8)	Demonstration/ Prototype	
Delivery Straight Truck – Small	Medium Duty Vehicles (Class 3-6)	Limited	
Delivery Straight Truck – Large	Medium Duty Vehicles (Class 3-6)	Limited	
Delivery Step Van – Small	Medium Duty Vehicles (Class 3-6)	Limited	
Delivery Step Van – Large	Medium Duty Vehicles (Class 3-6)	Limited	
Cargo Van	Medium Duty Vehicles (Class 3-6)	Limited	

This chart shows the commercial availability of different medium- and heavy-duty vehicles with some truck applications still in the prototype phase of development.

Source: Edison Electric Institute [61]

In the short-haul market, Freightliner is testing their eM2, an electric version of their bestselling M2 106 Class 6 box truck. Similar to the eCascadia, the eM2 is still in the testing phase and Freightliner's "Innovation Fleet" of electric trucks reached a combined 300,000 miles in real-world use by customers in late July 2020 [62]. The short-haul market is filled out by newcomers to the U.S. market including Chinese manufacturer BYD and Canada-based Lion Electric. Both manufacturers offer Class 6 and Class 8 trucks for urban delivery and have deployed vehicles in a testing capacity in select markets [63]. In addition to short-haul trucks, an increasing number of electric refuse truck models have been entering the market. In

September 2020, New York City announced it would begin testing the first electric refuse trucks from Volvo's subsidiary, Mac Trucks [64]. Electric refuse trucks are also offered in a limited production capacity from BYD and Lion. Recology, the garbage service provider for the City of Seattle, deployed two electric refuse trucks by BYD in May 2019. The trucks were deployed as a part of the Seattle Public Utilities Green Fleet initiative that deployed 200 new vehicles including other all-electric, hybrid, and renewable natural gas vehicles in early 2020 [65].

Overall, an increasing number of electric trucks across all use cases are expected to reach the market as leaders like Freightliner ramp up production between late 2020 through 2022 [63]. The next wave of electrification will also include specialty vehicle types like fire trucks and construction vehicles that until now have had no electric option are beginning to enter the early demonstration stage of development. Los Angeles purchased one of the first concept fire trucks in February 2020 and Volvo is committing to mass production of electric construction vehicles, beginning with the ECR25 compact excavator and L25 compact front end loader [66, 67].

So far, the electrification of construction and other specialty equipment is still in the early stages in the United States. Construction equipment giant Caterpillar announced in 2018 a strategic investment in Fisker, a passenger EV startup, in order to advance research into solid state batteries that could accelerate the electrification of construction vehicles [68]. As of 2020, Volvo leads a group of manufacturers including Japanese conglomerates Hitachi and Komatsu to introduce electric excavators, backhoes, and dump trucks to the market [69]. Electric utilities in New York have purchased early versions of an electric backhoe loader manufactured by CASE [70]. Utilities are also set to benefit from the electrification of bucket trucks, which began with the introduction of plug-in hybrid vehicles made for Pacific Gas & Electric by Efficient Drivetrains Incorporated (EDI) in California in 2014 [71].

As is the case with fire trucks, ambulance electrification is only in early stages. Nissan deployed their debut electric ambulance in Tokyo in 2020 and will continue to roll out large electric vans serving other use cases [66].

The electrification of agricultural equipment has taken place more quickly overseas with several early tractor prototypes being piloted including one from John Deere in France. Startups like Solectrac have begun to roll out early models in the United States and some states have allocated VW Settlement funds to repower diesel irrigation equipment with electric engines [72].

Government and utility funding remain a key driver of electric truck deployment in the United States. Nationwide, more than $214 million in government funding has been awarded to public and private fleets for the purchase of electric trucks, most of which was allocated by California and New York [26]. The California HVIP and the New York Truck Voucher Incentive Project (NYTVIP) are the two most significant dedicated funding resources for electric trucks in the country, and California utilities are spearheading efforts to deploy charging infrastructure at truck stops along the entire length of Interstate 5 [41, 73]. Fleet operators looking to deploy electric trucks are expected to receive an additional $220 million for charging infrastructure from approved utility programs across the United States.

Looking ahead, a recent report from the North American Council for Freight Efficiency indicated that Washington is one of the highest priority markets for electric trucks in the country based on public and utility support, environmental needs, and technology availability [14]. While state government support for truck electrification continues to drive deployment around the country, commitments from large private companies operating truck fleets have also led to more electric trucks deployed [56]. Commitments from large retailers like Walmart and Amazon have helped to finance the development of new zero emission trucks from automakers including Kenworth, Freightliner, Volvo, and Tesla. This has also led to the formation of several smaller start-ups focused on electric trucks [56]. These commitments are expected to increase the number of heavy-duty trucks available on the market from five to 19 by 2023 [74]. Companies not only hope to achieve environmental goals and be seen as leaders in electrification among their competitors, but they also see potential for cost savings from reduced fuel and maintenance costs [56].

Deployment targets for electric trucks have now been set by 15 states and Washington DC, providing a clear signal to manufacturers to increase production volumes and bring new models to market. Nationwide, roughly 20 percent of funding available through the Volkswagen Settlement has been awarded to specific projects and electric trucks are eligible for more than $250 million in unspent allocations throughout the country. Multi-state and multi-stakeholder efforts like the West Coast Clean Transportation Corridor Initiative are positioned to supply the charging infrastructure needed to rapidly scale the number of electric trucks on the road [75].

ELECTRIC SCHOOL BUS MARKET OVERVIEW

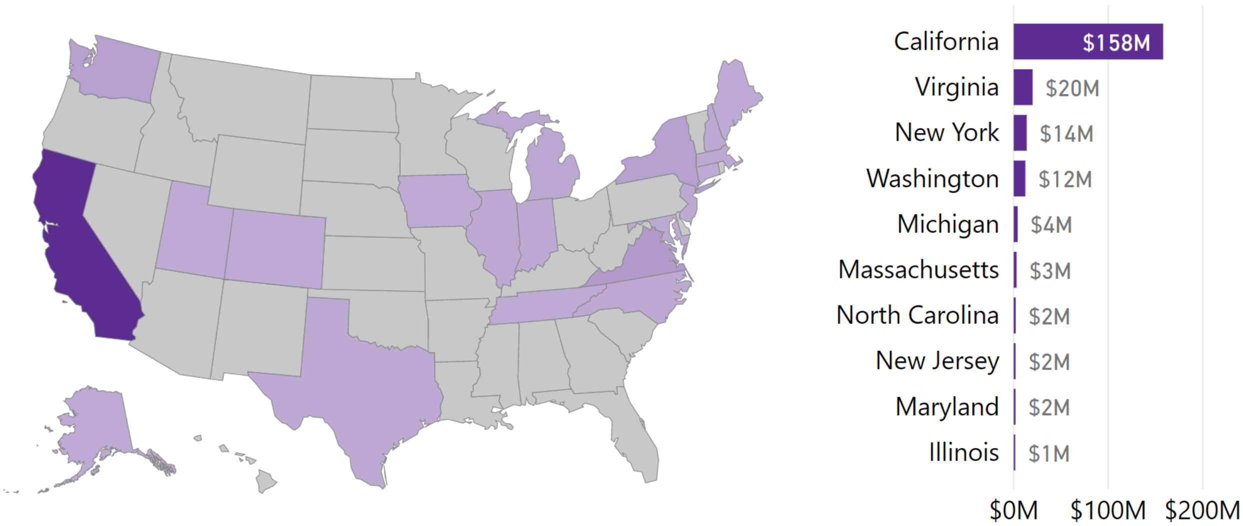
School bus electrification has accelerated rapidly since July 2019 due to a surge in state government funding for this technology through the VW Settlement and dedicated state programs in California. At the end of 2018, only $23 million had been awarded for electric school buses across the United States and by the end of 2019, school districts had received $175 million [53]. School bus electrification is an important opportunity to reduce emissions in Washington with 10,838 school buses reported representing 19 percent of the entire public fleet. Also, an estimated 44 percent of Washington's 1.1 million students use school buses to travel to and from school, a percentage slightly higher than the national estimate of 29.8 percent [76].

With close to 500,000 students relying on school buses, conversion of school bus fleets from diesel to electric has been highlighted for the health benefits that are passed on to child passengers, and the economic cost savings from bus batteries being used to benefit the electrical grid [77]. Other more widely understood benefits of reduced emissions were also understood as benefits to electric school buses however high upfront costs in comparison to their conventional models limited their production. Increased state grants for this technology kickstarted the market and reduced the upfront cost differential where an electric school bus can cost more than three times the amount of a diesel bus.

Beginning with the first large order of 150 electric school buses by First Priority GreenFleet in Sacramento, California in 2018 [78], electric school buses are now readily available from at least seven manufacturers. Through August 2020, more than $225 million has been awarded to school districts across 20 states, including Franklin Pierce school district in Pierce County, Washington, to deploy electric school buses in at least a pilot capacity [26]. Outside of California, 95 percent of these public funding awards have come from the Volkswagen Settlement. In the Golden State, school buses are eligible for funding under both the HVIP program and various other state programs. Figure 15shows the funding breakdown for electric school buses throughout the country.

Washington has awarded the third-highest amount of government funding to electric school buses following the announcement of a $12 million award through the Volkswagen Settlement in April 2020 funding 40 electric buses. These 40 buses will be deployed across 13 counties throughout the state [26], though as discussed in discussed in *Chapter 1*, these buses were not included in the results findings.

FIGURE 15: GOVERNMENT FUNDING FOR ELECTRIC SCHOOL BUSES BY STATE



This chart shows the government funding awards for electric school buses throughout the country. California leads with $158 million out of the total $225 million awarded to this technology.

Source: Atlas Public Policy [26]

Increased funding may have instigated new investments in manufacturing capacity in the United States as manufacturers now offer electric models across three of the four school bus types (A, C, and D) with a range of battery options based on different daily travel requirements. Lion Electric is currently one of the only all-EV manufacturers in the market and their larger Type C and D buses offer battery packs providing up to 220 kilowatt-hours and 155 miles in range [79]. Blue Bird is the only other manufacturer offering buses for all three types and has a statewide contract with Washington to facilitate easy procurement of Type D electric school buses at a set price [80]. Their Type A buses have 89 kilowatt-hour battery packs and provide up to 100 miles of range [79]. Long-time school bus manufacturer Thomas Built Buses is partnering with electric transit bus manufacturer Proterra to produce new electric school buses to compete with Lion and Blue Bird [81]. Starcraft, TransTech, IC Bus, and Collins fill out the remainder of the electric school bus market.

Several electric utilities are also actively supporting the electrification of school buses. Dominion Energy in Virginia has committed to deploy the largest fleet of school buses in the country with 50 buses already on order and plans to deploy of at least 1,000 more throughout their service territory by 2025 and to electrify all new school buses in their service territory by 2030. Dominion will cover the incremental cost of electric buses and charging infrastructure while school districts still have to provide funding equivalent to the cost of a comparable diesel bus. [82]. In Michigan, DTE Energy was approved in May 2019 to invest $1.9 million in charging for school buses and is one of the utilities partnering with the Department of Environment, Great Lakes, and Energy to supply charging infrastructure for buses funded through the VW Settlement [83].

A unique focus for school bus electrification is their potential application in bidirectional vehicle-to-grid integration (VGI) programs [84]. Utilities throughout the country have begun to use electric school buses to test bi-directional power flow, also known as V2G, allows utilities to both supply power to and draw power from EV batteries to serve as a distributed energy storage resource. School buses are particularly apt to provide this service due to their large battery sizes, predictable operational patterns, and long periods of downtime during the summer and while school is in session [85]. Potential grid benefits have helped improve the value proposition for utilities investing in this technology and school districts and private fleet operators are set to receive at least $60 million from utility programs supporting electric school bus deployment [53]. As VGI applications are further developed, school buses have the potential to provide benefits well-beyond their typical duties and fleets could potentially sell aggregated energy storage services to the grid, offsetting the high upfront costs [84]. V2G is further explained as a financing mechanism in *Chapter 8*.

ELECTRIC TRANSIT AND SHUTTLE BUS MARKET OVERVIEW

Electric transit buses are the most highly funded vehicle type in the medium- and heavy-duty market [53]. In Washington, transit buses made up approximately six percent of the total public fleet as of 2018 and at least 22 of these buses are battery electric. In addition to this, the state has at least 176 electric trolley buses in operation that are operate along fixed routes with overhead wires. While these trolley buses provide reliable, clean transportation, this section focuses on battery electric transit and shuttle buses and the growth in that market.

Nationwide, the first all-electric transit buses were deployed around 2010 in California and deployment has proliferated across the United States since then [86]. Transit bus electrification is expected to accelerate rapidly around the world with BNEF predicting in their 2020 EV Outlook that electric transit buses will make up 67 percent of the global fleet by 2040 [15].

In the United States, CALSTART estimates that electric transit bus deployment rose by 37 percent in 2019 and there were 2,225 buses deployed in the country through October of 2019. Transit bus electrification has been led by major commitments from states and local transit agencies to convert their fleets to zero emission vehicles. California was the first state to announce a commitment to a completely zero emission transit fleet by 2040 and New Jersey followed in February 2020 with a commitment to only purchase zero emission transit buses after 2032. Similar commitments have been made by transit agencies serving large cities like King County Metro in the Seattle area and the Metropolitan Transit Authority in New York City [3, 87].

Public transit agencies benefit from dedicated funding sources available for the conversion of fleets to EVs. Namely, the Federal Low or No-Emission (Low-No) Vehicle Program has awarded almost $430 million to transit agencies for electric transit buses and charging infrastructure since it began in 2015 [26]. In addition to this, $155 million for electric transit buses has been awarded through the Volkswagen Settlement through September 2020. Electric utilities have also pledged to provide at least $169 million in funding for transit buses that will go primarily towards charging infrastructure [53].

Washington had the second largest fleet of electric transit buses as of 2019 after California with at least 211 vehicles ordered or in operation [13]. King County metro alone has committed to purchasing 120 electric transit buses worth $130 million, with other Transit agencies such as Link Transit, Everett Transit, and Spokane Transit among others all planning to expand existing electric bus operations through the end of 2020 [3, 4, 5, 6]. Transit agencies across Washington benefit from the state's Green Transportation Capital Grant Program, which awarded $12 million for transit bus electrification projects in the 2019-2021 cycle [88]. When analyzing the electrification potential of transit buses in Washington, the study team took these transit bus orders were taken into consideration.

Increased government funding for electric transit buses has spurred growth in domestic manufacturing with four major companies including Proterra, BYD, New Flyer, and Gillig all operating electric transit bus manufacturing facilities in the United States. Each of these manufacturers offer multiple variations of transit bus models ranging in size from 30 to 60 feet with variations in battery capacity and range. Manufacturers are also exploring different methods of refueling and transit agencies like Link Transit are working with charging innovators Momentum Dynamics to charge their buses wirelessly [5]. Link Transit's pilot program for wireless charging has been successful and the agency is currently in the process of expanding wireless charging to more bus routes. Proterra has developed an innovative financing approach which allows transit agencies to lease the batteries for their buses while purchasing the vehicle chassis to equalize the upfront cost of their buses with comparable diesel models [89].

While electric transit buses ranging from small 30-foot models to articulated 60-foot buses are widely available to transit agencies throughout the United States, there are several types of specialty transit vehicles where electric models are still in the testing phase. BYD announced the development of an electric double-decker bus in February 2020 and is the only manufacturer to do so [90]. There are nearly 100 of these double-decker buses across transit fleets in Washington. Electric long-range coach buses are also being developed and launched for travel along major routes such as Los Angeles to San Diego, San Francisco to Sacramento, Portland to Seattle, and New York to Philadelphia [91].

Transit buses are only one component of the transit fleet in Washington and other transit vehicles like shuttle buses and vans account for 33 and 29 percent of the transit fleet, respectively. EV alternatives for these vehicle types have been slower to enter the market due to low production volumes and limited adoption by transit agencies. However, this market has also grown and model availability has expanded in since 2018. Manufacturers including Lightning Systems, GreenPower Motor Company, Motiv Power, and Phoenix Motorcars have all brought electric shuttle buses to the market. However almost all of these manufacturers rely on after-market conversions of Ford and Chevrolet vehicles, such as Lightning System's converted electric Ford Transit passenger van [92]. Greenpower Motor Company is currently the only original equipment manufacturer for electric passenger vans, producing their own custom chassis. Electrified versions of vans and shuttle buses will be available directly from manufacturers in the next several years with Ford committing to an electric Ford Transit by 2022 [93].

The market for transit electrification is growing with the nation's largest transit fleets in cities like Los Angeles and New York City moving to electrify all buses over the next two decades [94, 95]. Some states have made policy commitments that will likely lead to a surge in new models across all categories of transit vehicles. For example, the California Clean Air Resources Board (CARB) passed the Advanced Clean Trucks Rule, which commits the state to electrify all segments of their public van, shuttle, and truck fleets [54]. In addition, eight states and the District of Columbia signed a Statement of Intent led by the Northeast States for Coordinated Air Use Management to accelerate the electrification of trucks and buses [96].

HYDROGEN VEHICLE MARKET OVERVIEW

The study team also considered the hydrogen fuel cell vehicles in this analysis. Like a battery electric vehicle, a fuel cell vehicle is zero tailpipe emissions and use electricity to power an electric motor. Instead of a battery, a hydrogen fuel cell vehicle uses compressed hydrogen gas to generate electricity using an onboard fuel cell. Also, like EVs, hydrogen fuel cell vehicles are more efficient than conventional vehicles on an energy-equivalent basis. They have a comparable refuel time to a gasoline or diesel vehicle, which can be an important characteristic in some use cases [97]. Despite these benefits, hydrogen fuel cell vehicles are constrained by higher production costs, fuel pricing, and limited refueling infrastructure when compared to EVs. This section outlines current hydrogen fuel technology in the United States and its role in the study as an alternative to conventional vehicles.

While there are both light-duty and heavy-duty hydrogen vehicles available for sale, the market has grown very slowly compared to battery electric vehicles. In the light-duty sector of the United States, there are only three passenger hydrogen fuel cell vehicles from leading manufacturers compared to more than 52 battery electric and plug-in hybrid electric vehicles as of August 2020 [98, 2]. Of the three hydrogen vehicles on the U.S. market, only the Toyota Mirai is available outside of California. Consumers in Hawaii can also purchase the Mirai and Toyota has sought to increase demand by providing up to three years of free fuel [99]. Honda also offers a hydrogen sedan through their Clarity line and the Hyundai Nexo is the only midsize fuel cell vehicle available on the market [98].

The growth potential of the hydrogen vehicle market is limited under current conditions where passenger vehicle model offerings are limited to California. Furthermore, the upfront cost of the Hyundai Nexo is $20,000 higher than that of the company's leading all-electric crossover vehicle, the Kona [100].

In addition to high upfront costs and limited model availability, hydrogen vehicle drivers also face a more limited refueling infrastructure compared to EVs. The U.S. Department of Energy Alternative Fuels Data Center estimated that there were just 43 retail hydrogen refueling stations nationwide with almost all of them concentrated in California [101]. As of 2020, there are no retail hydrogen fueling stations in Washington state. By comparison, there are 98,000 publicly accessible EV charging ports throughout the country, with nearly 1,200 in Washington state [102].

While the lack of infrastructure is a serious barrier, the cost of fuel may be an even larger challenge for fuel cell vehicles to compete with gasoline or diesel vehicles. Whereas EVs can often be refueled at the gasoline-equivalent of a $1 a gallon, for hydrogen vehicles, the retail price is considerably higher at more than $15 per gallon of gasoline equivalent as of April 2020 [103].

Analysts predict that the market for hydrogen buses and trucks will grow faster for heavy-duty trucks than for passenger vehicles. Globally, BNEF's 2020 EV Outlook expects only one percent of global passenger vehicles to be hydrogen fuel cell vehicles by 2040. The Outlook predicts that these vehicles will account for roughly 3.6 percent of new heavy-duty truck sales and 6.5 percent of bus sales over the same timeline [15].

Several of the same companies offering hydrogen passenger vehicles are also targeting the heavy-duty hydrogen truck market. Both Toyota and Hyundai have plans to commercialize hydrogen freight trucks for the U.S. market before 2022. In 2018, Toyota partnered with Kenworth to deploy 10 hydrogen freight trucks at the Ports of Los Angeles and Long Beach through a $41 million grant from the California Climate Investments program [104]. This round of funding from the program totaled $53 million for medium- and heavy-duty hydrogen vehicles and also included grants for other vehicle types including delivery trucks and yard tractors [26]. Hyundai, another manufacturer focused on development of hydrogen vehicles, unveiled their hydrogen freight truck in 2019 [105].

Toyota was one of the partners on a $1.9 million grant awarded by the Centralia Coal Transition Board to Douglas County Public Utility District and the Bonneville Environmental Foundation in October 2020. The grant will fund the Renewable Hydrogen Demonstration Project, which will deploy the first hydrogen fueling station in the state. The infrastructure installed through the project will support anticipated growth in both the fuel cell passenger vehicle and truck markets and will also include funding for demonstration vehicles when the station opens in 2021 [106].

In addition to the established manufacturers, startup Nikola Motors is planning to enter both the light- and heavy-duty hydrogen market. Nikola has garnered significant attention in recent years with major retailers including Anheuser-Busch logging orders for hundreds of fuel cell trucks in 2018 [107]. The company has since pledged to invest $1.6 billion as they look to produce their first vehicles by the end of 2022 and broke ground on a factory in Arizona in July 2020 [108]. However, Nikola faced significant scrutiny in late 2020 amid claims of non-functioning prototype vehicles, leading to the stepping down of the founder and casting doubt over the timelines estimating when Nikola hydrogen vehicles will enter the market. Overall, there are a limited number of hydrogen trucks on the market and all models are still in the pilot or pre-production phase.

The hydrogen bus market is more mature and widespread in the United States compared to the truck market. Since 2015, more than $38 million has been awarded to transit agencies in Ohio, Illinois, Nevada, and California through the Federal Low-No program and state grants for the purchase of fuel cell buses [26]. New Flyer is the leading manufacturer of fuel cell buses in the United States and the manufacturer received a $12.5 million grant through the CCI program in 2017 to provide five new buses to SunLine Transit in the Coachella Valley of California [26]. As of September 2019, CALSTART estimated there were at least 70 hydrogen fuel cell transit buses in the United States compared to more than 2,100 battery electric transit buses [13].

While some transit agencies have focused on this technology, the majority of government funding through the VW Settlement and Federal Low-No program has gone toward supporting battery electric technologies. Transit agencies have been awarded $590 million for electric buses through the two programs compared to just $26 million for hydrogen buses [26].

A 2018 report on fuel cell bus pilot projects from NREL placed the cost of a 40 foot fuel cell bus at $1.2 million, a figure two to three times the price of equivalent internal combustion buses and nearly 50 percent more than equivalent battery electric buses listed on the Washington state transit bus contract [109]. Pilot deployments of fuel cell buses have been considerably more expensive to fuel on a per mile basis than conventional vehicles [110, 111].

Due to the limitations present in the hydrogen sector including limited model availability, lack of sufficient refueling infrastructure, and high upfront and fuel costs, the study team did not consider hydrogen fuel cell vehicles as viable alternatives to internal combustion vehicles currently owned by the state and they were excluded from the total cost of ownership analysis.

CHAPTER 3: ANALYSIS METHODOLOGY

To accurately assess the electrification potential of public vehicles in Washington state, the project team reviewed the fleet inventory detailed in *Chapter 1* and selected vehicles for which sufficient data was available and a suitable electric alternative existed, to conduct a multivariate analysis. This analysis compared the total cost of ownership (TCO) of existing internal combustion vehicles in the public fleet with up to three electric alternatives under a wide array of scenarios (see Box 2).

The comparative analysis considered a state in which the public agencies would replace currently owned vehicles with their 2019 or 2020 model year equivalents or with an equivalent EV. The analysis assumed that all vehicles would be used in the same manner as they had been previously; that the annual mileage, useful life, and vehicle location, would be consistent for a replacement vehicle.

In the sections below, the process for assembling, selecting, and standardizing fleet data, determination of likely fuel and electricity prices, selecting EV alternatives, determining vehicle maintenance costs and fuel economy, projecting future vehicle costs, and selection of potential charging scenarios and policy options are detailed. For a full listing of all inputs used in the TCO analysis, see *Appendix A*.

Box 2. Cost Effectiveness Evaluations Using Total Cost of Ownership

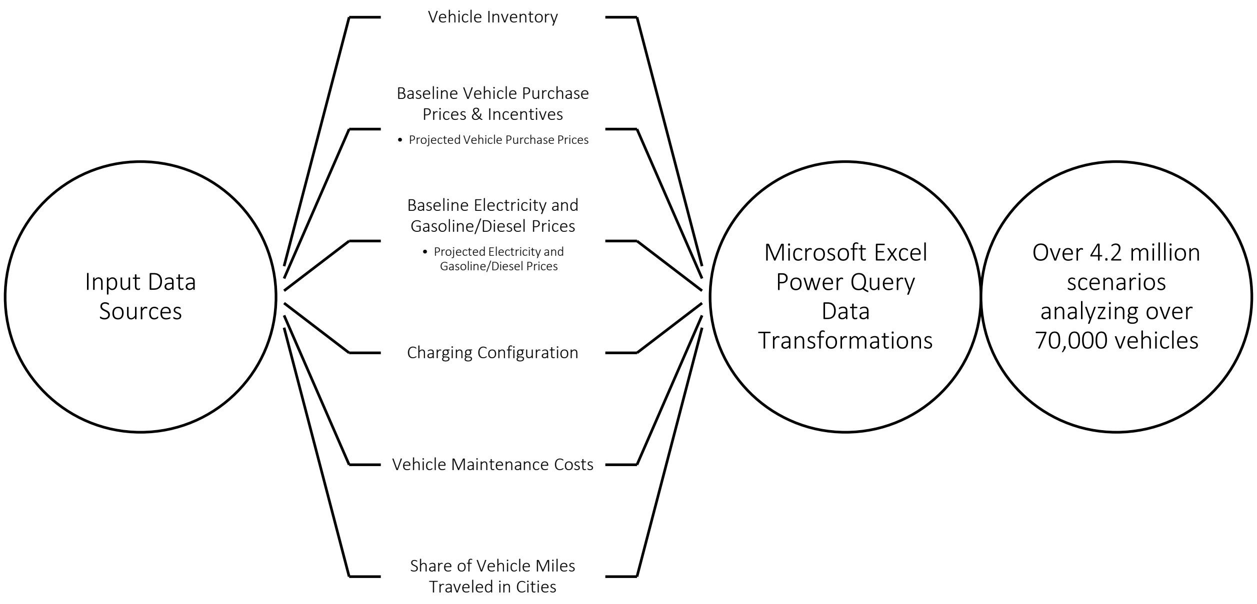
In order to evaluate the cost effectiveness of transitioning to an EV, the study team chose to use total cost of ownership as the metric of comparison. Total cost of ownership reflects the lifetime costs or savings associated with electrification (including vehicle purchase, fueling infrastructure, and discounted fuel and maintenance costs) and is already used by Washington for financial comparisons of EVs and internal combustion vehicles as described in WAC 194-28 and 194-29. At present, the primary financial benefit from transitioning to an EV is operational cost savings from lower maintenance and fuel costs and these savings are best captured in a vehicle's total cost of ownership. It should be noted, however, that TCO does not capture the externalized costs associated with internal combustion vehicles such as greenhouse gas emissions unless a price on pollution is included. If the environmental costs associated with internal combustion vehicles were to be monetized, the comparison between EVs and internal combustion vehicles would be more favorable. The effect of monetizing these environmental benefits via a price on carbon is explored in *Chapter 8*.

DATA ASSEMBLY PROCESS

For this study, several data tables were merged and transformed to allow for a vehicle-by-vehicle multivariate scenario analysis on the total cost of ownership of publicly owned vehicles for 2020, 2025, 2030, and 2035. For projection scenarios, inputs for electric alternatives, purchase prices, and fuel prices were updated using the best available public projections. For the purposes of projecting the future total cost of ownership of electric and internal combustion vehicles, the study team did not include public policy options outside of the existing federal EV tax credit and Washington sales tax exemption. All remaining input parameters (e.g., vehicle inventory, procurement method, resale value estimation, insurance, maintenance, vehicle miles traveled, charging configurations) were assumed consistent with the present-day analysis.

The diagram below depicts the process of data aggregation and transformation performed to create the multivariate scenario analysis.

FIGURE 16: DATAFLOW FOR MULITVARIATE SCENARIO ANALYSIS



Below, each category of inputs into the analysis are described, including methodology and assumptions along with each category's effect on the total number of scenarios analyzed (scenario multiplier).

VEHICLE INVENTORY AND ELECTRIC ALTERNATIVES

The study team reviewed the initial vehicle inventory and determined vehicles were to be included in the analysis if they were internal combustion engine vehicles with an identifiable make and model and had a an EV equivalent. With data collected on over 46,912 vehicles, the study team found fleet data from state agencies, public transit agencies, and school districts to be the most comprehensive. Survey data collected from city and county fleet managers on the number of vehicles in their fleet and vehicle types, was considered incomplete. After removing incomplete data, existing electric vehicles, and vehicles without an electric alternative from the entire fleet inventory, the study team found 28,913 vehicles to analyze.

In the case where a vehicle owned by the state was no longer in production, the project team selected the 2019 equivalent model from the same manufacturer. A table that maps existing vehicle makes and models owned by state agencies onto their 2019 or 2020 equivalent along with EV alternatives is available in *Appendix B*.

Electric alternatives applied in the present-day analysis were updated to account for projected changes in purchase price in five-year increments from 2025 to 2035. In cases where an electric alternative was not available for the present-day analysis (as was more often the case in the medium- and heavy-duty segments) a hypothetical vehicle was considered with price and performance attributes estimated based on recent analysis results from Argonne National Laboratory [112, 113].

LOOKUP TABLES

In order to make the data across the inventory compatible for the analysis and the Microsoft Power BI software used for visualizations, several lookup tables were created, including:

- **Agency Lookup**: Used to make public agency names consistent across data sources.
- **City-County Lookup**: Used to map city and county fleet names with valid counties in Washington.
- **DNR Region Lookup**: Used to map Department of Natural Resources region to valid counties in Washington.
- **Counties where an Agency Operates**: While county-specific location data was included for many vehicles, the study team relied on the primary county where an agency operates when no data was available. Several agencies operate in more than one county, including school districts, public transit agencies, and state agencies. Although state agencies have operations across the state, the inventory of vehicles provided by state agencies included a county assignment for the vast majority of vehicles. For vehicles which did not have a specific county assignment, a statewide average was used. For agencies that operate in multiple counties, a weighted average was completed using the counties where the agency operates. The average was weighted either by population for Gasoline/Diesel prices or the number of electricity customers for electricity prices.
- **Use Case**: Used to map use cases (e.g., Police Pursuit) as defined in the inventory with a vehicle class (light-, medium-, or heavy-duty).
- **Fuel Types Text Replacement**:
    - Replace Hybrid with Gasoline-Hybrid
    - Replace Flexible Fuel Vehicle (FFV) with FFV
    - Replace Compressed Natural Gas (CNG) with CNG
    - Replace Gas with Gasoline
    - Replace missing values with Gasoline
- **Use Case Text Replacement**:
    - Replace VAN with Van
    - Replace SEDAN with Sedan
    - Replace suv with SUV

IMPUTED AND MISSING DATA

In addition to the lookup tables described above, the fleet inventory used for analysis had instances of missing or inaccurate data. To address this issue, the study team applied the following methodology:

- **Annual Vehicle Miles Traveled (VMT)**: Atlas's Fleet Procurement Analysis Tool, the tool used to calculate the total cost of ownership estimates, uses annual VMT as an input. In most cases, the inventory included total mileage. To convert that into an annual figure, the project team divided the total mileage by the age of the vehicle. For vehicles included in the analysis with no VMT data available (zero or missing) or for which a full year of data was not available, the study team assumed the average VMT for the specific use case would apply. Average VMT per use case was calculated from other vehicles for which VMT data was available in the inventory. A key exception for VMT data was for school buses. The mileage data provided to the study team was by school district and not by individual bus. The study team assumed all buses within a given district traveled the same mileage each year. School closures due to the outbreak of COVID-19 limited data availability and the study team was unable to ascertain more detailed information on school bus VMT. For vehicles analyzed where no data was available or derivable as described above, annual VMT of 10,000 miles was assumed.

- **Useful Life:** The study relied upon the planned useful life rules established by each agency to determine the expected useful life for a given vehicle. If a vehicle exceeded its agency's planned useful life, the study assumed the useful life of a replacement vehicle would be equal to the vehicle's current age up to a maximum of 25 years. For vehicles which relied on maximum mileage to determine replacement schedules instead of years of ownership, the useful life was calculated by determining the average annual VMT and dividing the maximum mileage by that figure, capped at a maximum of 25 years. For vehicles analyzed where no data was available or derivable as described above, a useful life of 10 years was assumed.
- **Vehicle Make, Model, Year, Weight Class, and Fuel Type:** To overcome potential user error in the fleet inventory and standardize vehicle naming conventions for vehicle make, model, year, weight class, and fuel type, the Vehicle Identification Number (VIN) for each vehicle was decoded using the National Highway Traffic Safety Administration's vPIC decoder (https://vpic.nhtsa.dot.gov) when available to accurately determine this information. When VIN data was not available, the study team relied on the Washington-provided information in the inventory. Vehicle weight classes were divided into Light, Medium, and Heavy following the classification system established by the Federal Highway Administration. The exception to this methodology is that all vehicles in class 2b were included in the Medium class instead of Light, based upon the application of California's Advanced Clean Truck rule.
- **Use Case:** For light-duty vehicles and school buses, the study team relied on the use case as defined by Washington. The exception to this rule was for the Ford C-max, a sedan which is currently out of production and for which the model replacement was a Ford Escape, an SUV. These vehicles were recategorized as SUVs for the purpose of the analysis. For medium- and heavy-duty trucks and vans, the study team relied on the vehicle equipment description to determine the use case for each vehicle. For transit buses, the study team relied on decoded VIN data to differentiate between 30', 35', 40' and 60' transit buses. For shuttle buses, the study team relied on the reported passenger capacity from the fleet inventory to place vehicles into categories of 8-12, 12-16, 16-20, 20-24, and 24+ passengers. 0 lists all use cases analyzed in the analysis.

EV ALTERNATIVES

After combining and standardizing inventory data as described above, the study team next determined the set of vehicles to include in the analysis. To determine if a vehicle would be analyzed, the following methodology was adhered to:

- Existing electric and plug-in hybrid electric vehicles were excluded from the analysis.
- All vehicles from the city and county fleets were excluded from the analysis due to a lack of detailed data on vehicle make and model, annual mileage, and useful life.
- School buses, public transit vehicles, and state agency fleet vehicles that could not be mapped to an available light-, medium-, and heavy-duty vehicle were excluded from the analysis.
- Vehicles for which available detailed data was insufficient and for which no data alternatives could be identified were excluded from the analysis.

To select appropriate EV alternatives for each vehicle, the study team referred to the vehicle use case to determine the range of potential EV alternatives. With the range of potential alternatives, the study team deferred first to vehicles already being purchased by the state or on offer on the statewide vehicle contract.

Within each use case, the study team deferred to vehicle characteristics to inform the selection of an appropriate EV alternative. Seating capacity, drive type, and storage capacity were all considered when selecting EV alternatives, in each case pairing internal combustion vehicles with EV alternatives which most closely matched the vehicle characteristics.

It is important to note that the study team did not have access to information on daily driving behavior for vehicles and therefore did not give consideration to EV range when selecting an EV alternative, except in the case of school and transit buses. To reduce the potential that a vehicle would not have sufficient range, no battery electric light-duty vehicles with less than 200 miles of range were selected as alternatives.

For medium- and heavy-duty trucks, model availability and detailed vehicle data, such as manufacturer suggested retail price (MSRP), was a limiting factor and EV alternatives were selected based on use case and available information for any EV alternatives. In many cases, the EV alternative was limited to one vehicle. It should be noted that the team avoided analyzing the total cost of ownership of repowering existing medium- and heavy-duty vehicles owned by the state. The study team did not consider this a prevailing electrification strategy in the future.

For school and transit buses, the study team selected vehicles which met the criteria defined during the bid process for selecting vendors for statewide vehicle contracts. In the case of school buses, if a vehicle traveled less than 35 miles per day based on the total annual mileage divided by the number of school days in a year, then an additional alternative was included with a smaller range and lower price. Alternatively, if a bus traveled more than 75 miles per day, the additional alternative vehicle was a EV with a longer range and higher price.

Scenario Multiplier: There were more than 46,912 vehicles in the inventory. Of this amount, 28,913 vehicles were included in the analysis (city and county vehicles were excluded along with existing publicly-owned electric vehicles). For each present day vehicle, between one and three electric alternatives were included totaling 44,279 electric vehicles. In sum, 77,374 unique vehicle models were included in the analysis.

VEHICLE RESALE VALUE

For light-duty vehicles, the study team compiled used vehicle sale prices from Autotrader across the metro regions of San Francisco, Washington, D.C., Atlanta, and Minneapolis to update the existing depreciation calculation within the Fleet Procurement Analysis Tool. For medium- and heavy-duty vehicles, the study team followed the methodology used in Argonne National Lab's AFLEET tool, assuming a flat percentage decrease in vehicle value each year. At the end of a vehicle's useful life, the study team assumed that a vehicle would be sold at its depreciated value.

Scenario Multiplier: N/A

PRESENT DAY VEHICLE PURCHASE PRICES AND VEHICLE INCENTIVES

Present day vehicle purchase prices were taken from Washington statewide vehicle contracts for light-duty vehicles, transit and shuttle buses, and school buses. For light-duty vehicles which were not on offer on the Contract Automobile Request System (CARS), an average percentage discount for equivalent vehicles offered on CARS was applied to MSRP data from Edmunds. Light-duty vehicle prices were inclusive of the sales tax exemption for qualifying clean alternative fuel and plug-in hybrid vehicles. Vehicle MSRPs for medium- and heavy-duty trucks were based upon replacement values listed in the Washington state agency inventory and average prices from commercialtrucktrader.com. For electric vehicles, values were also taken from Washington statewide vehicle contracts, with additional pricing data coming from vehicle contracts from the state of Georgia and California. Several manufacturers including Lion and GreenPower Motor Company provided quotes for vehicles which were used when no pricing data from publicly available contracts were available. Based on conversations with representatives from the Department of Enterprise Services, the Washington sales tax rate of 6.5 percent was applied to all vehicles, though local sales taxes may be higher. The exception to this was light-duty vehicles qualifying for the sales tax exemption in Washington state.

INCENTIVES

For medium- and heavy-duty vehicles, scenarios were evaluated with incentives based on California's Hybrid and Zero-Emission Truck and Bus Program incentive amounts. These incentive amounts are defined by the Vehicle Inventory's Use Case and are only available for battery electric vehicles. This was meant to simulate a hypothetical incentive program for trucks and buses that could be implemented by Washington state government. Scenarios were run in the present day (2020) with and without these incentives for battery electric vehicles. Note, no incentive was assumed in the projection scenarios.

For light-duty vehicles, scenarios were evaluated with the federal EV tax credit. As of late 2020, this credit was available for all auto manufacturers except Tesla and General Motors, which have both exceeded the credit's sales cap of 200,000 EVs; the credit depends on the on-board battery size, is available for plug-in hybrid and battery electric vehicles, and caps at $7,500. By default, 50 percent of the tax credit was assumed to be captured in a procurement for eligible vehicles. An alternate scenario was also considered whereby 100 percent of the tax credit was captured in a procurement.

The study team assumed that motorcycles would be treated in the same manner as other light-duty vehicles for the purposes of applying the federal EV tax credit.

PROCUREMENT METHOD

To model likely procurement scenarios in Washington state, the study team chose to model cash purchasing of vehicles based upon conversations with representatives from the Department of Enterprise Services (DES) and Department of Revenue (DOR). The state regularly engages in both cash and financed purchases of vehicles, though the interest rates for financed purchases are typically very low ranging between 1.5 and 2.5 percent depending on the loan term and are not determining factors in vehicle purchase decisions [114].

Scenario Multiplier: Each light-duty vehicle has up to two scenarios: one with 50 percent of the federal EV tax credit and one with 100 percent of the credit. Medium- and heavy-duty vehicles also have up to two scenarios modeling a state grant based on California's truck and bus program. If a vehicle was ineligible for an incentive (e.g., Tesla is not eligible for the federal EV tax credit), then that incentive was not modeled for that vehicle; this does not include the light-duty scenario with 50 percent of the federal EV tax credit as that is the default scenario for those vehicles.

PROJECTED VEHICLE PURCHASE PRICES

Projections on vehicle prices were made by vehicle class, use case, and drivetrain for 2025, 2030, and 2035. For these projections, the Manufacturer Suggested Retail Prices (MSRP) of currently available vehicles—electric and conventional—are projected in the future. MSRP is estimated by leveraging projections for vehicle technology costs from the US Department of Energy (DOE) for Light-Duty Vehicles [112] and Medium- and Heavy-Duty Trucks [115]. As per these reports, there are two different cost projections, a business-as-usual (BAU) projection, referred as the BAU Tech scenario, and an R&D Success scenario.

As the name suggests, the BAU Tech projections forecast vehicle costs assuming the current trends in technology continue in the future. While the R&D Success scenario assume the DOE targets are achieved and implemented in the automotive market. These scenarios are used to reflect the uncertainty associated with projecting automotive technology costs, including for engines, motors, power electronics, and batteries.

As these reports put forth the projected costs and not the MSRPs, a methodology was developed to forecast the MSRP from vehicle technology costs. First, for each technology a percentage change in projected costs for each vehicle class and year ($\alpha_{c,y}$) was estimated with respect to 2020 technology costs (Equation 1). Further, a ‘cost ratio’ was estimated for each technology (t) for each vehicle class (c) and each year (y). A ‘cost ratio’ can be defined as a ratio of projected cost of an EV to the projected cost of a conventional vehicle (Equation 2). The percentage changes (α) along with the cost factors, were used as multiplying factors to estimate the MSRP projections for each vehicle class and each powertrain variant (conventional and electric), as shown in the Equation 3.

$$\alpha_{c,y}\ (in\ \%) = \frac{Cost_{c,y} - Cost_{c,2020}}{Cost_{c,2020}};$$
$$c = vehicle\ class, y = 2020\ to\ 2035$$

EQUATION 1

$$Cost\ Ratio_{t,c,y} = \frac{Cost_{\ t,c,y}}{Cost_{t=conventional,c,y}};$$
$$t = technology,$$

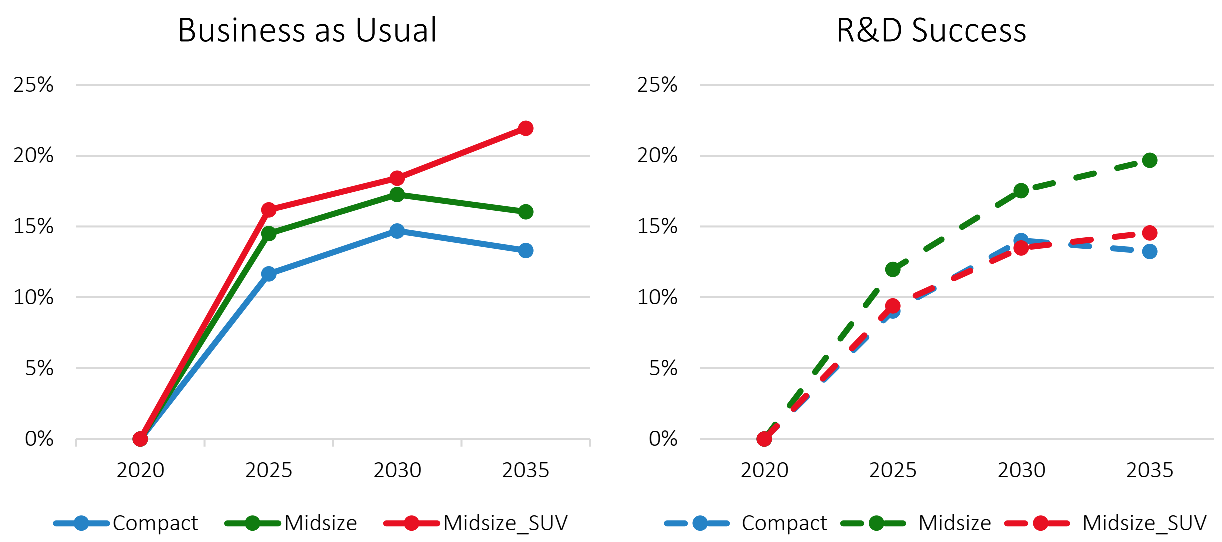
EQUATION 2

$$MSRP_{t,c,y} = MSRP_{t,c,2020} \times\ Cost\ Ratio_{t,c,y}\ \times\ \alpha_{c,y}$$

EQUATION 3

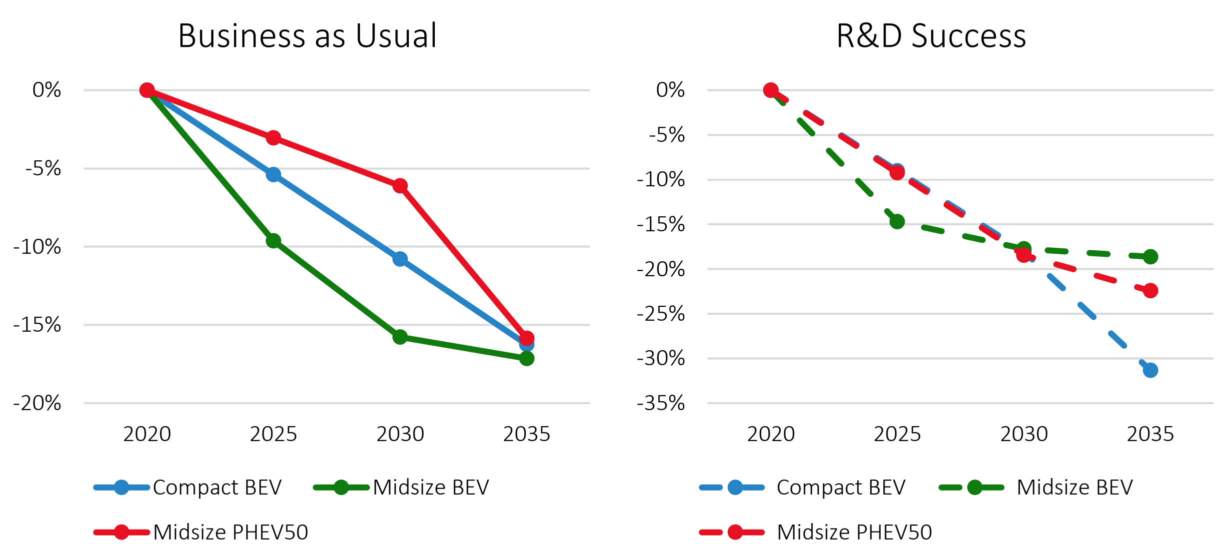
In these projections, the costs for conventional vehicles increase over time as a result of integrating advanced fuel economy technologies. The costs of BEVs and PHEVs decrease because of cost reductions primarily associated with high voltage batteries. Therefore, for conventional vehicles the MSRPs are generally expected to increase in the BAU Tech as well as the R&D Success projections. On the contrary, the MSRPs of BEVs and PHEVs are expected to decrease. However, the R&D Success scenario projects a more optimistic case for BEVs and PHEVs than that of the BAU Tech scenario. Figure 17 and Figure 18 show the projected percentage changes in light-duty vehicles for BAU Tech and R&D Success scenarios. The conventional vehicles are projected to get more expensive by 13 to 20 percent whereas BEVs and PHEVs are expected to get cheaper by 16 to 31 percent compared to 2020 MSRPs.

FIGURE 17: PROJECTED PERCENTAGE CHANGES IN MSRP OF CONVENTIONAL LIGHT-DUTY VEHICLES IN BAU TECH AND R&D SUCCESS SCENARIOS



This figure shows the percentage change for conventional light-duty vehicles in MSRP from 2020 through 2035 in the BAU Tech and R&D Success scenario.

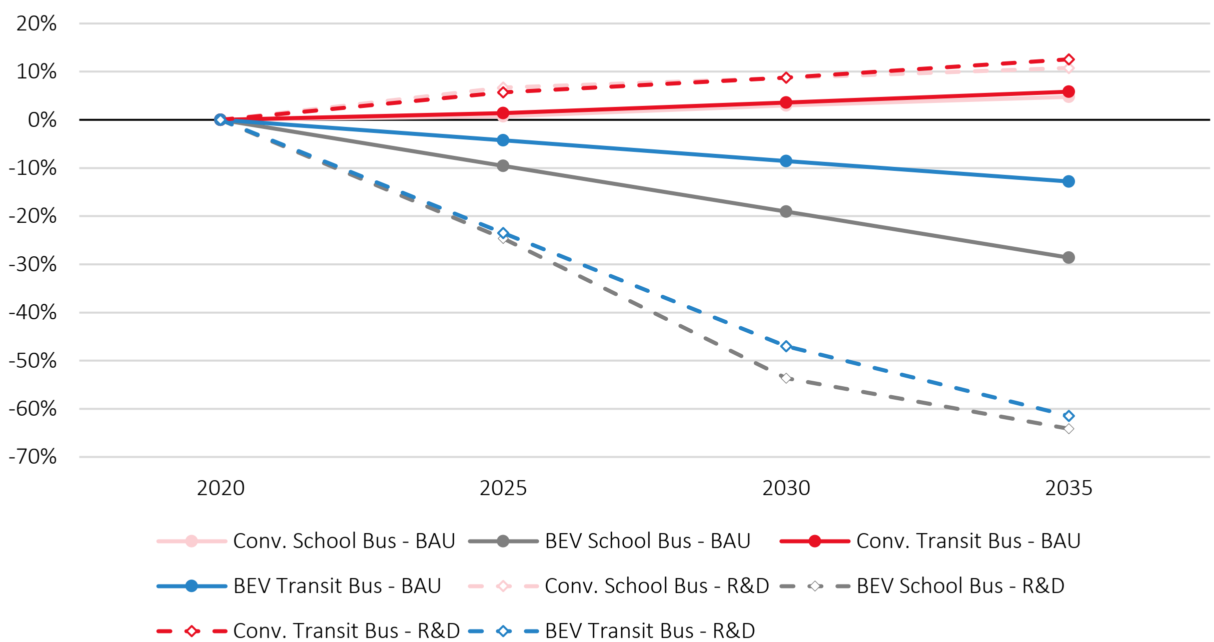
FIGURE 18: PROJECTED PERCENTAGE CHANGES IN MSRP OF BEV AND PHEV LIGHT-DUTY VEHICLES IN BAU TECH AND R&D SUCCESS SCENARIOS



This figure shows the percentage changes in MSRP of BEV and PHEV Light-Duty Vehicles in the BAU Tech and R&D Success scenarios.

This analysis followed a similar approach for projecting MSRPs for medium- and heavy-duty vehicles. Figure 19 shows percentage projections for school and transit buses, selected for display based on their relatively high share within the WA State public fleet. The MSRPs for conventional school buses show an increase of up to 5 and 11 percent in 2035 between BAU Tech and R&D Success scenario, respectively. Similarly, the MSRPs for conventional transit buses are forecasted to increase up to 6 and 13 percent in 2035 between BAU Tech and R&D Success scenarios, respectively. On the other hand, the MSRPs for battery-electric school buses are projected to decrease up to 29 percent in the BAU Tech scenario by 2035, and 64 percent in the R&D Success scenario. For transit buses, the forecasted percentage changes in MSRPs by 2035 are up to 13 percent in BAU Tech scenario and 61 percent in the R&D Success scenario. Note, the MSRP projections for the remaining relevant vehicle classes are included in *Appendix D*.

FIGURE 19: PROJECTED PERCENTAGE CHANGES IN MSRP FOR SCHOOL AND TRANSIT BUSES IN BAU TECH AND R&D SUCCESS SCENARIOS



This figure shows the projected percentage changes in MSRP for School and transit buses in Business-as-usual and R&D Success scenarios.

The BAU Tech scenario assumed a "business-as-usual" trajectory for research and development in which advancements in technology and production processes for both electric and internal combustion vehicles would follow a similar trajectory as they have to date. The R&D Success scenario assumed that research and development targets for electric vehicle technology established by the U.S. Department of Energy would be met. These results were mapped to each vehicle make and model used in the analysis and its 2020 purchase price using the vehicle's class, use case, and drivetrain as a key. This resulted in a table of individual vehicle makes and models, projection scenario, and vehicle purchase price; vehicle purchase price was rounded to the nearest dollar.

INCENTIVES

The study team assumed that the existing federal tax incentive for light-duty EVs would be carried forward into the future. No incentive for medium- or heavy-duty vehicles was considered.

PROCUREMENT METHOD

The study team assumed the procurement method for projection scenarios was cash purchases as was done in the present-day scenarios.

Scenario Multiplier: N/A

ELECTRICITY PRICES

Five electricity rate types were considered in the analysis: a residential rate, a base commercial rate, a commercial rate with electricity demand charges, a commercial rate with smart charging, and a commercial rate with smart charging and vehicle-to-grid integration technology. The latter was considered a public policy incentive while the first three rates were considered along with other policy incentives. That is, for each scenario combination, these three electricity rates were evaluated while the last rate was only evaluated in scenarios without other policy incentives. Demand charges and smart charging were modeled as modifiers of the base commercial rate based upon a review of publications on charging of electric fleets. Demand charges were modeled as a 100 percent increase in the base commercial rate and smart charging, a way to mitigate demand charges, was modeled as a 50 percent increase in the base commercial rate. For the VGI policy, the rate was assumed to be less than the smart charging rate, at 1.2 times the flat commercial rate based on the proposed EV-specific demand charge reduction from the electric utility Southern California Edison.

Electricity prices were derived depending on the public agency using either predominant utility serving the county where the agency or vehicle operates, or through a weighted average if the agency operates in more than one county. The predominant utility was determined based on the number of customers serving the county where the agency operates using data from the U.S. Energy Information Administration (EIA) Survey 861 [116]. The weighted average was computed using the counties where the agency operates, again relying the federal government survey for customer data to serve as the weight in the average computation. The counties where the agency operates is defined in the *Vehicle Inventory and Electric Alternatives* section above.

The projected electricity prices were determined using projections from the U.S. EIA's 2020 Annual Energy Outlook for 2025, 2030, and 2035 under a BAU Tech and R&D Success scenarios. Similar to vehicle prices, the data compiled was a percentage change from the 2020 prices. The resulting calculation was rounded to three decimal places.

Note, only the base commercial rate was used in the projection scenarios. The study team determined that the likely future of vehicle charging would be done at the base commercial rate as the grid-related benefits of mass deployments of electric vehicles are realized.

Scenario Multiplier: Five electricity rates were included but only four are used for all scenario combinations relevant to the present day analysis. The commercial rate with smart charging and vehicle-to-grid integration technology is used exclusive of other public policy incentives.

GASOLINE AND DIESEL PRICES

Similar to electricity prices, gasoline and diesel prices vary by public agency. The possible configurations the analysis considered included agencies that purchase fuel in bulk at prices determined by the statewide fuel contract, weighted averages for agencies that purchase fuel at different prices, and agencies that purchase a mix of fuel on contract and from retail fueling stations.

Gasoline and diesel prices were derived depending on the public agency using either region serving the county where the agency operates, or through a weighted average if the agency operates in more than one county. The region was determined using a lookup table of regions to counties; weighted averages considered the population of the county. The counties where the agency operates is defined in the *Vehicle Inventory and Electric Alternatives* section above. For the state fleet agencies purchase a mix of fuel from the state fuel contract and commercial gas stations and a lookup table was created to map agency to the source of gasoline and diesel prices. For public transit agencies and school districts, the gasoline price used was for 10 percent ethanol blend (also referred to as gasohol). The diesel price for public transit agencies was five percent biodiesel blend and for school buses was the ultra low sulfur diesel #2 clean fuel.

Gasoline and diesel fuel prices were determined using projections from the U.S. EIA's 2020 Annual Energy Outlook for 2025, 2030, and 2035 under BAU Tech and R&D Success scenarios. Similar to vehicle prices, the data compiled was a percentage change from the 2020 prices. The resulting calculation was rounded to three decimal places. These results were mapped to public agency and source of fuel prices.

These vehicle and fuel projection prices were applied to a subset of scenarios.

Scenario Multiplier: N/A

VEHICLE INSURANCE COSTS

To model insurance costs for vehicles owned by the state, the study team assumed that vehicles would be insured at the quoted rate for blanket vehicle collision insurance provided by DES, except in the case of transit agencies where the rate used was that of the Washington State Transit Insurance Pool. The insurance rate provided by DES was equivalent to 0.74 percent of a vehicles depreciated value. To accommodate this calculation, the Fleet Procurement Analysis Tool was updated to calculate annual insurance payments based upon the depreciated value of vehicles each year. For the Washington State Transit Insurance Pool, vehicles are insured based upon full replacement value and a flat annual payment was calculated based on a vehicle's MSRP. The annual payment was equivalent to $0.3107 per $1,000 of vehicle replacement value, defined here as vehicle MSRP.

Scenario Multiplier: N/A

VEHICLE MAINTENANCE COSTS

Vehicle maintenance costs were derived from real-world maintenance cost data from DES. These data were available on a vehicle-by-vehicle basis for SUVs, sedans, pickups, minivans, and larger passenger vans. The vehicle miles traveled and cost data were first aggregated by vehicle and fuel type The cost per mile was then computed rounded to three digits based on the total cost and total miles traveled by vehicle and fuel type.

In cases where maintenance cost data from DES was available for internal combustion but not electric vehicles of a particular use case, the methodology from Argonne National Lab's AFLEET tool was followed and the maintenance cost difference between internal combustion and electric vehicles from an alternative use case was applied. Note, the vehicle type was mapped to the Use Case category and the fuel type was mapped to the Fuel Type category from the Vehicle Inventory. For other vehicle use cases where Washington data was insufficient, fleet studies from NREL, the California Air Resources Board, the American Transportation Research Institute, Ernst & Young, and The International Council on Clean Transportation were referenced to determine average maintenance cost per mile by vehicle class. Maintenance cost figures from the above studies were weighted by the total mileage referenced in the study to align with the methodology used to calculate real-world maintenance costs.

Scenario Multiplier: N/A

SHARE OF VEHICLE MILES TRAVELED IN CITIES

The share of miles traveled in cities versus highways used in the analysis varied by vehicle class (light-, medium-, and heavy-duty). For light-duty vehicles, a constant 55 percent of miles in cities using the same figure as the U.S. Environmental Protection Agency's (EPA) website, fueleconomy.gov. For medium-duty public transit vehicles and school buses, the analysis used the U.S. EPA assumption for vocational vehicles (Class 2B through Class 7) used in the agency's greenhouse gas rule for medium- and heavy-duty engines and vehicles (92 percent of miles traveled in cities) [117]. For heavy-duty vehicles, the analysis again relied on the U.S. EPA rule and varied the share of miles in cities based on the Vehicle Inventory's Use Case.

Scenario Multiplier: N/A

EV CHARGING EQUIPMENT

The study team considered different charging equipment and infrastructure needed based off vehicle type and use case. This section describes public and home charging, charging depots with Level 2 and DC fast charging (DCFC) equipment, and on-route chargers used for transit buses. How the study team analyzed the needs of EVs to charging stations are discussed in *Charging Configurations*, and Table 8 shows the different configurations used for this study.

PUBLIC OR HOME CHARGING

Charging at home or in the public is common for light-duty EVs, which means these fleet vehicles have options outside a State-operated charging depot. Survey responses from fleet managers across the state revealed light-duty vehicles can be parked at a driver's residence. Using the fleet manager's responses of how often vehicles are parked overnight, the study team calculated a weighted average to estimate 10 percent of total light-duty EVs could be charged outside of State-operated charging depots, using at-home Level 2 charging equipment or publicly available charging. These charging resources were assumed to not be available for medium- and heavy-duty vehicles.

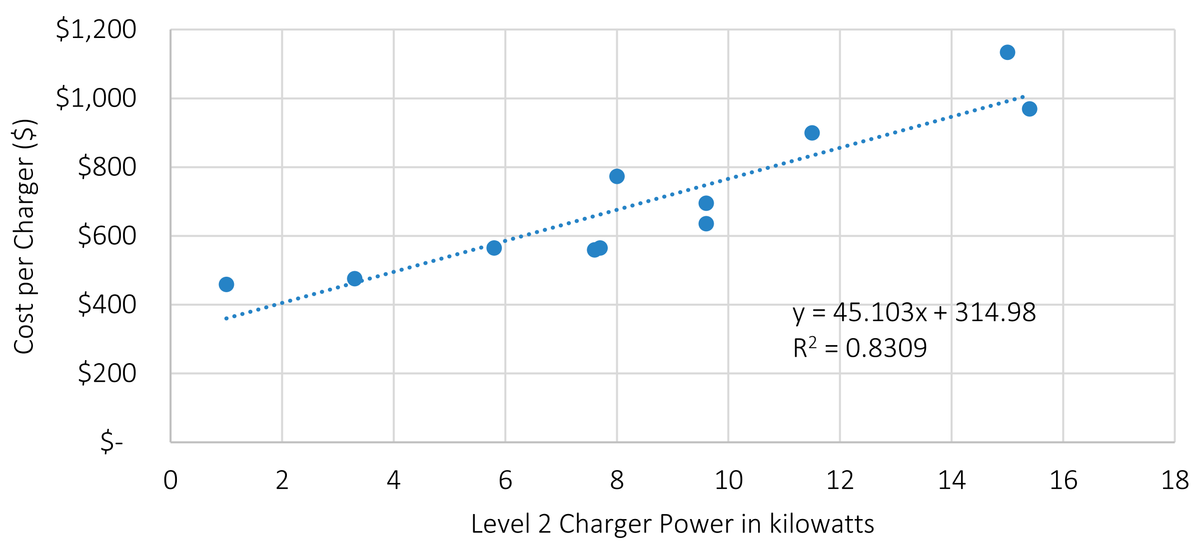
DEPOT CHARGING: LEVEL 2

High-powered Level 2 charging stations can be used for all light- and medium-duty vehicles as well as heavy-duty school buses. A Level 2 charging station can deliver a power from three to 19 kilowatts. However, most light-duty vehicle manufacturers today limit the charging power of onboard chargers to 11.5 kilowatts; the study team used this rating as the maximum power for Level 2.

The study team reviewed various power ratios available from multiple manufacturers of commercial charging equipment to estimate the cost of Level 2 charging stations. Figure 20 shows the relationship between the cost of an additional Level 2 charging station as the equipment's power increases. The resources reviewed for estimating the cost of Level 2 equipment are in *Appendix E*. As noted above, light-duty vehicle manufacturers currently limit charging power in Level 2 equipment to 11.5 kilowatts but may introduce higher power ratings in the future.

The study team also assumed a station at a depot could charge two light-duty vehicles per one 11.5-kilowatt Level 2 charging station. The study team also assumed this charging depot setup could accommodate Class 2B-3 and Class 4-6 vehicles. For some scenarios, these medium-duty electric vehicles were assumed to share high-powered Level 2 charging stations due to low average mileage, which would not necessitate consistent daily charging.

FIGURE 20: COST PER STATION AND POWER OF LEVEL 2 CHARGING STATIONS



This chart shows the relationship between the cost of an additional Level 2 charger as the charger power increase.

DEPOT CHARGING: DCFC (50 AND 150 KILOWATT)

The costs for DCFC equipment and installations are higher than Level 2 charging stations since they can accommodate considerably higher power levels; the study team considered DCFC stations that could charge at 50 or 150 kilowatts. With higher costs and higher power ratings than Level 2 equipment, the study team assumed one 50 kilowatt DCFC would charge 10 light-duty vehicles. A DCFC with 50 kilowatts of power is also capable of charging up to five medium-duty vehicles.

For heavy-duty vehicles, the study team used a DCFC charging station capable of delivering up to 150 kilowatts. This increased power level would likely require onsite electrical grid or interconnection upgrades, which can be costly depending on site-readiness. However, the benefits of increased vehicle charging capacity and faster charge times could increase fleet operating efficiencies and improve the suitability of EVs as an alternative to conventional vehicles. The study team considered this level of DCFC charging as an option for heavy-duty transit buses and trucks and assumed five vehicles per one heavy-duty DCFC.

ON-ROUTE CHARGING

On-route chargers were used for electric transit buses as King County Metro Transit currently uses on-route chargers for its electric buses. There are wired and induction-wireless charging options, which have different cost implications. How to choose between wired or wireless charging depends on site-readiness, operations, and whether the electric buses are equipped to integrate with the on-route charger technology.

The study team used the General Transit Feed Specification (GTFS) data repository to extract average daily vehicle miles traveled (daily-VMT) for the transit buses in Washington [118]. For electric transit buses with daily-VMT that exceeded the average electric range, the study team assumed an on-route charger would be installed and used. For electric transit buses with daily-VMT that fell below the average electric range, the study team assumed an on-route charger would be unnecessary.

Scenarios Multiplier: Discussed in *Charging Configurations*.

CHARGING CONFIGURATIONS

The analysis evaluated multiple charging configurations including a rebate from the electric utility and a charging rate incentive related to vehicle-grid integration. In addition, a number of charging configurations were evaluated depending on the vehicle class (light-, medium-, and heavy-duty) and category (state fleet, public transit, or school buses). These configurations varied the number of charging stations used per vehicle and the power level of the stations. These factors had a direct effect on the cost of purchasing, installing, and operating the charging stations. Additional discussion on the type of charging equipment chosen for each vehicle class is in the *EV Charging Equipment* section.

To select charging scenarios for each vehicle class and category, Washington fleet managers were consulted to determine planned and existing charging configurations for light-duty vehicles, transit buses, and school buses. As the state does not currently own any electric trucks and these vehicles were not part of current charging infrastructure planning, the study team relied on vehicle characteristics such as battery size, vehicle range, and annual mileage to determine likely charging configurations for these vehicles. To provide a range of potential charging scenarios beyond those currently being planned for, options were chosen based upon vehicle class and use case, with determinations being made around potential charging needs, battery sizes, average VMT, and potential downtime for charging vehicles.

For light-duty vehicles, options for Level 2 residential and depot charging on a one-to-one vehicle to charging station ratio were chosen based upon input from Washington fleet managers regarding charging scenarios currently being employed for electric vehicles in the state fleet. A 50 kilowatt DCFC option was included to account for smaller depots which may have constraints around the number of charging stations able to be installed or for use cases which may require more immediate charging options such as police vehicles. In this case, the DCFC was assumed to support ten vehicles. To model scenarios in which vehicle daily mileage is low and requires infrequent charging, a two-to-one vehicle to charger ratio was chosen. Over 1,300 light-duty vehicles included in the analysis travel fewer than 7,000 miles per year or an average of less than 30 miles per day and would not necessarily require daily charging.

For medium-duty trucks and vans as well as school buses, a depot charging solution using a Level 2 charging solution with a one-to-one vehicle to charger ratio was chosen based upon average annual mileage reported, average vehicle battery size, as well as input from representatives from the California Air Resources Board responsible for development of the Advanced Clean Trucks rule.

For school buses, a Level 2 charging solution is already being implemented for the electric school buses currently being operated in Washington. To meet the charging needs of these vehicles, a high-powered Level 2 charging solution was chosen capable to charging vehicles at 15.4 kilowatts. Similar to light-duty vehicles, DCFC options were included to account for scenarios in which a single charging solution was necessary due to site constraints or the need for rapid charging.

For heavy-duty trucks, DCFC charging scenarios were chosen exclusively based upon average vehicle mileage, vehicle ranges, and battery sizes of available heavy-duty electric trucks. An additional scenario for heavy-duty trucks was chosen to model charging at high-powered 150-kilowatt DCFC stations to account for the necessity to rapidly charge vehicles with battery packs in excess of 400 kilowatt-hours.

For transit buses, a one-to-one DCFC and ten-to-one on-route charging scenario were chosen based upon information on planned charging strategies provided by fleet managers of transit agencies in Washington. Though the on-route charging solution would be entirely route-dependent, the study team chose a ten-to-one vehicle to charger ratio based upon bus volume on a route between 500 and 2,000 passengers per hour. Additionally, the study team chose to include a two-to-one DCFC charging scenario to model lower-mileage buses that would require less frequent charging. Similar to heavy-duty trucks, a scenario was included to model charging at high-powered DCFC stations to account for rapid depot-charging solutions. The vehicle to charger ratio for this scenario was three-to-one to ensure that equivalent charging support could be provided on a per-bus basis as for a 50-kilowatt DCFC solution.

In addition, scenarios for vehicle replacement were included for light-, medium-, and heavy-duty vehicles to model scenarios when charging infrastructure was already installed and only replacement of charging equipment was necessary. This scenario was used to evaluate the total cost of ownership of future EV purchases when the initial infrastructure investments will have already been made.

Table 8 details the full set of charging scenarios considered for each fleet.

TABLE 8: CHARGING SCENARIOS BY VEHICLE CLASS

Vehicle Class	Charging Equipment	Charger Power (Kilowatts)	Vehicle to Charger Ratio
Light-Duty Vehicles	Level 2 Residential	7.6	1 to 1
	Level 2 Private Depot	11.5	1 to 1
	Level 2 Private Depot	11.5	2 to 1
	DCFC Private Depot	50	10 to 1
	Level 2 Private Depot	7.6	1 to 1
	Replace Level 2 at Private Depot	11.5	2 to 1

Vehicle Class	Charging Equipment	Charger Power (Kilowatts)	Vehicle to Charger Ratio
Medium-Duty Vehicles	Level 2 Depot	15.4	1 to 1
	DCFC Depot	50	5 to 1
	DCFC Depot	50	2 to 1
	Replace Level 2 at Private Depot	15.4	1 to 1
Heavy-Duty Trucks	DCFC Depot	150	5 to 1
	DCFC Depot	50	2 to 1
	DCFC Depot	50	1 to 1
	Replace DCFC	50	2 to 1
School Buses	Level 2 Depot	15.4	1 to 1
	DCFC Depot	50	5 to 1
	Replace Level 2 at Private Depot	15.4	1 to 1
Transit Buses	DCFC Depot	150	3 to 1
	DCFC Depot	50	1 to 1
	DCFC	50	2 to 1
	On-Route	N/A	10 to 1
	Replace DCFC at Private Depot	50	1 to 1

This table details the charging scenarios considered for each vehicle in the analysis. Different charging scenarios were considered for the different weight classes of light-, medium-, and heavy-duty. Within medium-duty vehicles, school buses were assigned separate charging scenarios. Within heavy-duty vehicles, school buses, transit buses, and trucks were all separately identified.

Scenario Multiplier: The number of scenarios added depends on the vehicle class and category and is affected the number of charging configurations and the charging infrastructure grant.

PUBLIC POLICY OPTIONS AND FINANCING MECHANISMS

In addition to examining present day scenarios which modeled procurements in Washington state, the study team also considered several potential public policies and financing mechanisms the state could employ to accelerate the adoption of electric vehicles. For each policy or mechanism analyzed, the study team referred to existing policies in place in similar states or planned policies already under consideration in Washington. The study team modeled the following policy options and financing mechanisms:

- **Charging Infrastructure Grants:** To model potential charging infrastructure grants, the study team reviewed funding programs currently offered by utilities in Washington as well as from the state as part of the Volkswagen settlement. After discussion with representatives from the Department of Commerce familiar with EV policy in Washington, the study team determined that likely charging infrastructure grant scenarios would be grants covering 100 percent of the equipment and installation costs for Level 2 charging infrastructure and 50 percent the equipment and installation costs for DCFC charging infrastructure.

- **Carbon Pricing:** To model the effect of including a statewide tax on carbon, the study team modeled a carbon price of $74 per ton based upon the social cost of carbon as determined by Washington in WAC 194-40-100.
- **Federal Incentives:** State and local governments can claim federal tax credit for light-duty electric vehicles but cannot do so directly. Instead, they must have a vehicle dealer claim the credit on their behalf and pass the savings along to them in the form of a lower vehicle price. To model the effect of claiming the federal incentive on the electrification of eligible light-duty vehicles, the study team relied on data from past electric vehicle procurements in Washington to determine a default of capturing 50 percent of the eligible credit. To model an optimal procurement of an electric vehicle, the study team also included a scenario in which the state claimed 100 percent of the eligible credit.
- **Voucher Incentive Programs:** To model the effect of an incentive program for medium- and heavy-duty electric vehicles, the study team included a scenario in which these vehicles received the voucher amounts from the California Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project.
- **Vehicle-to-Grid Integration:** To model the benefits from vehicle-to-grid integration, in which vehicles act as a distributed storage resource for utilities, the study team modeled a 40 percent reduction in electricity price from the smart charging rate based upon a review of proposed tariffs from utilities in California targeted at EVs

Other policy options considered in the study, such as right-to-charge legislation that would enable the state to more easily install charging infrastructure at leased properties, did not have a direct effect on vehicle total cost of ownership and were not explicitly modeled.

Scenario Multiplier: The number of scenarios dependent on policy option above. Many charging configurations included two scenarios, one with and one without a grant. Many scenarios included a version with and without a carbon price. The federal and voucher vehicle incentive was described in *Present Day Vehicle Purchase Prices and Vehicle* Incentives and *Projected Vehicle Purchase Prices*. Finally, the vehicle-to-grid integration scenario was described in *Electricity Prices*.

EV CHARGING INSTALLATION COSTS

To estimate the cost of charging equipment and installation, the study team researched case studies and literature reviews to find installation costs associated with fleet-level charging station installations. Due to a lack of data from existing installations, the study team chose not to include any local grid upgrade costs beyond that of charging equipment and installation.

While there were limited literature and case studies written on the infrastructure costs of fleet electrification, research revealed the cost of installing each charging station decreases with an increase in the number of charging stations installed at a given location [119, 120, 121, 71, 122]. In instances where costs were reported, they varied significantly from site-to-site, thus the study team chose the average costs for each type of charging equipment. Table 9 provides the average charging equipment and installation costs for different charger types and the sources for the costs.

TABLE 9: CHARGING EQUIPMENT AND INSTALLATION COSTS

Type of Charger	Site	Charger Power (kilowatts)	Avg. Charging Equipment ($)	Avg. Installation Costs per Charger ($)	Source
Level 2	Residential	7.6	$550	$1,286	[123]
	Public	7.6	$3,500	$2,500	[123]
	Depot	11.5	$8,342	$2,180	[119, 120]
	Depot	15.4	$10,103	$2,180	[119, 120]
DCFC	Depot	50	$38,000	$20,000	[123]
Heavy-duty DCFC	Depot	150	$87,800	$60,000	[122, 123]
On-route Wired Charger	On-route wired	varying	$495,636	$202,811	[124]

DEFINITION OF ELECTRIFICATION POTENTIAL FOR VEHICLES

A key goal of this analysis was to provide Washington with an estimate for the number of vehicles currently owned by the state that could be electrified most cost effectively. To do so, the study team applied the criteria established in WAC 194-28 for defining if a vehicle is "practicable" to electrify. Under this criterion, any internal combustion vehicle for which an EV alternative is within five percent of the total cost of ownership is identified as a vehicle that is practicable to electrify.

To determine the total cost of ownership for EVs, the study team averaged the total cost of ownership results across all scenarios described previously in this chapter including charging configurations, electricity rates, and EV models. The internal combustion vehicles only had a single total cost of ownership scenario and this was compared with the averaged EV total cost of ownership.

When determining the total cost of ownership for EVs and internal combustion vehicles, the study team calculated the net present value (NPV) of total cost of ownership. The net present value calculation accounts for the time value of money and discounts future payments or income. For this analysis, the discount rate was set at 1.36 percent, the average two-year bond rate over the prior decade for equipment purchases in Washington.

When reporting results, the study team reported the electrification potential of vehicles under an initial and subsequent EV deployment scenario. Under the initial EV deployment scenario, the study team averaged the total cost of ownership results for EVs across all scenarios under consideration. Under the subsequent EV deployment scenario, the study team limited the scenarios under consideration to just those that modeled to cost of charging infrastructure for a subsequent EV purchase; in these cases, the analysis assumed there would be no cost for construction and electrical grid upgrades. The subsequent EV

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[2] Estimated from multiple sources. Please check Annexure for details.

[3] Estimated from multiple sources. Please check Annexure for details.

deployment scenario is intended to reflect the long-term savings potential of EVs once the upfront investments in charging infrastructure will have already been made.

Scenario Multiplier: This was described in *EV Charging Equipment*.

FLEET PROCUREMENT ANALYSIS TOOL

The data described above served as inputs into the total cost of ownership calculator used in this study, Atlas's Fleet Procurement Analysis Tool. The Fleet Procurement Analysis Tool equips users with decision-relevant information on the financial viability and environmental impact of light-, medium-, and heavy-duty vehicle fleet procurements. The Microsoft Excel-based tool can evaluate a variety of procurement ownership structures, vehicle types, and procurement scenarios including the cost of charging infrastructure for electric vehicles. The tool compares procurements side-by-side on a cost-per-mile as well as NPV basis and provides an analysis of cash flows and location-specific lifecycle emissions. The tool is highly flexible, supports customizable sensitivity variables, and produces user-friendly results summaries.

The tool includes a special mode whereby a multivariate analysis can be completed by running thousands of scenarios that vary input fields. This mode was used to complete the multivariate analysis for this report.

The Fleet Procurement Analysis Tool can be downloaded from Atlas's website here: https://atlaspolicy.com/rand/fleet-procurement-analysis-tool. The tool was originally developed by the Cadmus Group and Atlas Public Policy and has been maintained by Atlas Public Policy since 2017.

LIKELIHOOD OF ELECTRIFICATION

To provide an overall picture of the electrification potential of the EVs examined in this analysis, the likelihood of vehicle electrification was separated into six categories: Very Likely, Likely, Neither Likely nor Unlikely, Unlikely, Very Unlikely and Nearly Impossible. These likelihood categories were defined based on the percentage difference in average total cost of ownership across all scenarios between an EV and an equivalent internal combustion vehicle. While the total cost of ownership for an EV may be higher than an internal combustion equivalent on average across all scenarios, viable situations may exist where the EV is a cost-effective choice.

Electric and internal combustion vehicle procurements were matched based on common factors, such as use case, years of ownership, and VMT in order to create an apples-to-apples comparison for each scenario. The breakdown of the Likelihood categories is included in Table 10.

To determine the number of vehicles suitable for electrification, the study team applied the total cost of ownership criteria established under WAC 194-28 to any electric alternative within five percent of the total cost of ownership of an internal combustion counterpart. A separate standard exists for local governments established in WAC 194-29 in which vehicles must have a lower total cost of ownership to qualify as practicable to electrify. The study team chose the standard from WAC 194-28 because the study analysis incorporated the full upfront cost of charging infrastructure in the majority of scenarios.

TABLE 10: LIKELIHOOD CATEGORIES

Likelihood Category	TCO Percentage Difference from Internal Combustion Equivalent
Very Likely	At least 10% lower
Likely	Between 10% lower and 5% higher
Neither Likely nor Unlikely	Between 5% and 20% higher
Unlikely	Between 20% and 35% higher
Very Unlikely	Between 35% and 100% higher
Nearly Impossible	More than 100% higher

Analysis results for vehicles within the Likely or Very Likely categories in Table 10 met the threshold for electrification by the study team. While the study team selected EV alternatives which were intended to be capable of meeting the operational duties of a given use case, there was no analysis of whether an EV alternative would meet the daily operating requirements of a particular vehicle.

CHAPTER 4: TOTAL COST OF OWNERSHIP ANALYSES (PRESENT DAY)

This chapter presents the results of the multivariate analysis for the present day along with key takeaways and insights. The discussion of results is broken down by the three fleets for which the project team received detailed vehicle data: the state agency fleet, the school bus fleet, and the transit agency fleet. Within each section, the overall total cost of ownership (TCO) results for electric and internal combustion vehicle procurements is compared to determine the likelihood that a given vehicle is a suitable candidate for electrification as described in *Chapter 3*. Additionally, an in-depth analysis was performed on procurement elements such as vehicle use case, annual VMT, charging scenarios, fuel and electricity prices, and useful life to highlight the relative effect each has on the electrification potential of vehicles. While many insights are summarized, many more interpretations of the results are possible with the more than 2.7 million scenarios relevant to this chapter (see Box 3).

Box 3. Total Cost of Ownership Results

The results presented in this chapter represent the summarization of major insights from the present-day total cost of ownership analysis. This is not a comprehensive review of all information gained from the analysis. The complete set of results for all 2.7 million scenarios will be made available via an interactive dashboard hosted on the Atlas Public Policy website. Users will be able to analyze TCO results for individual vehicles across all scenarios included in the analysis and draw their own insights and conclusions. The interactive dashboard will allow for comparison of different EV alternatives, charging configurations, and electricity rates, among other variables for each of the 28,913 vehicles included in the analysis.

The analysis included the complete set of possible scenario combinations for each vehicle from the state agency, school bus, and transit agency fleet described in *Chapter 1* and 2,734,067 scenarios in total were analyzed for the analysis of vehicle electrification in the present day. This included 28,913 internal combustion vehicles paired with 48,461 EV alternatives and separated into 30 use cases. The city and county fleets lacked sufficient detailed vehicle data and were excluded from the analysis, though insights can still be gained based on the results of this analysis (See Box 4). Results are given as the net present value (NPV) of the lifetime total cost of ownership of each procurement scenario. Vehicles were analyzed on an individual basis and each scenario models a procurement of a single vehicle. The NPV figures reported below are reflective of current market conditions in Washington as of 2020. When determining if a vehicle is practicable to electrify, the study team followed the criteria established under WAC 194-28, which stipulates that all vehicles for which an EV was within five percent of the total cost of ownership met the threshold for electrification. A separate analysis of the electrification potential of public vehicles under different policy conditions is presented in *Chapter 8*.

This report presents the electrification potential of vehicles under two scenarios, an initial EV deployment scenario and subsequent EV deployment scenario. Under the initial deployment scenario, the study team averaged the TCO results for EVs across all scenarios under consideration, including various charging configurations, EV models, and electricity rates. Under the subsequent deployment scenario, the study team limited the scenarios under consideration to just those that modeled the cost of charging infrastructure for a subsequent EV purchase; in these cases, the analysis assumed there would be no cost for construction and electrical grid upgrades. The subsequent scenario is intended to reflect the long-term savings potential of EVs once the upfront investments in charging infrastructure have already been made.

Box 4: City and County Fleets

Due to lack of available detailed vehicle data for city and county fleets, these vehicles were not included in the TCO analysis. However, the makeup and electrification potential of these local government fleets is likely similar to that of state agencies; primarily light-duty vehicles serving in similar functions. One key difference between state agency and city and county fleets is access to resources necessary to properly plan for, procure, and install charging infrastructure. Smaller local governments in particular may need technical assistance for cost-effective electrification which could be provided by the state or local electric utility.

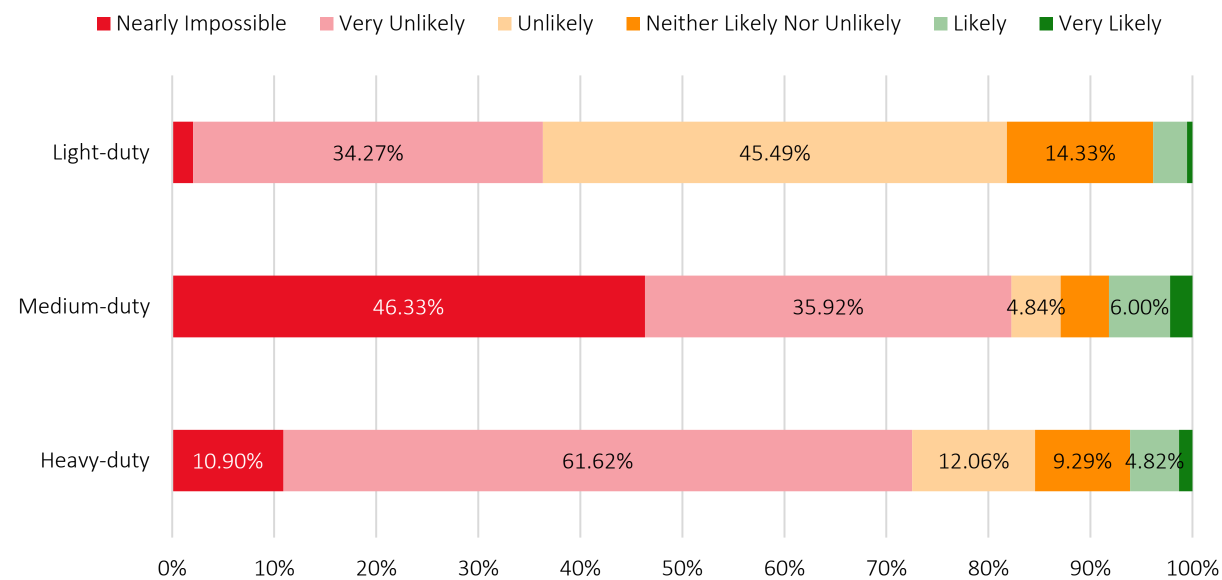
OVERALL RESULTS

About six percent (1,650 vehicles) of the nearly 29,000 vehicles analyzed in the present day had an EV alternative within five percent of the total cost of ownership of the conventional counterpart. The cumulative savings from electrifying these vehicles was more than $72 million, primarily accounted for by substantial savings from transit bus electrification. These results varied widely across the fleets and scenarios included in the analysis ranging from more than 21 percent of the public fleet (6,175 vehicles) in the best case to two percent in the worst case.

Of the vehicles included in the analysis, medium-duty vehicles had the highest proportion that met the electrification threshold at more than eight percent. This was due to the high number of medium-duty transit buses which could be electrified cost effectively; almost no other medium-duty vehicles met the threshold. These were followed by heavy-duty vehicles and light-duty vehicles at six and four percent, respectively. Figure 21 shows the likelihood results in an initial deployment of EVs for all vehicles included in the analysis separated by weight class.

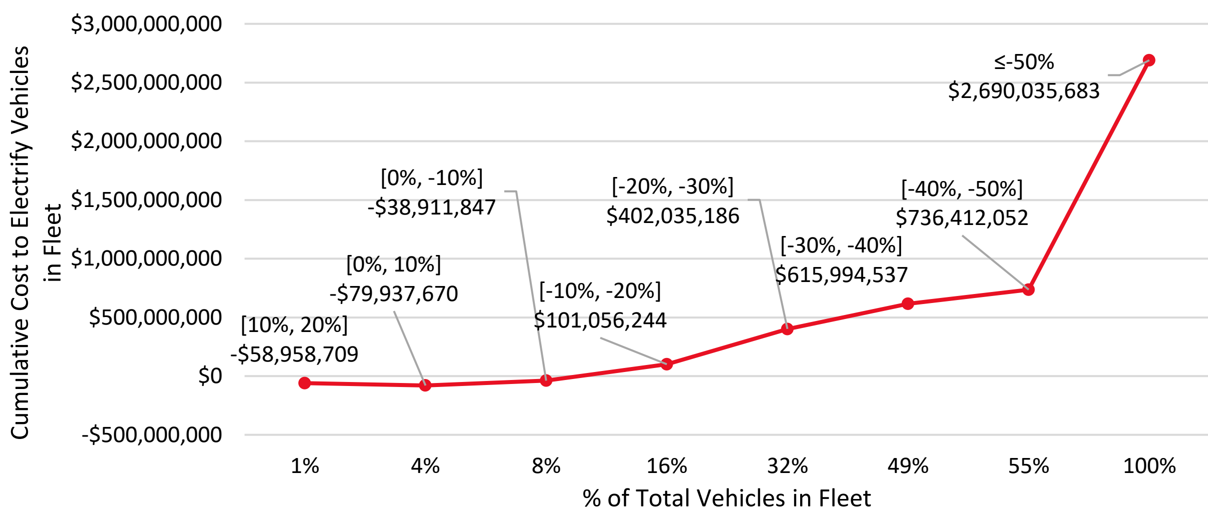
From a cost perspective, government can electrify many thousands of vehicles today at a net savings. As mentioned above, using a TCO threshold of five percent yields 1,650 vehicles but government can electrify nearly 2,500 vehicles at a net savings of more than $38 million on average. Figure 22 shows the net cost of electrification as the TCO threshold is increased. As shown in the figure, it is likely infeasible to electrify all public vehicles in Washington today.

FIGURE 21: LIKELIHOOD RESULTS FOR ALL VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the likelihood results for all vehicles included in the analysis broken down by weight class.

FIGURE 22: CUMULATIVE COST TO ELECTRIFY ALL VEHICLES IN AN INITIAL EV DEPLOYMENT



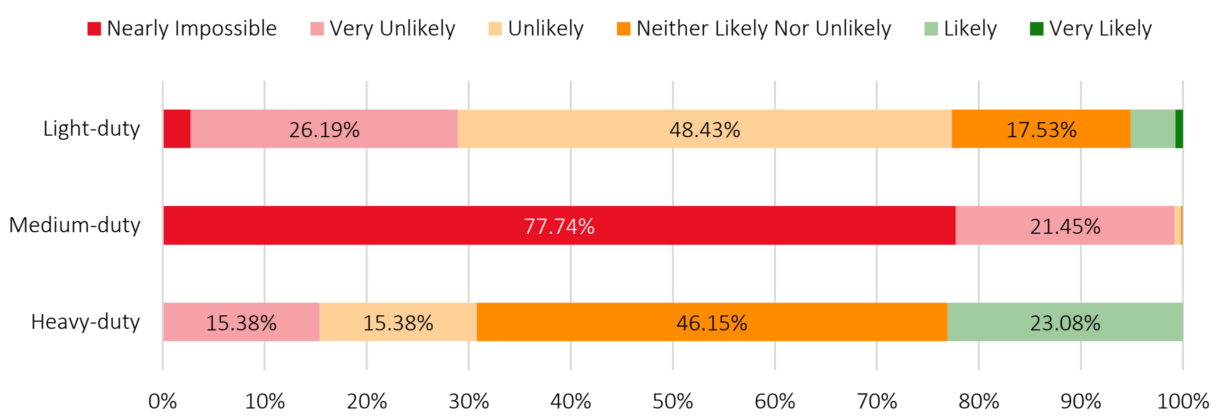
This figure shows the cumulative cost or savings to electrify all vehicles included in the analysis in an initial deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $2.7 billion on average to electrify all vehicles included in the analysis, though it could electrify nearly 10 percent of vehicles at an average savings of more than $38.9 million.

STATE AGENCY ANALYSIS RESULTS

The largest set of fleet data the collected by the study team covered vehicles owned by state agencies. In total, the state agency fleet included information on over 13,000 vehicles. Of these vehicles, the study team identified 9,205 for which sufficient detailed vehicle data existed and for which there was at least one EV alternative and included them in the analysis, accounting for 32 percent of all vehicles included in the analysis. The analysis covered vehicles across the Department of Enterprise Services, Department of Transportation, State Patrol, Department of Natural Resources, Department of Fish and Wildlife, and Department of Social Health Services fleets. Detailed vehicle data was not available for the State Parks agency and they were not included in the analysis. Each of these vehicles was mapped to up to three electric alternatives, including both battery electric and plug-in hybrids. A TCO analysis was completed for both the internal combustion and electric alternatives.

Aside from the small number of heavy-duty vehicles analyzed, light-duty state agency vehicles offered the most compelling case for electrification with more than five percent of vehicles meeting the threshold for electrification. Nearly a quarter of vehicles fell within 20 percent of the TCO of an internal combustion equivalent and could meet the threshold for electrification with only slight shifts in TCO. This was true even in a market where EV alternatives for several common use cases like pickup trucks are currently limited to expensive luxury models. The results for medium-duty vehicles indicated that the market for these vehicles is still in its infancy and will need to further develop before large-scale electrification is financially feasible. Figure 23 shows the likelihood results for all state agency vehicles by weight class in an initial EV deployment. The sections below explore the results by use case in both initial and subsequent deployments for light-, medium-, and heavy-duty vehicles.

FIGURE 23: LIKELIHOOD RESULTS FOR ALL STATE AGENCY VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the likelihood results for all state agency vehicles included in the analysis separated by weight class

LIGHT-DUTY VEHICLES

Light-duty vehicles owned by state agencies include passenger vehicles like sedans, SUVs and vans, light trucks, police vehicles, and motorcycles. Light-duty vehicles made up the overwhelming majority of state agency vehicles included in the analysis. Of the 9,205 state agency vehicles analyzed, light-duty vehicles accounted for 8,199, or nearly 90 percent. Among light-duty vehicles, SUVs were the most common use case, followed by pickups, sedans, police pursuit vehicles, vans, and finally motorcycles. Table 11 breaks down the number of vehicles analyzed by use case:

TABLE 11: STATE AGENCY LIGHT-DUTY VEHICLES ANALYZED

Use Case	Total Vehicles
SUV	2,668
PICKUP	2,495
SEDAN	1,422
POLICE PURSUIT	961
VAN	588
MOTORCYCLE	65
TOTAL	**8,199**

This table lists the number of light-duty vehicles included in the state agency analysis by use case.

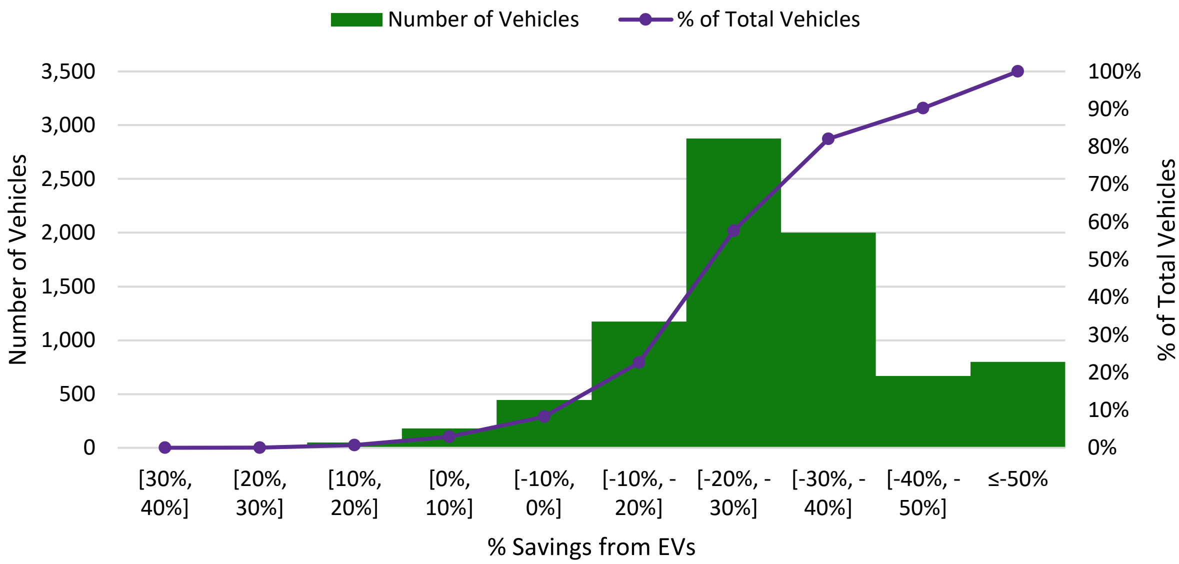
The sections below explore the TCO results for both the initial EV deployment and subsequent EV deployment scenarios. Results are presented in terms of both TCO and electrification likelihood as described in Chapter 3, with the two categories of Likely and Very Likely meeting the threshold for electrification.

INITIAL EV DEPLOYMENT ANALYSIS RESULTS

The full range of TCO results under the initial deployment scenario demonstrates that state agencies can cost-effectively electrify light-duty vehicles across all use cases. Though the overall number of vehicles that met the five percent threshold for electrification in the present day was relatively low at 418, or just under five percent, the majority of EVs analyzed had a TCO between five and 30 percent higher than an equivalent internal combustion vehicle and slight changes in electricity rate, vehicle price, or charging configuration could bring them above the threshold for electrification. Additionally, there are significant potential savings from electrifying the 418 vehicles that met the threshold. If the state chose to electrify each of these vehicles now, it could achieve a cumulative cost savings of $757,561 on average over the life of these vehicles. In the best case, these vehicles could save up to $4,374,205 and in the worst case, these vehicles would cost an additional $3,130,980. As mentioned previously, the analysis covered multiple scenarios for each EV and savings or costs from electrification depended on the EV procurement scenario in question with the best and worst cases representing a procurement with the lowest- and highest-price EV model, the least and most expensive charging configuration, and the lowest and highest electricity rate, respectively.

Increasing the threshold to electrify vehicles to 20 percent, capturing 23 percent of all state agency light-duty vehicles, would have an incremental cost of $ $9,161,470 over the life of these vehicles on average. The potential cost to electrify all light-duty vehicles included in the analysis is $98.2 million, ranging from a low of a $22.9 million to a high of $176 million in additional cost. Figure 24 and Figure 25 show the number of light-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify light-duty vehicles, respectively.

FIGURE 24: NUMBER OF LIGHT-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT

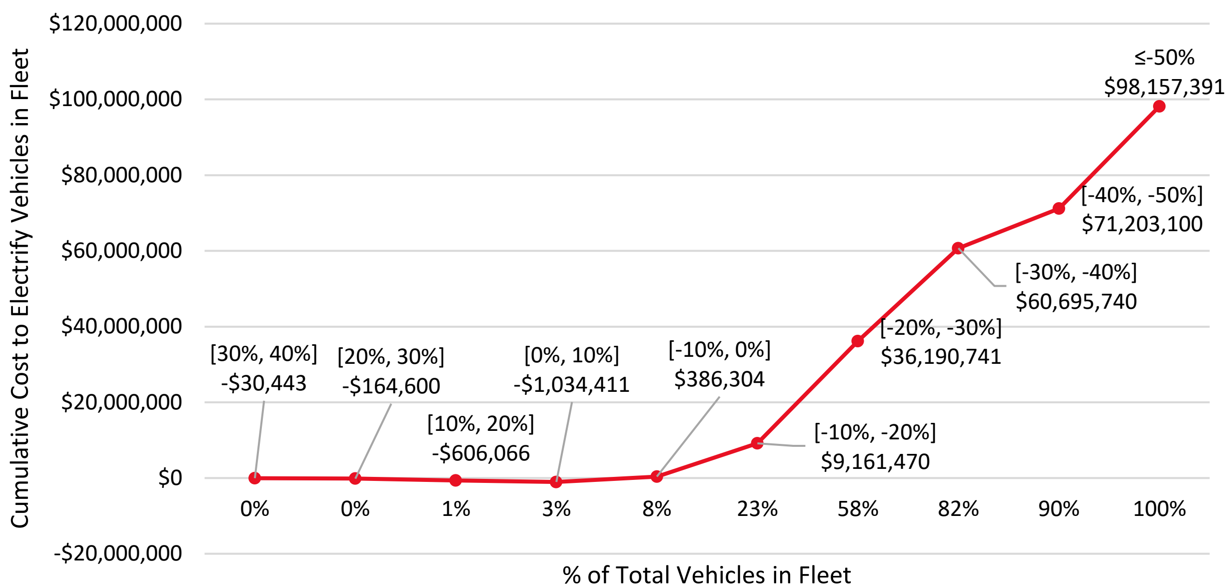


This chart highlights the number of light-duty vehicles included in the analysis by their average percentage savings from electrification. Nearly a quarter of the vehicles analyzed had an EV that was within 20 percent of the TCO of an equivalent internal combustion vehicle.

Though all use cases analyzed had vehicles which met the five percent threshold for electrification, certain light-duty use cases were significantly more cost effective to electrify than others. Of the use cases analyzed, only sedans have a well-developed market with competitively priced options for compact, midsize, and full-size sedans. While all other use cases have commercially available or soon-to-be available EV alternatives, the EV markets for SUVs, vans, pickups, and motorcycles are more limited and, in the case of pickups, are currently restricted to luxury EVs that will become available starting in 2021. The price included in the analysis for the Ford F-150, the most popular pickup model owned by the state, was between $22,973 and $25,976 depending on options. The lowest price for an electric pickup included in the analysis was $39,519, the advertised starting price of the least expensive version of the Tesla Cybertruck. Other EV pickups considered has purchase prices as high as $68,341 before incentives. Even with the operational savings resulting from lower maintenance costs and better fuel economy, many of these vehicles were not able to recoup the difference in upfront cost over the vehicles' lifetime.

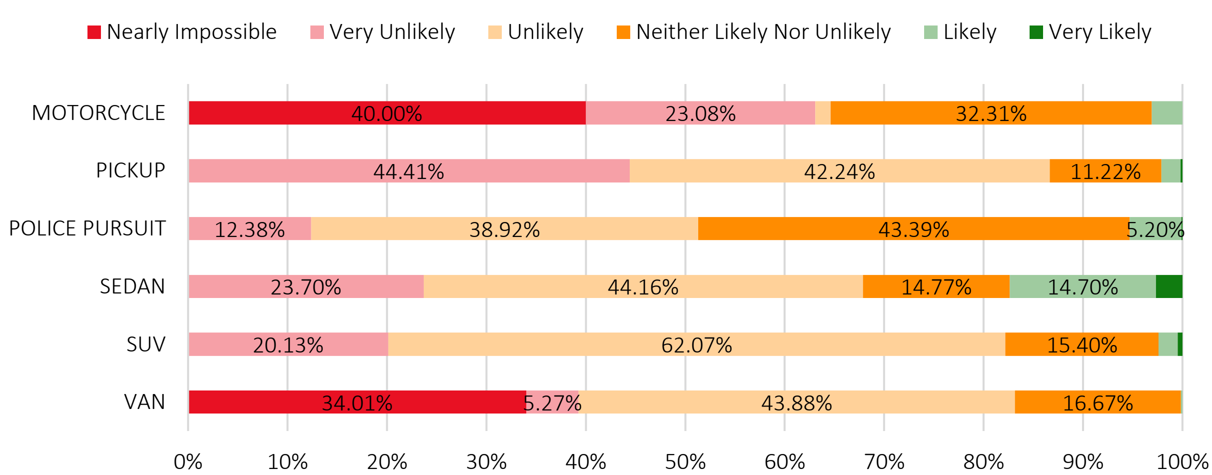
However, as mentioned in *Chapter 3*, the TCO for EV alternatives are averaged over all scenarios, including different EV models. This means that the TCO results for a given vehicle can vary depending on which vehicle model is chosen, how the vehicle is charged, and the electricity rate. If limiting the EV alternatives for pickup trucks to just the Tesla Cybertruck, the number of pickups meeting the five percent threshold for electrification increases from 53 to 209. Figure 26 shows the likelihood results for all 8,199 vehicles analyzed under the initial EV deployment scenario.

FIGURE 25: CUMULATIVE COST TO ELECTRIFY LIGHT-DUTY VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the light-duty vehicles included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $98.1 million to electrify all of the light-duty vehicles included in the analysis now, though it could electrify nearly 60 percent of vehicles more at roughly a third of the cost and more than 23 precent of vehicles for a cumulative cost of $9.2 million.

FIGURE 26: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR LIGHT-DUTY VEHICLES



This figure shows the likelihood results in an initial EV deployment for state agency light-duty vehicles broken down by use case.

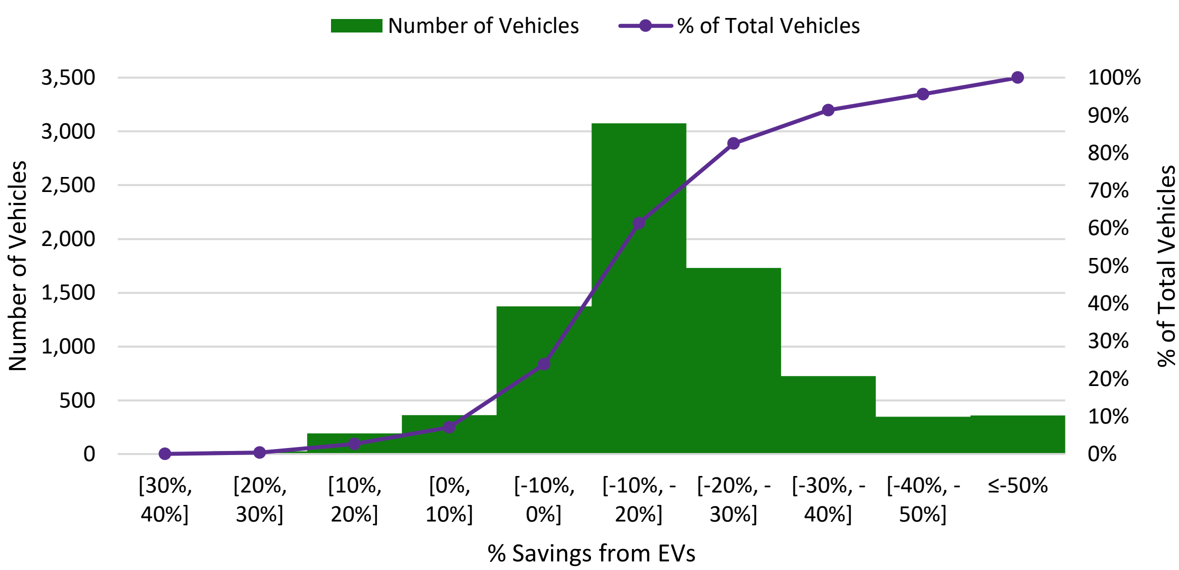
As shown in Figure 26, the most common likelihood category was Neither Likely nor Unlikely, signifying EVs that had an average TCO five to 30 percent of higher than an equivalent internal combustion vehicle. Although the figure above appears to portray EVs as largely non-competitive today from a TCO standpoint, it is important to note that even small changes in the threshold for electrification result in dramatic changes in the number of qualifying vehicles. Increasing the threshold from five percent to ten percent of the TCO increases the number of vehicles identified to electrify by 63 percent, from 418 to 682. Increasing the threshold from five to twenty percent more than triples the number of vehicles that qualify for electrification on a TCO basis, bringing the total to 1,855. The incremental cost to the state to electrify all 1,855 vehicles that were within 20 percent of the TCO of an internal combustion equivalent would be just over $9.2 million or approximately $2.8 million less than the most recently approved funding for the Green Transportation Capital Grant program.

Although the averaged TCO figures represented in Figure 26 show that only five percent of the fleet can be cost-effectively electrified in the present day, the potential for large-scale, cost-effective electrification of the light-duty fleet is high and well-planned procurements which focus on low-cost EV models can improve the electrification potential of vehicles dramatically.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

Under the subsequent deployment scenario, the EV TCO does not include the construction and installation costs for charging stations. The cost of installing a Level 2 charging station for a light-duty vehicle is low relative to the average TCO for a light-duty EV. Removing this factor only resulted in an average savings of approximately $3,700 per vehicle, or just under seven percent of the average TCO for light-duty EVs.

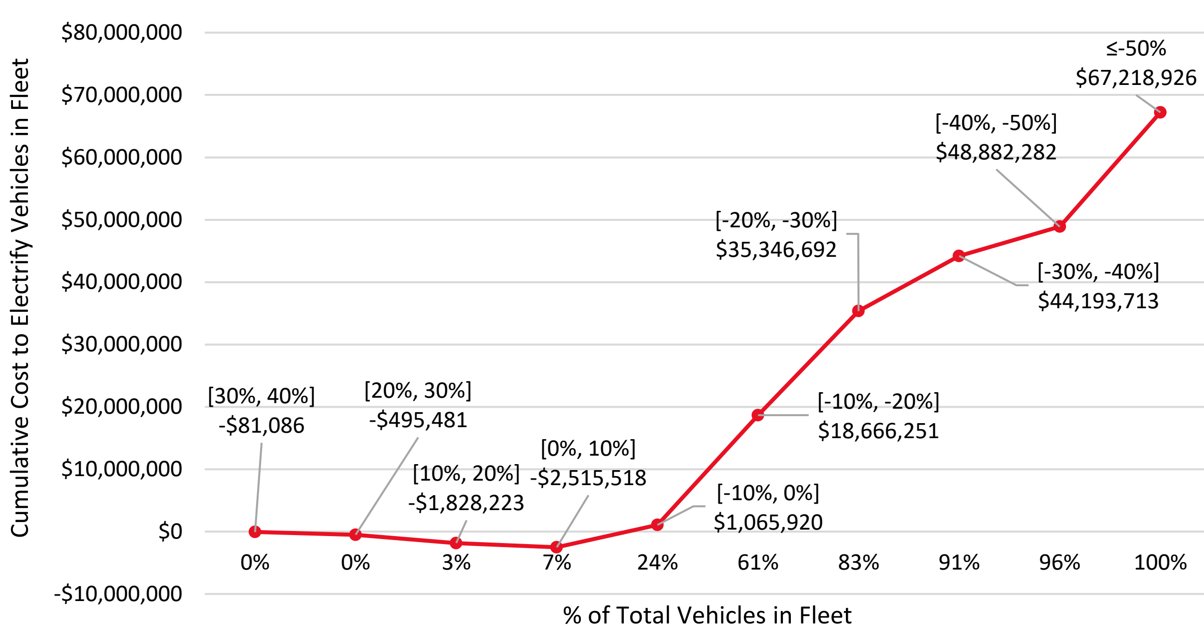
FIGURE 27: NUMBER OF LIGHT-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



This chart highlights the number of light-duty vehicles included in the analysis by their average percentage savings from electrification. More than 60 percent the vehicles analyzed had an EV that was within 20 percent of the TCO of an equivalent internal combustion vehicle.

Despite the small change, the results of the TCO analysis are significantly better for EVs under the subsequent EV deployment scenario. The overall percentage of vehicles that meet the five percent threshold to electrify today more than doubles to over 13 percent. In terms of total number of vehicles, the number that meet the threshold to electrify in the present day increases from 418 to 1,038. The cumulative potential savings from electrifying these vehicles was over $1.9 million on average and ranged from an additional cost of $4.1 million in the worst case to a savings of $7.4 million in the best case. The incremental cost to electrify the remaining light-duty vehicles included in the analysis was $67.2 million on average, approximately $31 million lower than in the initial deployment scenario. This figure ranged from a low of $13.9 million to a high of $123.6 million. Figure 27 and Figure 28 show the number of light-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify light-duty vehicles, respectively.

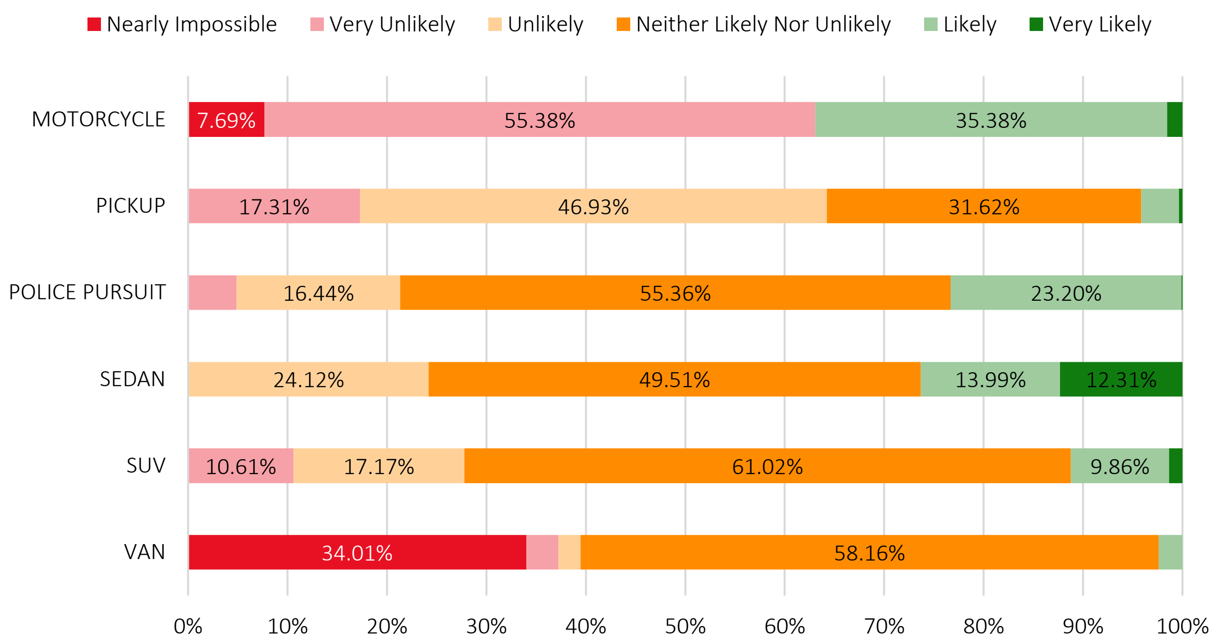
FIGURE 28: CUMULATIVE COST TO ELECTRIFY LIGHT-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the light-duty vehicles included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $67 million on average to electrify all of the light-duty vehicles included in the analysis, though it could electrify more than 60 percent those vehicles for less than a third of the cost and more than 24 percent of vehicles for at a cumulative cost of $1 million.

As highlighted previously, small changes in the costs of EVs can produce considerable changes in the number of vehicles which can be electrified in the present day. Figure 29 demonstrates the increased electrification potential of light-duty vehicles after realizing an average savings of only approximately $3,500. For context, the full value of the federal tax rebate for battery electric light-duty vehicles is $7,500. As mentioned previously, the number of vehicles that meet the five percent threshold for electrification increases from 418 in the initial deployment scenario to 1,038 in the subsequent deployment scenario. This includes 10 percent of pickups, 22 percent of police pursuit vehicles, 29 percent of SUVs, and 36 percent of sedans, again reflective of the relative maturity of the EV market for some vehicles. The key finding from the comparison of the initial and subsequent deployment scenarios is that a large number of vehicles have the potential to electrify in the current market and any savings the state can achieve via either incentives, vehicle selection, price reductions, or charging infrastructure planning can cause large shifts in the number of vehicles that can be electrified cost effectively. This is true for a market in which options for pickups, the second most common type of vehicle owned by the state, and large SUVs only have luxury options available as EV alternatives. As the market for EVs continues to mature and the price for vehicles in those segments fall, the potential for electrification of light-duty vehicles will likely increase markedly.

FIGURE 29: SUBSEQUENT EV LIKELIHOOD RESULTS FOR LIGHT-DUTY VEHICLES



This figure shows the likelihood results in a subsequent EV deployment for state agency light-duty vehicles broken down by use case.

MEDIUM- AND HEAVY-DUTY VEHICLES

The remaining 1,006 vehicles included in the state agency analysis were medium and heavy-duty vehicles. Although the state owns more than 3,000 medium- and heavy-duty vehicles, the majority of these vehicles did not have an available EV alternative outside of potential repowers of existing vehicles or lacked sufficient detailed vehicle data and were excluded from the analysis (see *Chapter 2* for more information on EV availability).

Of the 1,006 state agency medium- and heavy-duty vehicles analyzed, medium-duty vehicles accounted for 993 and heavy-duty the remaining 13. For heavy-duty vehicles, a limiting factor was the number of road construction vehicles for which no EV alternative existed. As of the publishing of this report, the available heavy-duty electric trucks for which the study team was able to gather detailed data were limited to just short- and long-haul semi tractors and refuse vehicles. In both cases, state agencies owned relatively few of these vehicles. Table breaks down the number of vehicles analyzed by use case and vehicle weight class.

TABLE 12: STATE AGENCY MEDIUM- AND HEAVY-DUTY VEHICLES ANALYZED

Use Case	Vehicle Class	Total Vehicles
REFUSE TRUCK	Heavy	8
SHORT HAUL	Heavy	5
BOX TRUCK	Medium	25
CARGO VAN	Medium	249
FLATBED TRUCK	Medium	193
PASSENGER VAN 7 - 15 PASSENGER	Medium	251
SERVICE BODY/WORK TRUCK	Medium	195
SHUTTLE BUS, 15+ PASSENGER	Medium	68
STEP VAN	Medium	12
TOTAL		**1,006**

This table lists the breakdown of medium- and heavy-duty vehicles included in the state agency analysis by use case and weight class.

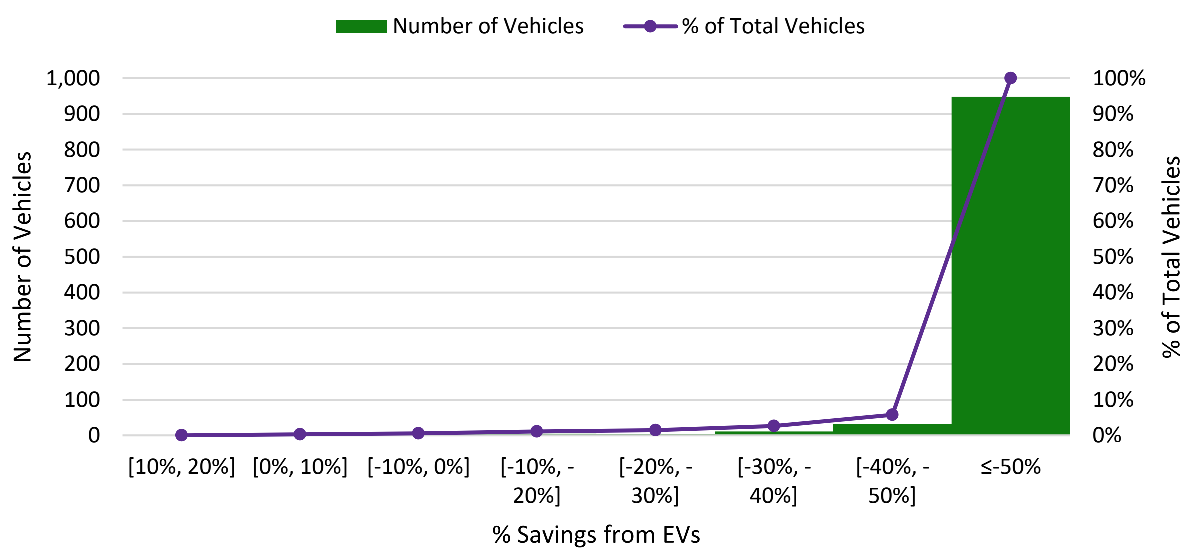
INITIAL EV DEPLOYMENT ANALYSIS RESULTS

Under the baseline scenario in which the TCO of EVs are averaged across all scenarios, only four vehicles had EV alternatives within five percent of the TCO of the comparable conventional vehicle under present-day conditions. For more than 75 percent of the vehicles analyzed, the averaged TCO of an EV alternative was at least 100 percent higher than the internal combustion equivalent. The potential cost savings of electrifying the four vehicles that met the five percent threshold for electrification was $20,032 on average, with a high of $176,624 in savings in the best case and a low of $176,168 in additional cost in the worst case. Savings or costs from electrification depended on the EV procurement scenario in question with the best and worst cases representing a procurement with the lowest- and highest-price EV model, the least and most expensive charging configuration, and the lowest and highest electricity rate, respectively. The potential incremental cost to electrify all medium- and heavy-duty vehicles would be more than $114.9 million on average. This figure ranged between $89.2 million in the best case and $144.2 million in the worst case.

Increasing the threshold from five to 20 percent raises the total number of qualifying vehicles to electrify by eight, bringing the total to 11 vehicles. These 11 vehicles could be electrified for a total average additional cost of $455,574. As shown in Figure 31, electrifying more than one percent of the vehicles analyzed would result in additional costs to the state. Figure 30 and Figure 31 show the number of medium- and heavy-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify these vehicles, respectively.

As detailed in *Chapter 2*, the medium-duty electric truck and van market has the most limited range of EV models from original equipment manufacturers of all EV market segments. The primary offering in this market is for third-party electrification of vehicle chassis purchased from major vehicle manufacturers like Ford and Chevrolet. These vehicles are typified by high upfront costs as the manufacturers are typically smaller companies that cannot achieve the savings from mass production of vehicles. These EVs had upfront price premiums of between two to five times that of an equivalent internal combustion vehicle. For example, the average MSRP of the internal combustion engine cargo vans included in the analysis was $30,453 while the average MSRP for the battery electric cargo vans was $115,123. As a result, many of the EV alternatives had a TCO in excess of 100 percent higher than their internal combustion counterparts. Before attempting wide-scale electrification, this market segment will need to develop beyond offerings from small, third-party manufacturers.

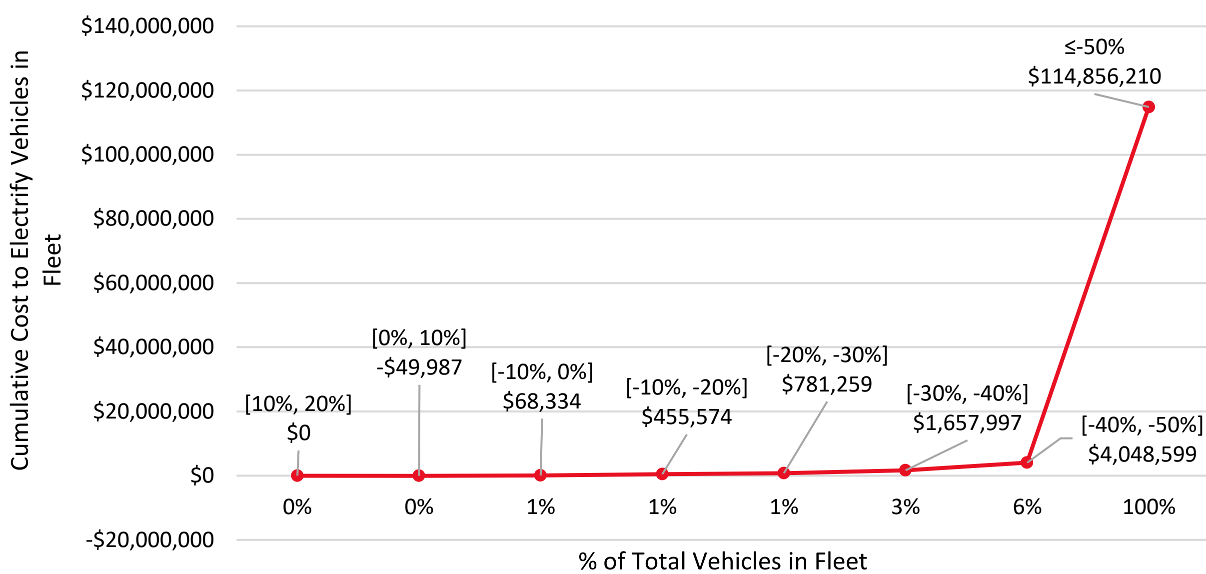
FIGURE 30: NUMBER OF MEDIUM- AND HEAVY DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT



This chart highlights the number of medium- and heavy-duty vehicles included in the analysis by their average percentage savings from electrification. More than 90 percent the vehicles analyzed had an EV with a TCO that was more than 50 percent higher than an equivalent internal combustion vehicle.

By contrast, the heavy-duty EVs included in the analysis were produced by a first-party manufacturer and the upfront price premium for these vehicles was smaller compared to the medium-duty EVs included in the analysis. As a result, these vehicles were more likely to meet the five percent threshold for electrification. Refuse trucks, in particular, offered substantial potential savings with over 35 percent of these vehicles meeting the five percent threshold for electrification. In addition to having a relatively low price premium of 67 percent, electric refuse trucks also offered a fuel economy that was over five times higher than their diesel counterpart and were able to recoup any differences in upfront cost over the vehicles lifetime. An additional factor that contributed to the electrification potential of heavy-duty EVs was their high annual mileage compared to medium-duty vehicles. The average annual mileage for the heavy-duty vehicles included in the analysis was more than 28,800 miles per year compared to the 10,400 average annual mileage for medium-duty vehicles. This additional mileage allowed heavy-duty vehicles to accumulate more operational cost savings to offset differences in vehicle cost.

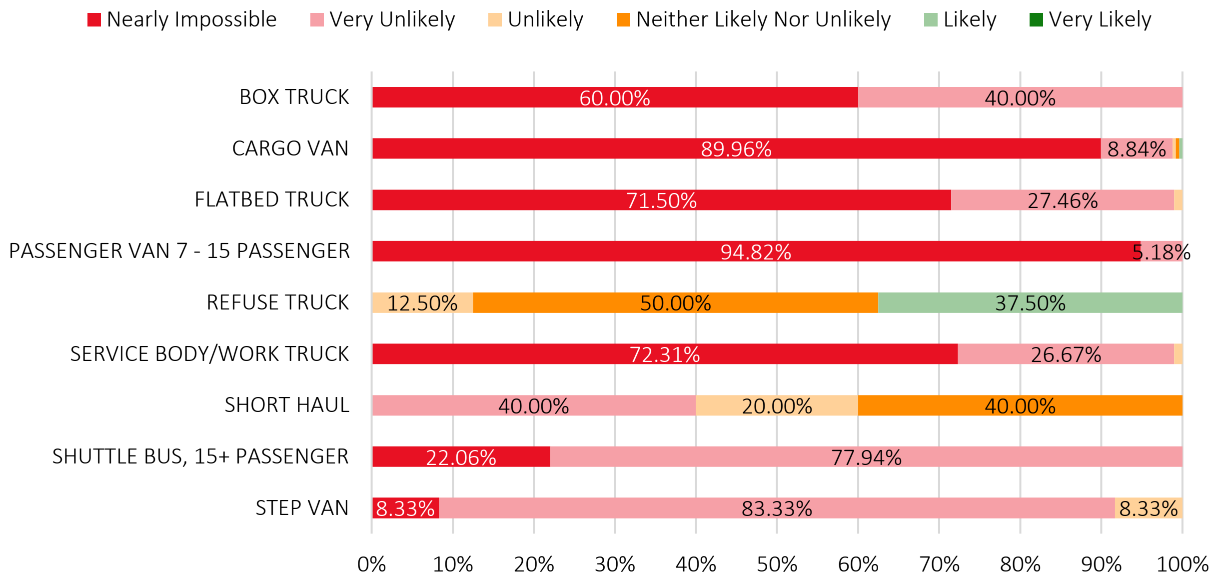
FIGURE 31: CUMULATIVE COST TO ELECTRIFY MEDIUM- AND HEAVY-DUTY VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the medium- and heavy-duty vehicles included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $114.9 million on average to electrify all of the medium- and heavy-duty vehicles included in the analysis. On average, less than one percent of the fleet could be electrified cost effectively.

Although the number of heavy-duty vehicles included in the analysis was low relative to light- and medium-duty vehicles, the annual mileage and fuel economy for these vehicles are similar to the average figures reported for refuse and short haul vehicles from the U.S. Department of Energy's Alternative Fuels Data Center meaning the vehicles analyzed were not operating outside of normal expectations [125]. Figure 32 shows the likelihood results for all medium- and heavy-duty vehicles included in the state agency fleet analysis broken down by use case.

FIGURE 32: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR MEDIUM- AND HEAVY-DUTY VEHICLES



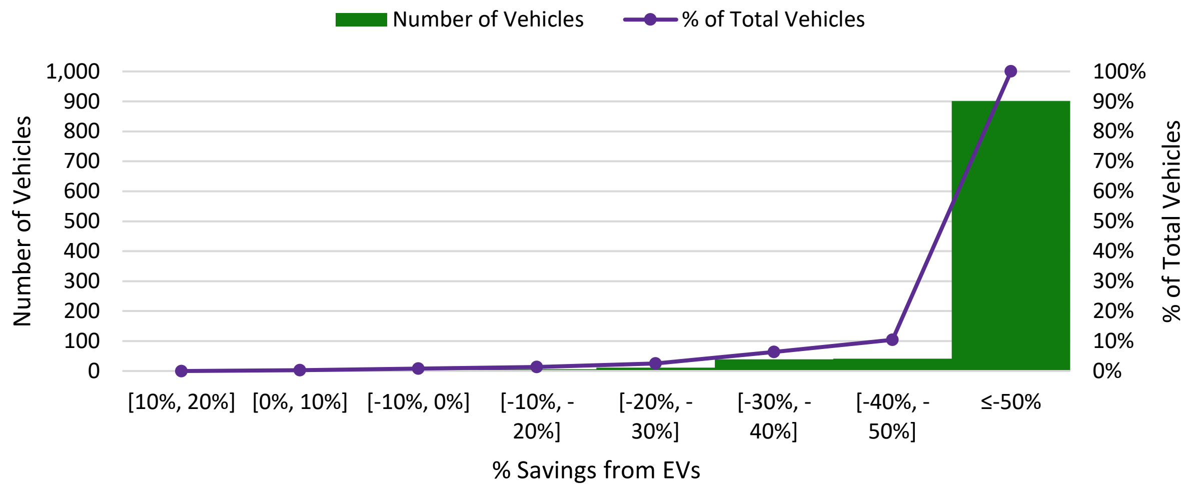
This figure shows the likelihood results in an initial EV deployment for state agency medium- and heavy-duty vehicles broken down by use case. Heavy-duty EVs were considerably more likely to meet the threshold for electrification than medium-duty EVs.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

Even when considering scenarios with reduced charging infrastructure costs, the number of vehicles that met the five percent threshold for electrification only increased from four to six. Similar to light-duty vehicles, the savings on charging infrastructure were relatively small compared to the average TCO for medium- and heavy-duty vehicles, representing an average decrease of eight and three percent, respectively. Only refuse trucks saw an increase in the number of vehicles (37.5 to 62.5 percent) that met the five percent threshold for electrification due to the lowered costs of charging infrastructure. The potential cost savings for electrifying all of the vehicles meeting the threshold for electrification in a subsequent EV deployment totaled $58,447 on average. This ranged between savings of $199,648 in the best case and an additional cost of $82,877 in the worst case. The total cost to electrify all medium- and heavy-duty vehicles included in the analysis was $98.0 million on average, ranging between $86.9 million in the best case and $108.9 million in the worst case. Figure 33 and Figure 34 show the number of medium- and heavy-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify these vehicles, respectively.

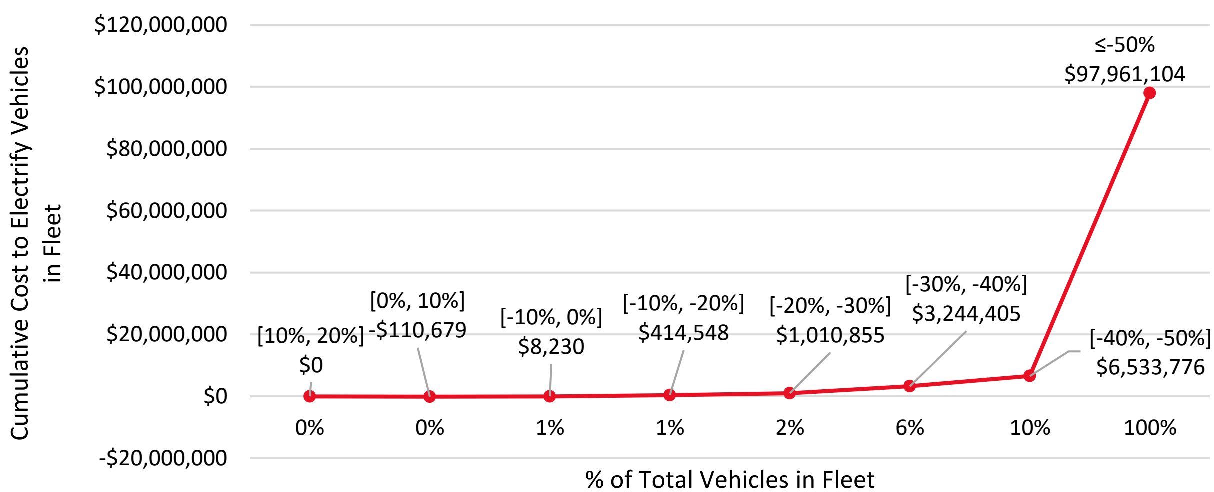
As was the case in the initial deployment scenario, heavy-duty EVs, refuse trucks in particular, were significantly more likely to meet the five percent threshold for electrification. Six of the eight refuse trucks analyzed met the five percent threshold for a net savings of $33,937. Figure 35 lists the full likelihood results for all medium- and heavy-duty vehicles included in the state agency analysis in a subsequent deployment scenario.

FIGURE 33: NUMBER OF MEDIUM- AND HEAVY DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



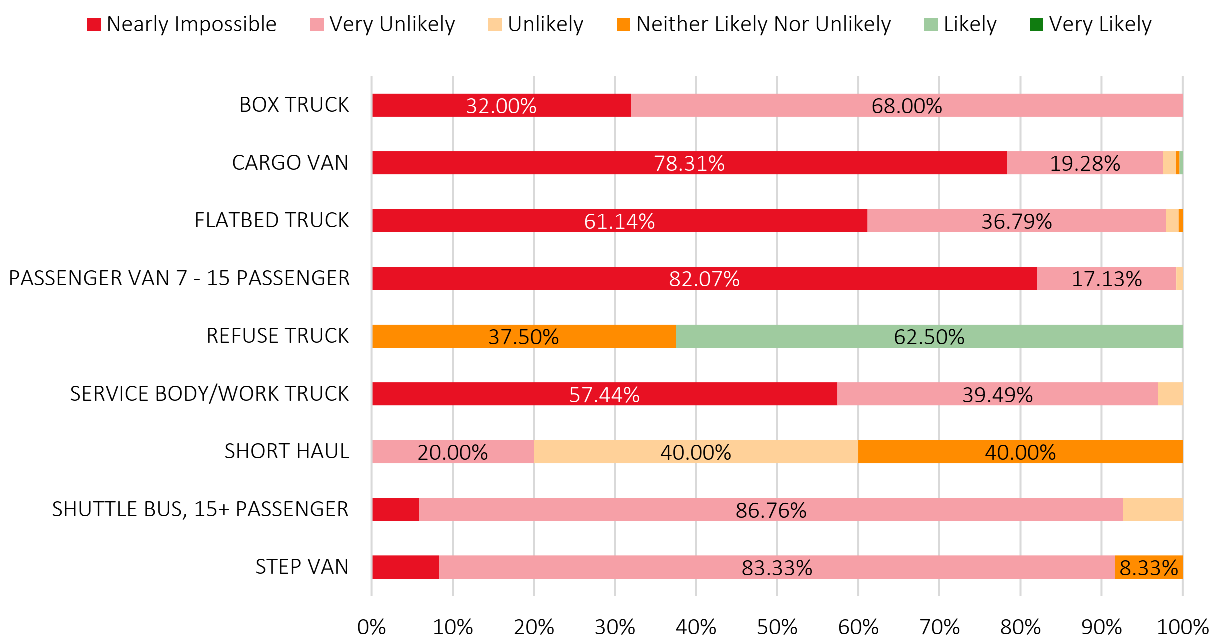
This chart highlights the number of medium- and heavy-duty vehicles included in the analysis by their average percentage savings from electrification. Nearly 90 percent the vehicles analyzed had an EV with a TCO that was more than 50 percent higher than an equivalent internal combustion vehicle.

FIGURE 34: CUMULATIVE COST TO ELECTRIFY MEDIUM AND HEAVY-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the medium- and heavy-duty vehicles included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $98.0 million on average to electrify all of the medium- and heavy-duty vehicles included in the analysis. On average, less than one percent of the fleet could be electrified cost effectively, though the state could electrify 10 percent of fleet for an incremental cost of $6.5 million.

FIGURE 35: LIKELIHOOD RESULTS FOR MEDIUM- AND HEAVY-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the likelihood results in a subsequent EV deployment for state agency medium- and heavy-duty vehicles broken down by use case. Heavy-duty EVs were considerably more likely to meet the threshold for electrification than medium-duty EVs.

SCHOOL BUS ANALYSIS RESULTS

The second largest set of fleet data collected by the study team covered school buses owned by school districts in Washington. The school bus data included information on over 10,838 vehicles, all of which were included in the analysis. Each of these vehicles was mapped to up to two electric alternatives depending on estimated average daily mileage, and a TCO analysis was completed for both the internal combustion and electric alternatives.

All categories of school bus, Type A, B, C, and D were included in the analysis, shared similar operational characteristics such as VMT and fuel price, and had similar EV alternative offerings; the TCO results for all school buses are presented together.

Heavy-duty Type D and C school buses represented the majority of the school bus fleet in Washington, accounting for 47 and 37 percent of the total fleet, respectively. Medium-duty Type A and B school buses accounted for the remaining 19 percent of the fleet, although Type B buses were highly uncommon and represented less than half of a percent of the total fleet. Table 13 breaks down the number of vehicles analyzed by use case.

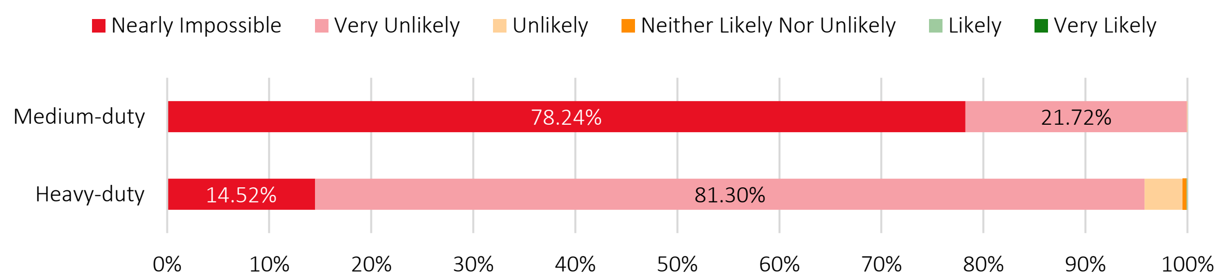
The analysis results demonstrated that school buses were not cost-effective targets for electrification for all but a handful of vehicles. Electrifying even one percent of the fleet could come at substantial additional cost in the absence of policy interventions. Figure 36 shows the likelihood results for all school buses by weight class in an initial EV deployment. The sections below explore the results for all school buses by use case in an initial and subsequent EV deployment.

TABLE 13: SCHOOL BUSES BY USE CASE

Use Case	Total Vehicles
TYPE A	2,028
TYPE B	35
TYPE C	3,986
TYPE D	4,789
TOTAL	**10,838**

This table lists the breakdown of school buses included in the state agency analysis by use case.

FIGURE 36: LIKELIHOOD RESULTS FOR ALL SCHOOL BUSES IN AN INITIAL EV DEPLOYMENT



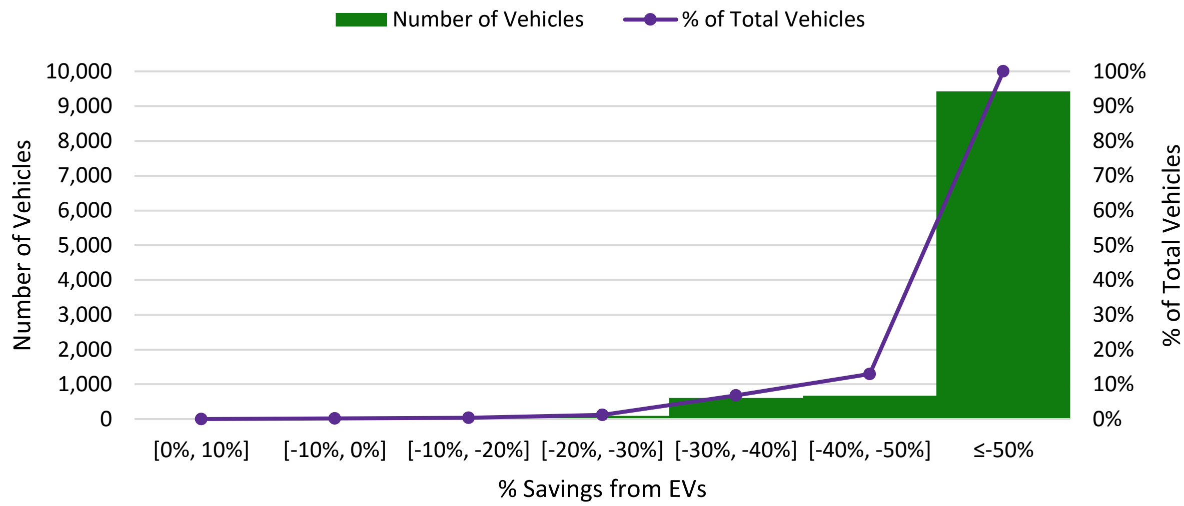
This figure shows the likelihood results for all school buses included in the analysis separated by weight class

INITIAL EV DEPLOYMENT ANALYSIS RESULTS

Very few school buses owned by Washington that were included in the analysis met the five percent threshold for electrification. Under the initial EV deployment scenario, only seven, all of which were Type C buses, met the electrification threshold under present-day conditions. For over 75 percent of the school buses analyzed, an EV had a TCO in excess of 50 percent higher than their internal combustion equivalent. The average cost of electrifying the seven vehicles that met the five percent threshold for electrification was only $93,660. In the best case, the savings from these vehicles were $$239,232 and in the worst case electrifying these vehicles would cost $426,451. The potential cost to electrify all buses would be more than $1.9 billion.

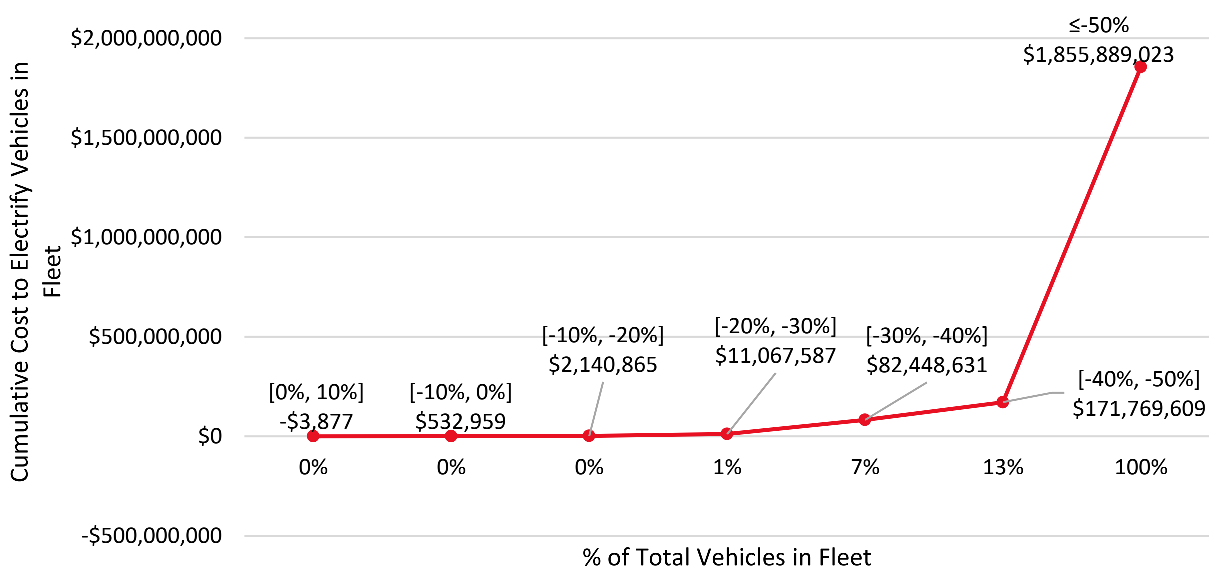
Increasing the threshold for electrification did little to improve the electrification potential of the school bus fleet in Washington. Raising the threshold for electrification from five percent to 20 percent resulted in 42 buses being electrified, less than one half of one percent of the total school bus fleet. The average cost to electrify all buses for which an EV was within 20 percent of the TCO of an equivalent internal combustion bus was $2.1 million. Figure 37 and Figure 38 show the number of school buses vehicles by the average percent savings from electrification and the cumulative average cost to electrify school buses, respectively.

FIGURE 37: NUMBER OF ELECTRIC SCHOOL BUSES BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT



This chart highlights the number of school buses included in the analysis by their average percentage savings from electrification. More than 75 percent the vehicles analyzed had an EV with a TCO that was more than 50 percent higher than an equivalent internal combustion vehicle.

FIGURE 38: CUMULATIVE COST TO ELECTRIFY SCHOOL BUSES IN AN INITIAL EV DEPLOYMENT

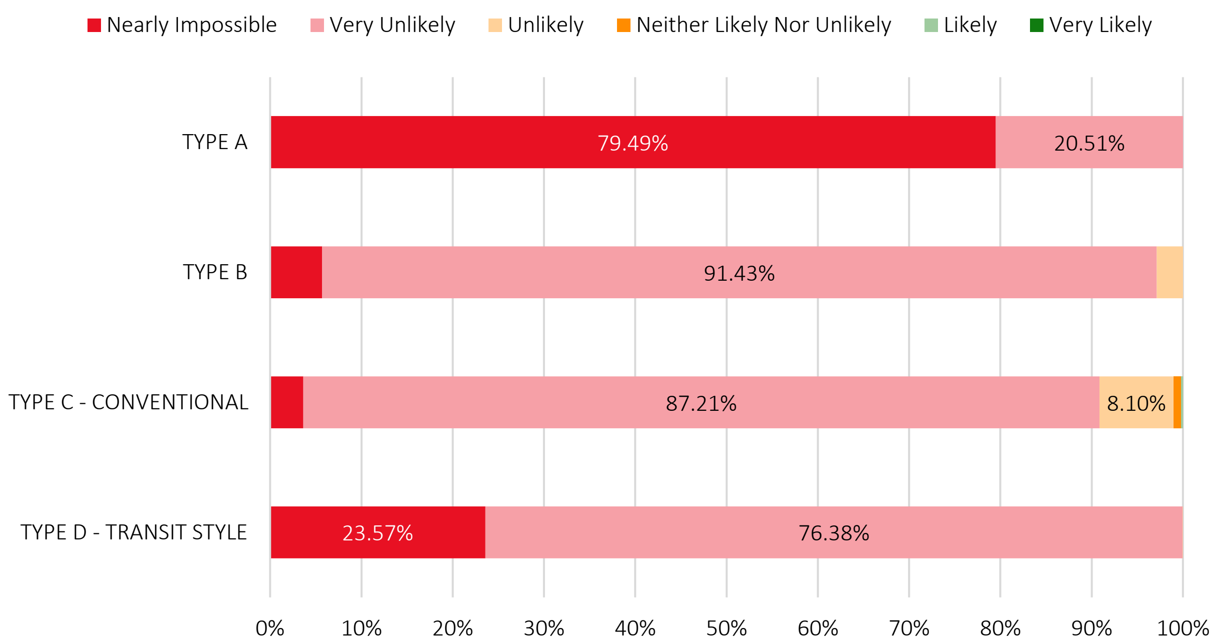


This figure shows the cumulative additional cost or savings to electrify the school buses included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $1.9 billion on average to electrify all the school buses included in the analysis. On average, less than one percent of the fleet could be electrified cost effectively.

Electric school buses, similar to medium-duty electric trucks and vans, have high price premiums compared to their internal combustion equivalents. The quoted prices of a gasoline Type A school buses listed on the Washington Office of the Superintendent of Public Instruction website range between approximately $58,000 and $66,000. The least expensive Type A EV alternative included in the analysis was nearly four times more expensive than its gasoline counterpart at more than $224,0000. Similar price premiums exist for both Type C and D buses, with each having EV alternatives greater than three times more expensive than their internal combustion versions. Type C buses, the only bus type that met the threshold for electrification, had the lowest price premium on average at 256 percent.

The annual mileages of these vehicles ranged between 9,000 and 11,000 miles per year depending on bus type. At these annual mileages, it was difficult for buses to accumulate enough operational cost savings from lower maintenance and fuel costs to offset their high price premiums. It should be noted, however, that one challenge surrounding the school bus data provided to the study team was a lack of mileage information for individual buses. Annual mileage data was only available at the school district level, meaning that all school buses in a given district were assumed to travel the same mileage each year. If certain buses travel significantly more miles than the average annual mileage for their school district, it could affect the TCO calculation and more vehicles could meet the threshold for electrification. Figure 39 shows the likelihood results for all school buses included in the analysis broken down by use case.

FIGURE 39: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR SCHOOL BUSES

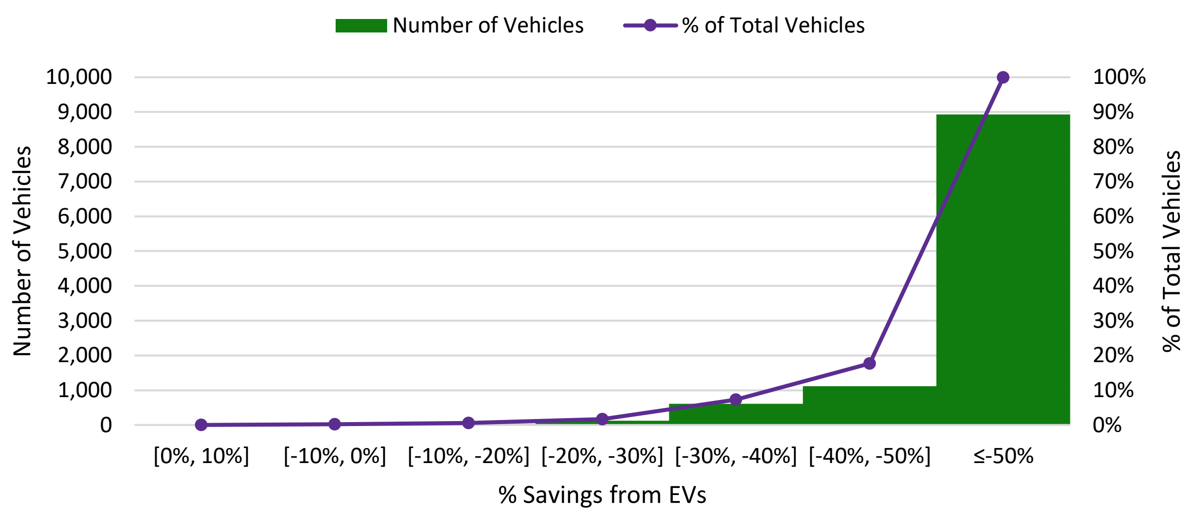


This figure shows the likelihood results in an initial EV deployment for school buses vehicles broken down by use case. Only seven buses, all Type C, were categorized as Likely meaning they met the five percent threshold for electrification.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

Under the subsequent EV deployment scenario, no additional vehicles met the five percent threshold for electrification. Despite only including costs for replacement of charging equipment, the TCO for electric school buses was still higher than the threshold for electrification for over 99 percent of vehicles analyzed. The average cost to electrify the seven buses that met the five percent threshold was $33,440, ranging from a savings of $$254,492 in the best case to an additional cost of $321,271 in the worst case. The average cost to electrify the entire school bus fleet fell by $100 million to $1.8 billion, ranging from $1.6 billion in the best case $1.9 billion in the worst case. Figure 40 and Figure 41 show the number of school buses vehicles by the average percent savings from electrification and the cumulative average cost to electrify school buses, respectively.

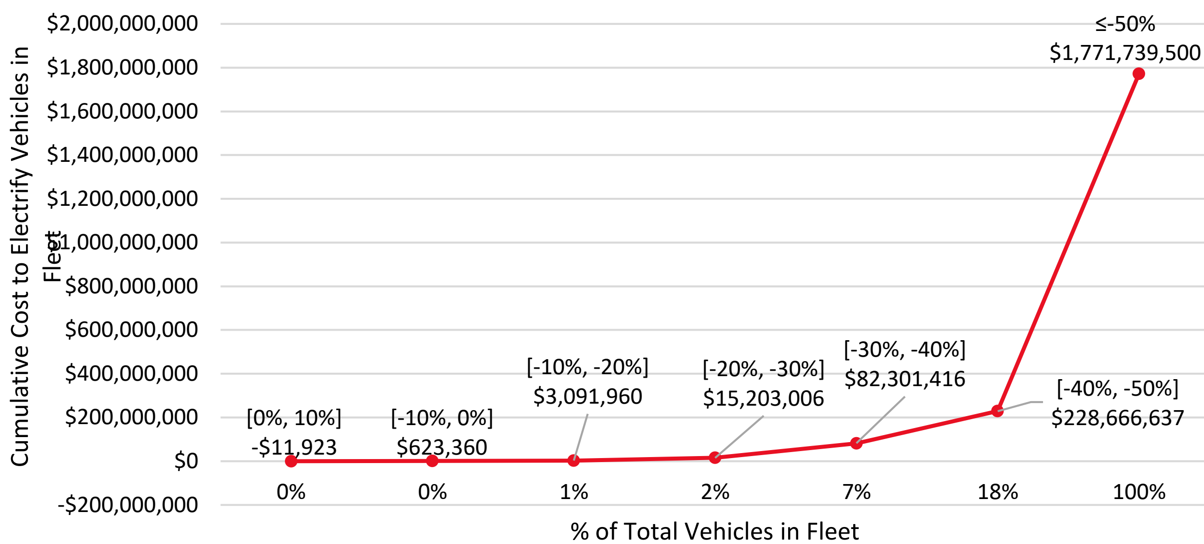
FIGURE 40: NUMBER OF ELECTRIC SCHOOL BUSES BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



This chart highlights the number of school buses included in the analysis by their average percentage savings from electrification. More than 70 percent the vehicles analyzed had an EV with a TCO that was more than 50 percent higher than an equivalent internal combustion vehicle.

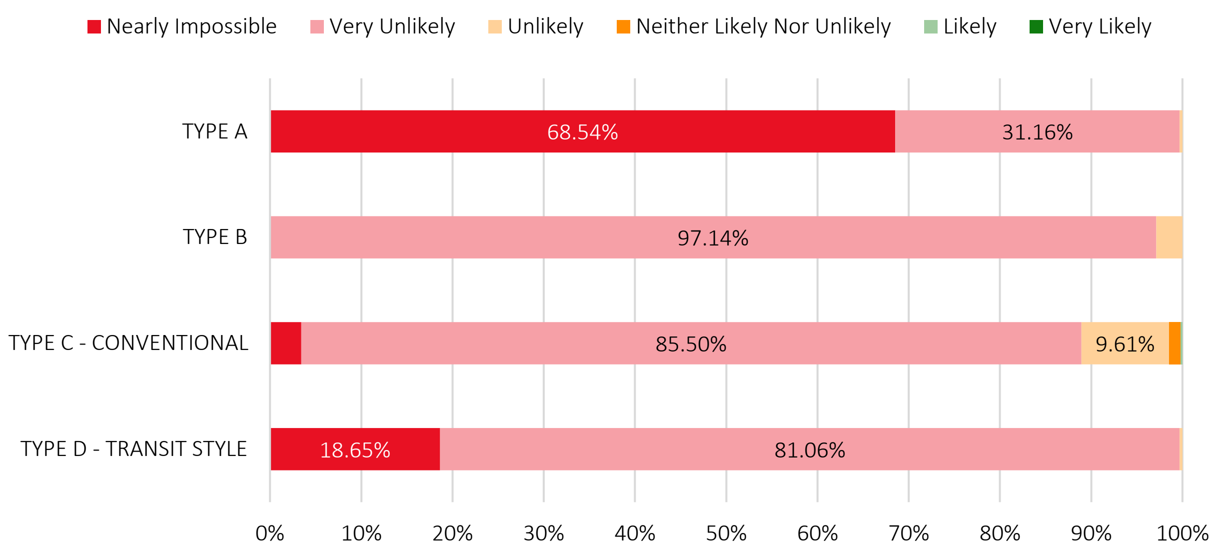
Including just the cost of replacement charging equipment lowered the total cost for an electric bus by just under $7,800 on average. The average TCO for electric buses in the initial deployment scenario was over $397,000 and the savings on charging infrastructure in the subsequent deployment scenario represented a decrease of less than two percent in TCO. Given that the vast majority of electric buses had total costs of ownership more than 50 percent higher than their internal combustion equivalents, the savings on charging infrastructure had little effect on the overall results. Although Washington already has one electric school bus in operation with plans to deploy 40 more, school districts have relied on grant funding from the Department of Ecology (resulting from the VW settlement) to help defray the incremental costs for electric buses and grant funding along with other incentives will remain a critical component for the electrification of school buses in the near future. Grant funding programs for vehicle purchases and their effect on EV TCO are discussed further in *Chapter 8*. Figure 42 shows the likelihood results for all school buses included in the analysis broken down by use case.

FIGURE 41: CUMULATIVE COST TO ELECTRIFY SCHOOL BUSES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the school buses included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $1.8 billion on average to electrify all the school buses included in the analysis. On average, less than one percent of the fleet could be electrified cost effectively.

FIGURE 42: SUBSEQUENT EV DEPLOYMENT LIKELIHOOD RESULTS FOR SCHOOL BUSES



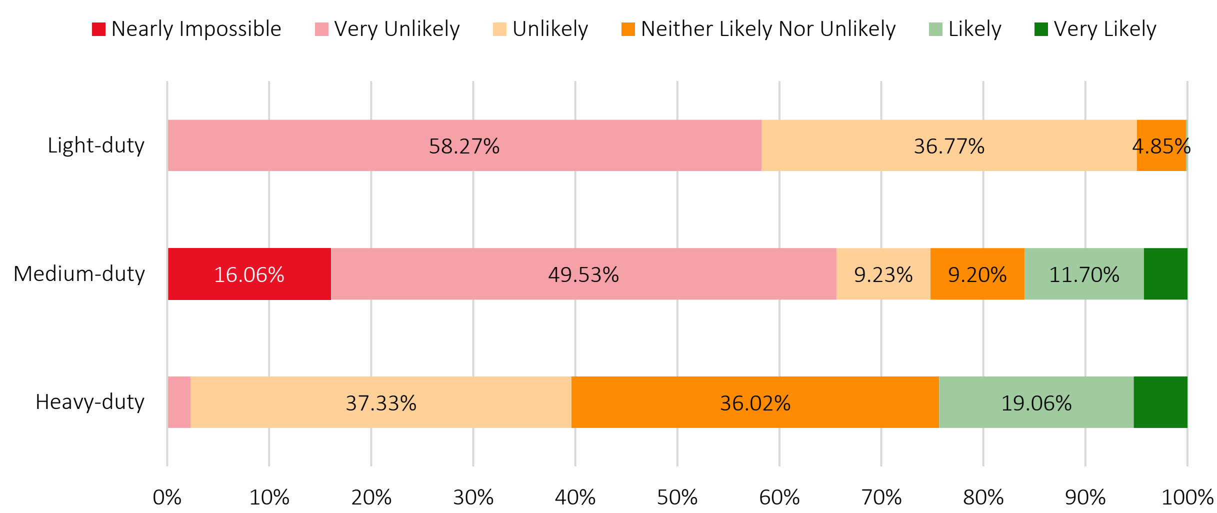
This figure shows the likelihood results in a subsequent EV deployment for school buses broken down by use case. No additional vehicles met the five percent threshold for electrification in a subsequent deployment scenario.

TRANSIT AGENCY ANALYSIS RESULTS

The third largest set of fleet data collected by the study team was for transit agencies in Washington. In total, the transit agency fleet included information on over 9,300 vehicles. Of these vehicles, the study team identified 8,870 for which sufficient detailed vehicle data existed and for which there was at least one EV alternative and included them in the analysis. The analysis covered vehicles across 29 transit agencies in Washington serving all areas of the state. Each of these vehicles was mapped to up to two electric alternatives, including both battery electric and plug-in hybrids, and a TCO analysis was completed for both the internal combustion and electric alternatives.

Outside of light-duty vehicles, transit vehicles were the most cost-effective to electrify across all vehicles included in the analysis and should be a priority for future electrification efforts. Electrifying all vehicles that met the five percent threshold would result in a cumulative savings of more than $70 million. If the state were to apply these savings toward vehicles with less compelling cases for electrification, it could electrify more than 20 percent of all transit agency vehicles before incurring additional costs. Figure 43 shows the likelihood results for all transit agency vehicles by weight class in an initial EV deployment. The sections below explore the results by use case for light-, medium-, and heavy-duty vehicles.

FIGURE 43: LIKELIHOOD RESULTS FOR ALL TRANSIT AGENCY VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the likelihood results for all transit vehicles included in the analysis separated by weight class

LIGHT-DUTY VEHICLES

Of the 8,870 vehicles included in the analysis, light-duty vehicles accounted for 2,763, or 31 percent. The majority of these light-duty vehicles were minivans used as part of vanpool programs providing commuting services to Washingtonians. Transit agencies in Washington also own several sedans, pickups, and SUVs which serve administrative functions. Table 14 breaks down the number of vehicles analyzed by use case.

TABLE 14: TRANSIT AGENCY LIGHT-DUTY VEHICLES ANALYZED

Use Case	Total Vehicles
PICKUP	8
SEDAN	20
SUV	123
MINIVAN	2,612
TOTAL	**2,763**

This table lists the breakdown of light-duty vehicles included in the transit agency analysis by use case

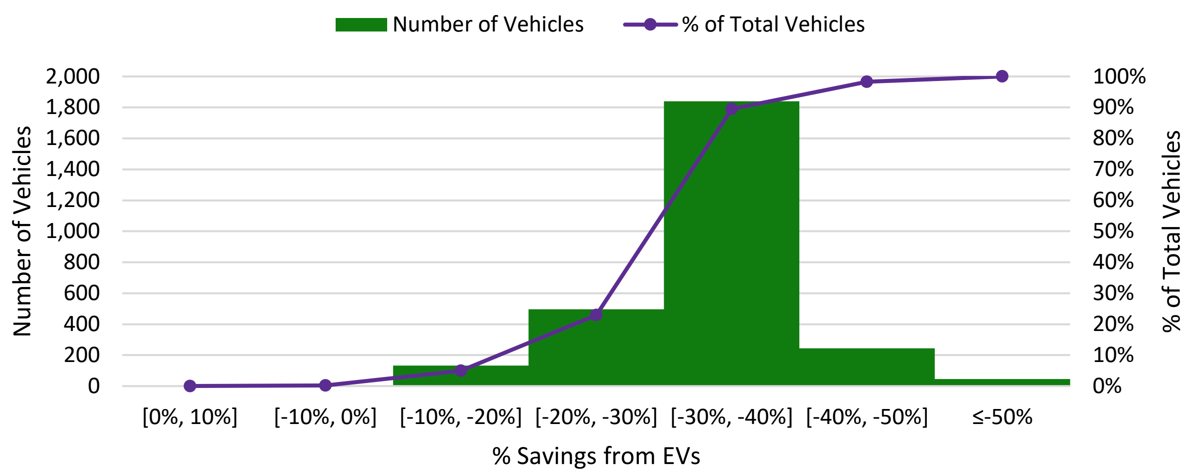
INITIAL EV DEPLOYMENT ANALYSIS RESULTS

Only three light-duty vehicles, all sedans, owned by transit agencies met the five percent threshold for electrification in the initial EV deployment scenario. It is important to highlight that none of the minivans, which constituted nearly 95 percent of the light-duty vehicles analyzed, met the threshold for electrification; more than 60 percent of electric vans had a TCO that was greater 35 percent higher than their internal combustion equivalent. Electrifying the six vehicles that met the threshold would result in an incremental cost of $1,541 on average, ranging from a savings of $14,663 in the best case to an additional cost of $16,911 in the worst case.

Increasing the threshold to electrify vehicles to 20 percent increased the number of vehicles to electrify from six to 137, or only five percent of all light-duty vehicles included in the transit agency analysis. Electrifying these 137 vehicles would result in an average incremental cost of $905,201. The potential cost to electrify all light-duty vehicles included in the analysis is $27.0 million, ranging from a low of a $12.0 million to a high of $41.0 million in additional cost. Figure 44 and Figure 45 show the number of light-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify light-duty vehicles, respectively.

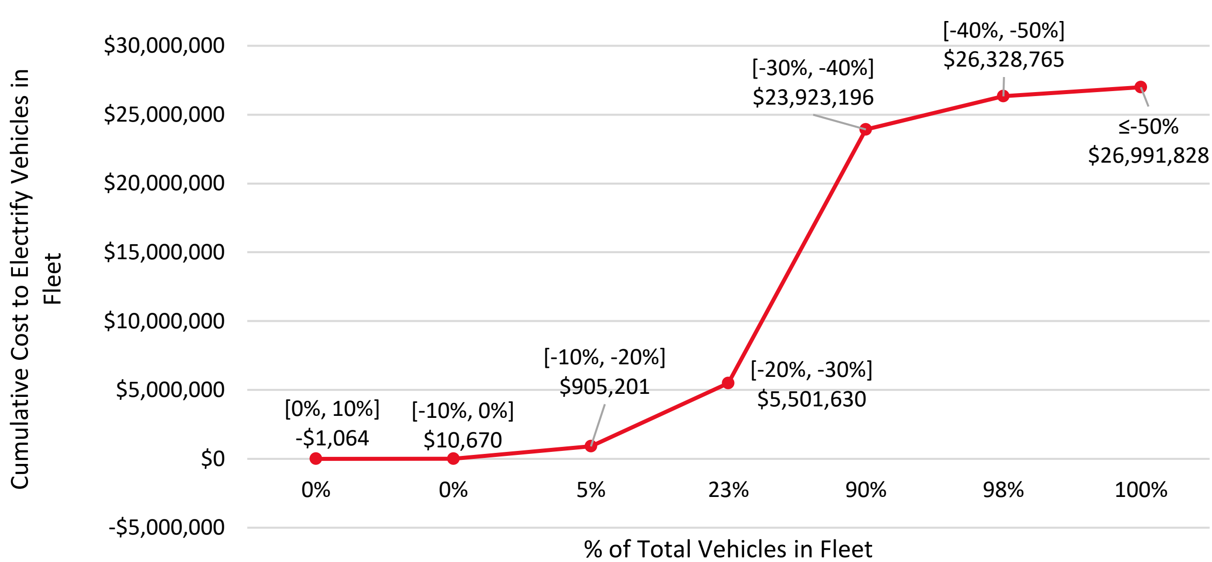
As was the case for light-duty vehicles owned by state agencies, light-duty use cases like sedans were more cost effective to electrify due to having more well-developed EV markets. Compared to sedans, the EV options for minivans are relatively limited with only one plug-in hybrid model, the Chrysler Pacifica hybrid, available as of 2020. Though no full battery electric minivan were at the time of this study, the study team included the seven-seat version of the Tesla Model Y as a potential full battery electric vehicle alternative. These two options for electric minivans came at much higher price premiums compared to other light-duty models. The price included in the analysis for the Dodge Grand Caravan, the most popular pickup model owned by the state, was $25,049. The lowest price for an electric van included in the analysis was $39,991 before incentives for the Chrysler Pacifica plug-in hybrid. The other EV alternative for vans, the seven-seat Model Y, was $50,686. Even in the best case, EV alternatives for vans had a price premium of nearly 60 percent, 16 percent higher than the average price premium for battery electric sedans. As a result, these vehicles were not generally able to recoup the difference in upfront cost over the vehicles' lifetime despite the savings from lower fuel and maintenance costs.

FIGURE 44: NUMBER OF LIGHT-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT



This chart highlights the number of light-duty vehicles included in the analysis by their average percentage savings from electrification. Around 95 percent of vehicles analyzed had an EV with a TCO that was at least 20 percent higher than an equivalent internal combustion vehicle.

FIGURE 45: CUMULATIVE COST TO ELECTRIFY LIGHT-DUTY VEHICLES IN AN INITIAL EV DEPLOYMENT

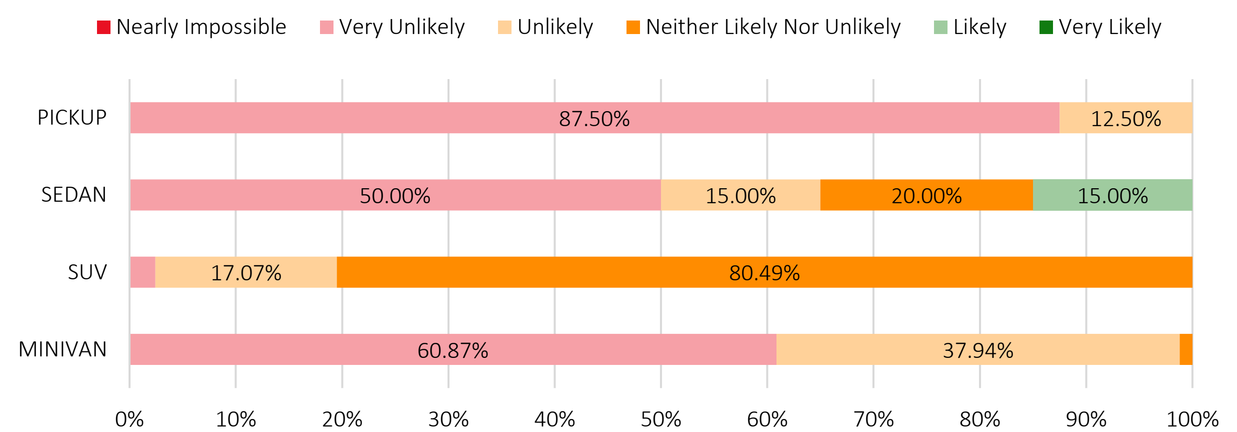


This figure shows the cumulative additional cost or savings to electrify the light-duty vehicles included in the analysis. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $27 million to electrify all of the light-duty vehicles included in the analysis now, though it could electrify more than nearly half of light-duty vehicles for less than half of the cost.

As discussed in the *Overall* Results section of this chapter, electric pickups face a similar hurdle with limited electric alternatives that all have high price premiums. Unlike in the state agency analysis of pickups, however, limiting the EV alternatives to just the least expensive EV, the Chrysler Pacifica plug-in hybrid, did little to improve the number of minivans that met the threshold for electrification. When only considering the Pacifica, the number of minivans that met the threshold for electrification was just six out of 2,612 vehicles. Because the Pacifica, a plug-in hybrid, relies on both an internal combustion engine and electric motor, it offers lower fuel cost savings than a full battery electric option. Maintenance costs for plug-in hybrids were higher than internal combustion vehicles for the Department of Enterprise Services, which further made the TCO challenging for these vehicles. For a more complete comparison of vehicle operating costs, see the *Nominal Cost Per Mile Breakdown* section of this chapter.

As a result of the hurdles for minivan electrification described above, only one percent of these vehicles had an EV alternative that was within 20 percent of an internal combustion equivalent. King County Metro has recognized the obstacles to minivan electrification and are instead seeking to supplement these vehicles with electric sedans, in particular the Nissan Leaf, as part of their MetroPool program. Figure 46 shows the likelihood results for all 2,763 vehicles analyzed under the initial EV deployment scenario.

FIGURE 46: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY LIGHT-DUTY VEHICLES

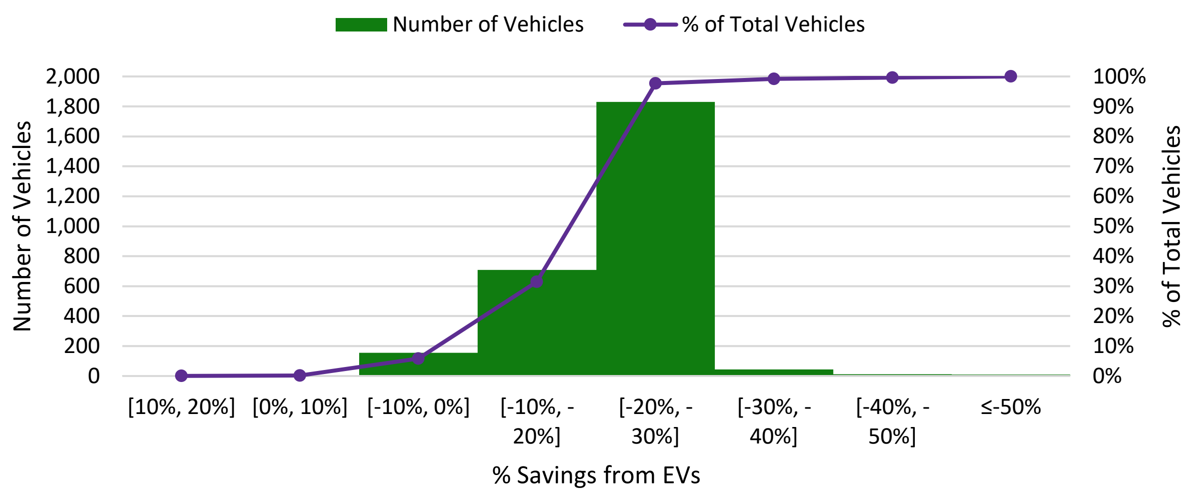


This figure shows the likelihood results in an initial EV deployment for transit agency light-duty vehicles broken down by use case. Results for sedans and SUVs were less favorable compared to state agency vehicles due to differences in vehicle annual mileage and electricity costs.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

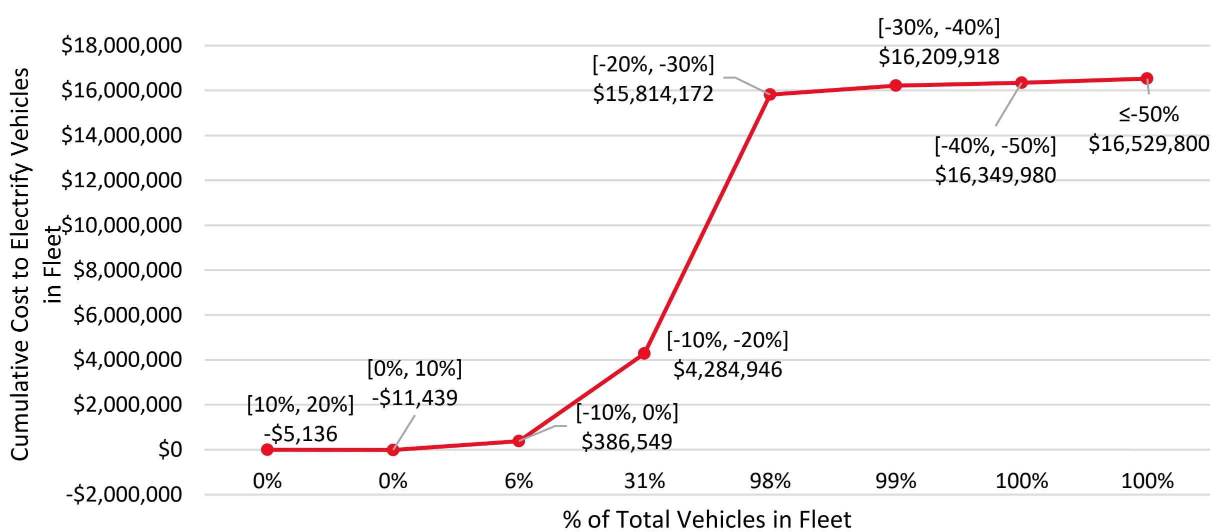
Under the subsequent deployment scenario, the EV TCO does not include the construction and installation costs for charging stations. As was highlighted in the analysis of state agency light-duty vehicles, the cost of installing a Level 2 charging station for a light-duty vehicle is low relative to the average TCO for a light-duty EV. Because of this, reducing these costs only resulted in an average savings of approximately $3,800 per vehicle, or 10 percent of the average TCO for light-duty EVs included in the transit agency analysis.

FIGURE 47: NUMBER OF LIGHT-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



This chart highlights the number of light-duty vehicles included in the analysis by their average percentage savings from electrification in a subsequent EV deployment. More than 30 percent of vehicles analyzed had an EV with a TCO that was within 20 percent of an equivalent internal combustion vehicle.

FIGURE 48: CUMULATIVE COST TO ELECTRIFY LIGHT-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT

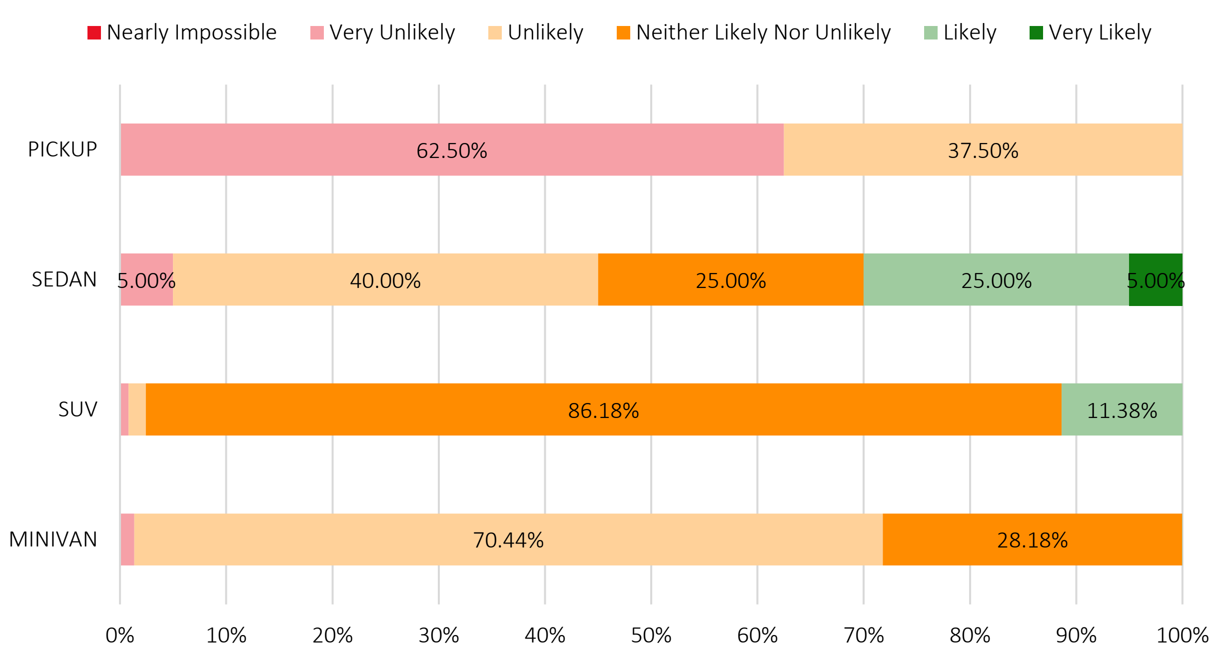


This figure shows the cumulative additional cost or savings to electrify the light-duty vehicles included in the analysis in a subsequent EV deployment. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $16.5 million to electrify all of the light-duty vehicles included in the analysis in the present day.

Despite the small change, the number of vehicles that met the five percent threshold for electrification increased from three to 21. Electrifying these vehicles would result in an additional cost of $6,166 on average, ranging from an additional cost of $81,155 in the worst case to a savings of $83,043 in the best case. The wide range in savings was the result of the wide variation in the prices for the EV models considered. The cost to electrify all public transit light-duty vehicles included in the analysis was $16.5 million on average, ranging from a low of $9.0 million to a high of $23.4 million. Importantly, an additional 115 SUVs, over 90 percent total, fell outside of the five percent threshold but would qualify for electrification under a 10 percent threshold for electrification. Figure 47 and Figure 48 show the number of light-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify light-duty vehicles, respectively.

As highlighted in the *State Agency Analysis Results* section of this chapter, relatively small changes in the costs of EVs can produce considerable changes in the number of vehicles which can be electrified in the present day. After realizing an average savings of approximately $3,800, roughly half of the full value of the federal tax rebate of $7,500, the number of vehicles that met the threshold for electrification increased substantially. While only one percent minivans met the threshold for electrification in a subsequent deployment of EVs, it should be noted that more than 30 percent of minivans had an EV that was within 20 percent of the TCO of an internal combustion vehicle. Minivans, like many light-duty vehicles, are near the tipping point for large-scale electrification and slight shifts in the TCO can mean the difference between cost-effective electrification of thousands of vehicles. Figure 49 shows the likelihood results for all 2,763 vehicles analyzed under the subsequent EV deployment scenario.

FIGURE 49: SUBSEQUENT EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY LIGHT-DUTY VEHICLES



This figure shows the likelihood results in a subsequent EV deployment for transit agency light-duty vehicles broken down by use case.

MEDIUM-DUTY BUSES

Medium-duty buses accounted for 3,206, or approximately one third, of the 9,376 vehicles included in the transit agency fleet. These vehicles are typically used to provide paratransit, accessibility, or vanpool services to residents across Washington. The majority of these vehicles were shuttle buses, defined in this analysis as vehicles with an aftermarket passenger body from manufacturers such as Eldorado, Champion, Startrans, and ARBOC. Table 15: breaks down the number of vehicles analyzed by use case.

TABLE 15: TRANSIT AGENCY MEDIUM-DUTY VEHICLES ANALYZED

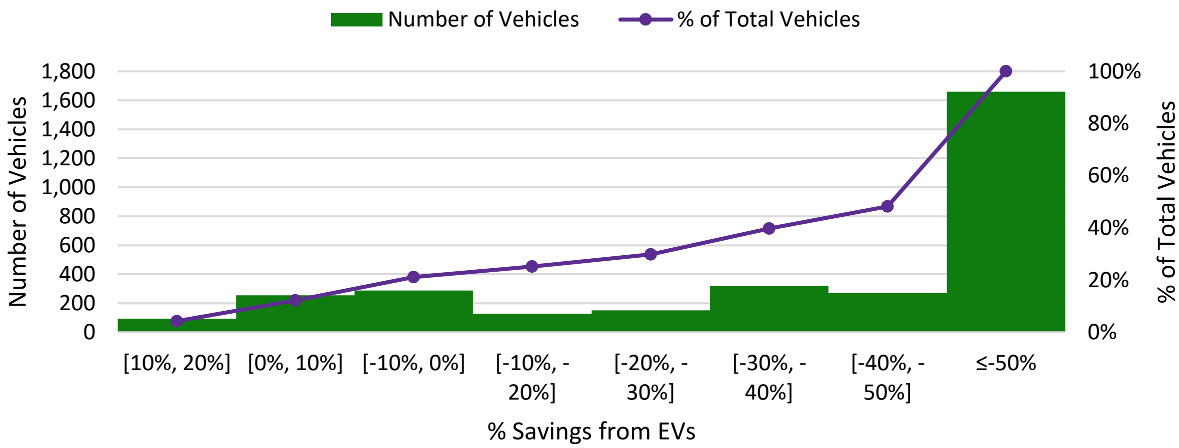
Use Case	Total Vehicles
CARGO VAN	6
PASSENGER VAN, <15 PASSENGER	138
SHUTTLE BUS, 8-12 PASSENGER	624
SHUTTLE BUS, 12-16 PASSENGER	1,297
SHUTTLE BUS, 16-20 PASSENGER	1,041
SHUTTLE BUS, 20-24 PASSENGER	40
SHUTTLE BUS, 24+ PASSENGER	60
TOTAL	**3,206**

This table lists the breakdown of medium-duty vehicles included in the transit agency analysis by use case

INITIAL EV DEPLOYMENT ANALYSIS RESULTS

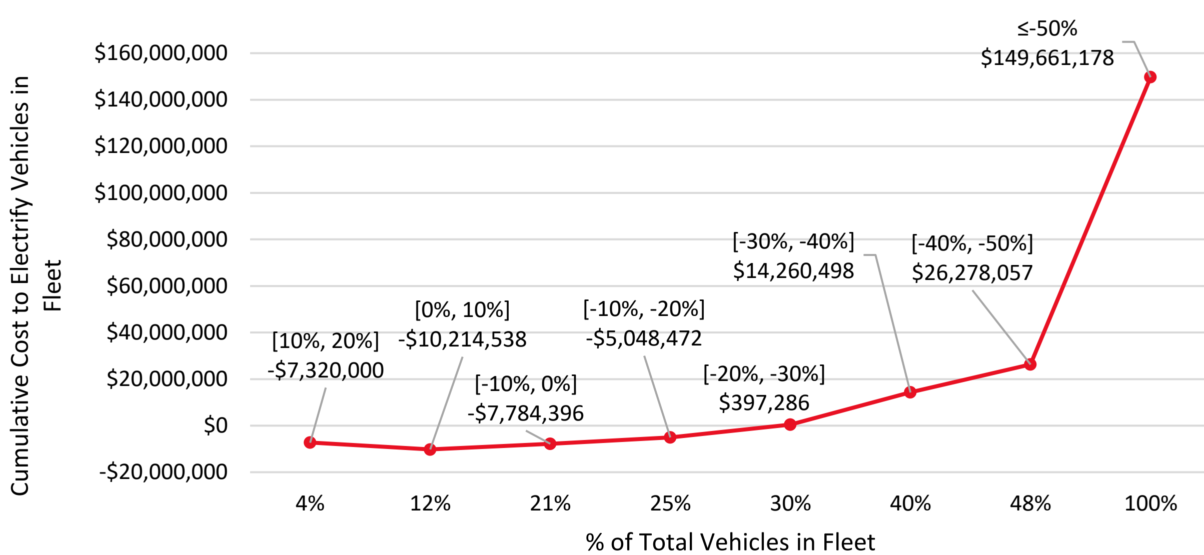
Unlike the analysis of state agency medium-duty vehicles, the TCO analysis results for medium-duty buses owned by transit agencies were much more favorable for cost-effective electrification. The number of medium-duty vehicles owned by transit agencies that met the five percent threshold for electrification was 512 or 16 percent of all medium-duty vehicles included in the transit agency analysis. Many of these vehicles offered substantial savings with over 130 vehicles having a TCO that was ten percent or greater savings compared to their internal combustion counterpart. Electrifying the 512 vehicles that met the threshold would result in a savings of $9.7 million on average, ranging from a savings of $27 million in the best case to an additional cost of $9.3 million in the worst case.

FIGURE 50: NUMBER OF MEDIUM- DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT



This chart highlights the number of medium-duty vehicles included in the analysis by their average percentage savings from electrification in an initial deployment of EVs. More than half of the vehicles analyzed had an EV with a TCO that was more than 50 percent higher than an equivalent internal combustion vehicle.

FIGURE 51: CUMULATIVE COST TO ELECTRIFY MEDIUM-DUTY VEHICLES IN AN INITIAL EV DEPLOYMENT

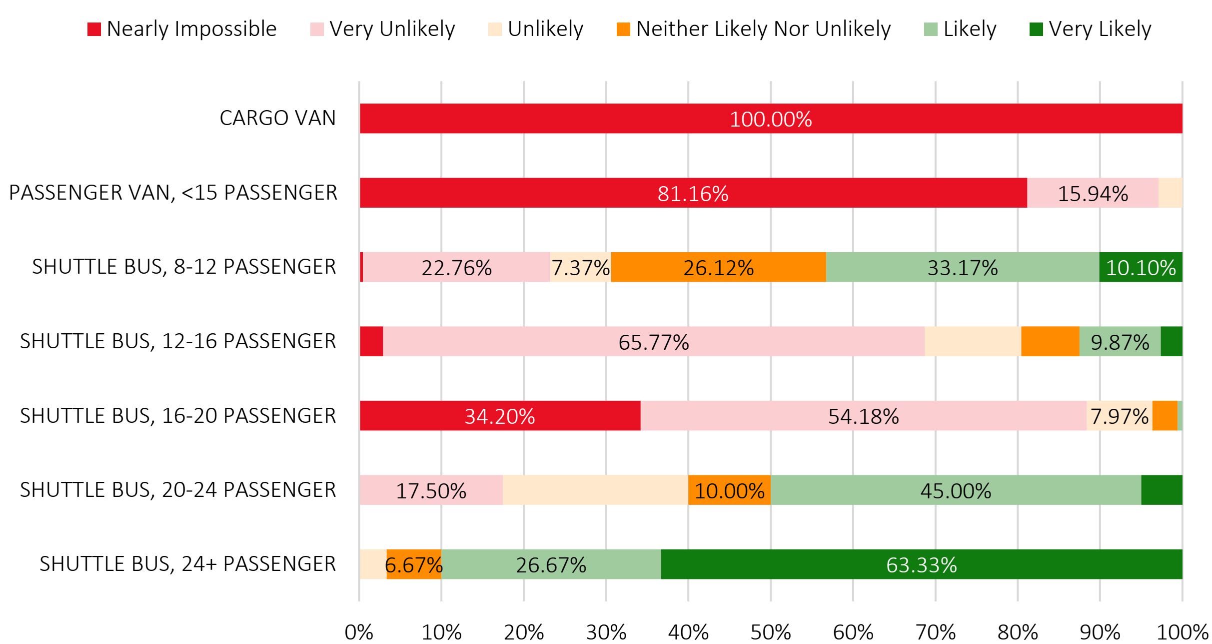


This figure shows the cumulative additional cost or savings to electrify the medium-duty vehicles included in the analysis in an initial deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $150 million on average to electrify all of the medium-duty vehicles included in the analysis, though it could electrify 40 percent of vehicles for less than one tenth of the cost and 30 percent of vehicles for less than $400,000.

Increasing the threshold to electrify vehicles from five to 20 percent results in the electrification of an additional 295 vehicles, bringing the total to 807 vehicles or 25 percent of the medium-duty fleet included in the analysis. Electrifying these 295 additional vehicles would result in an average incremental cost of $5 million. Further doubling the threshold for electrification to 40 percent results in the electrification of a cumulative total of 1,276 vehicles, about 40 percent of all vehicles analyzed. As show in Figure 51, the cumulative cost to electrify all vehicles for which an EV was within 40 percent of the TCO of an internal combustion equivalent is $14.3 million, which is $2.3 million more than the most recently approved funding for the Green Transportation Capital Grant program.

The potential cost to electrify all medium-duty vehicles included in the analysis is $150 million, ranging from a low of a $61.6 million to a high of $248.7 million in additional cost. Figure 50 and Figure 51 show the number of medium-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify medium-duty vehicles, respectively.

FIGURE 52: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY MEDIUM-DUTY VEHICLES



This figure shows the likelihood results in an initial EV deployment for transit agency medium-duty vehicles broken down by use case.

In comparison to the medium-duty trucks and vans included in the state agency analysis, medium-duty shuttle buses were substantially more cost effective to electrify. As mentioned in the *State Agency Analysis Results* section of this chapter, medium-duty shuttle buses were the only use case included in the analysis for which a first-party manufactured vehicle exists. The average price premium for these shuttle buses was 116 percent, less than half that of the average price premium across all medium-duty EVs in the state agency fleet. Although these vehicles were still more than twice as expensive as their internal combustion equivalents in most cases, these buses were able to recoup this difference through operational cost savings resulting from maintenance and fuel cost savings. It is important to note that the TCO results highlighted in Figure 52 are heavily influenced by the annual mileage of the vehicles being analyzed. The average annual mileage across the three use cases with the most favorable results for EVs, 8-12, 20-24, and 24+ Passenger Shuttle buses, was approximately 23,000 miles per year. This was roughly three times higher than the average annual mileage of shuttle buses included in the state agency fleet. For reference, no shuttle buses in the state agency fleet met the five percent threshold for electrification. A more in-depth analysis of the effect of annual mileage on vehicle electrification is covered in the *Annual Mileage* section of this chapter.

Although the results for shuttle buses are encouraging, the electrification potential of the other use cases analyzed is limited. In particular, medium-duty passenger vans produced by first party manufacturers like Chevrolet have no first party EV alternative and must rely on substantially more expensive after-market conversions for electrification. The lowest price EV alternative included in the analysis for the passenger van use case was nearly four times more expensive than its internal combustion equivalent. These vehicles also traveled far fewer miles than other use cases at just over 10,000 miles per year on average. Due to the high price premiums and low annual mileage for vans, more than 85 percent of vehicles analyzed had an EV alternative that was more than double the TCO of an internal combustion equivalent. Figure 52 shows the likelihood results for all 2,763 vehicles analyzed under the initial EV deployment scenario.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

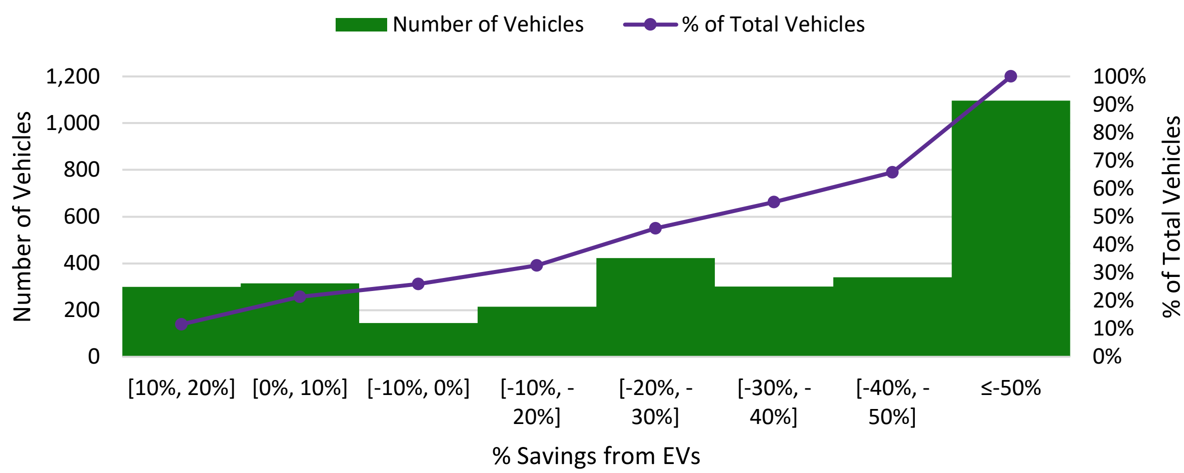
In a subsequent EV deployment, the number medium-duty vehicles owned by transit agencies that met the five percent threshold for electrification increased by 257 from 512 to 769, or 24 percent of all vehicles included in the analysis. In addition, the cost savings for many of these vehicles increased substantially with the number of EVs that had a TCO at least ten percent lower than their internal combustion counterparts nearly tripling from 137 to 372. This shift was all the result of an average 10 percent drop in TCO from reduced charging infrastructure costs. Electrifying the 769 vehicles that met the threshold would result in a savings of $18.4 million on average, ranging from a savings of $32.7 million in the best case to a savings of $4.0 million in the worst case.

Increasing the threshold to electrify vehicles from five to 20 percent results in the electrification of an additional 276 vehicles, or cumulatively 33 percent of the total vehicles analyzed. Electrifying these 1,045 vehicles would result in an average savings of $13.4 million As shown in Figure 54, the state could raise the electrification threshold to 40 percent, covering 55 percent of the medium-duty transit agency fleet, and incur a cumulative cost of $8,503,962.

The potential cost to electrify all medium-duty vehicles included in the analysis is $99 million, ranging from a low of a $54.6 million to a high of $143.5 million in additional cost. Figure 53 and Figure 54 show the number of medium-duty vehicles by the average percent savings from electrification and the cumulative average cost to electrify light-duty vehicles, respectively.

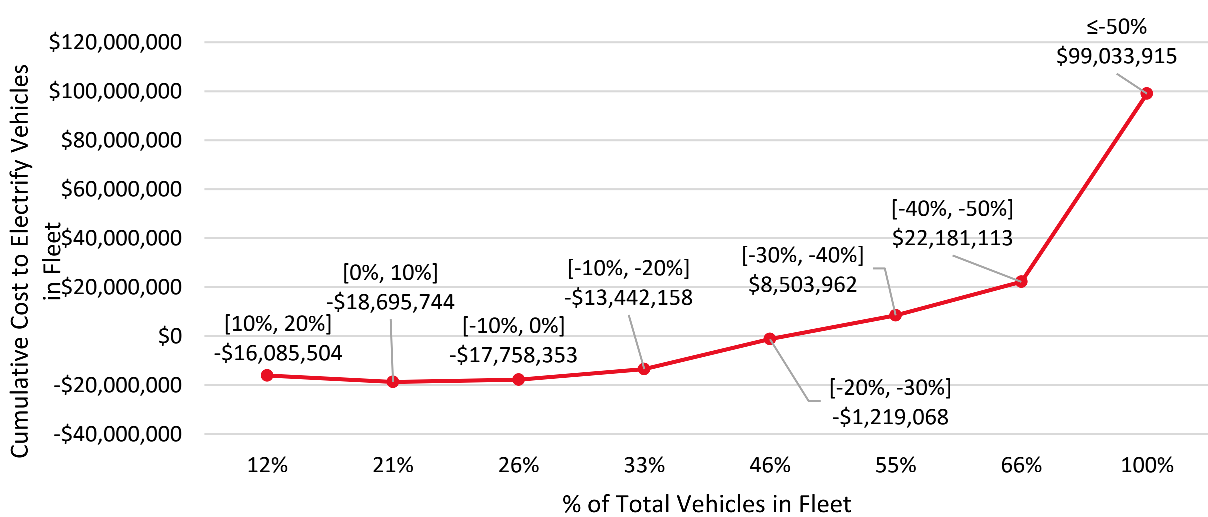
In a subsequent EV deployment, 25 percent of 8-12, 20-24, and 24+ passenger shuttle buses included in the analysis met the five percent threshold for electrification, including 95 percent of 24+ passenger shuttle buses. A significant increase was also seen for 12-16 passenger shuttle buses, the most common medium-duty vehicle owned by transit agencies in Washington. Of the 769 additional vehicles which met the threshold for electrification under the subsequent EV deployment scenario, 12-16 passenger shuttle buses accounted for 250. The number of these vehicles that were identified as being Neither Likely nor Unlikely to electrify, meaning they have a TCO between 5 and 20 percent higher than an internal combustion equivalent, reached 1,045 under the subsequent EV deployment scenario. Figure 55 shows the likelihood results for all 2,763 vehicles analyzed under the subsequent EV deployment scenario.

FIGURE 53: NUMBER OF MEDIUM- DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



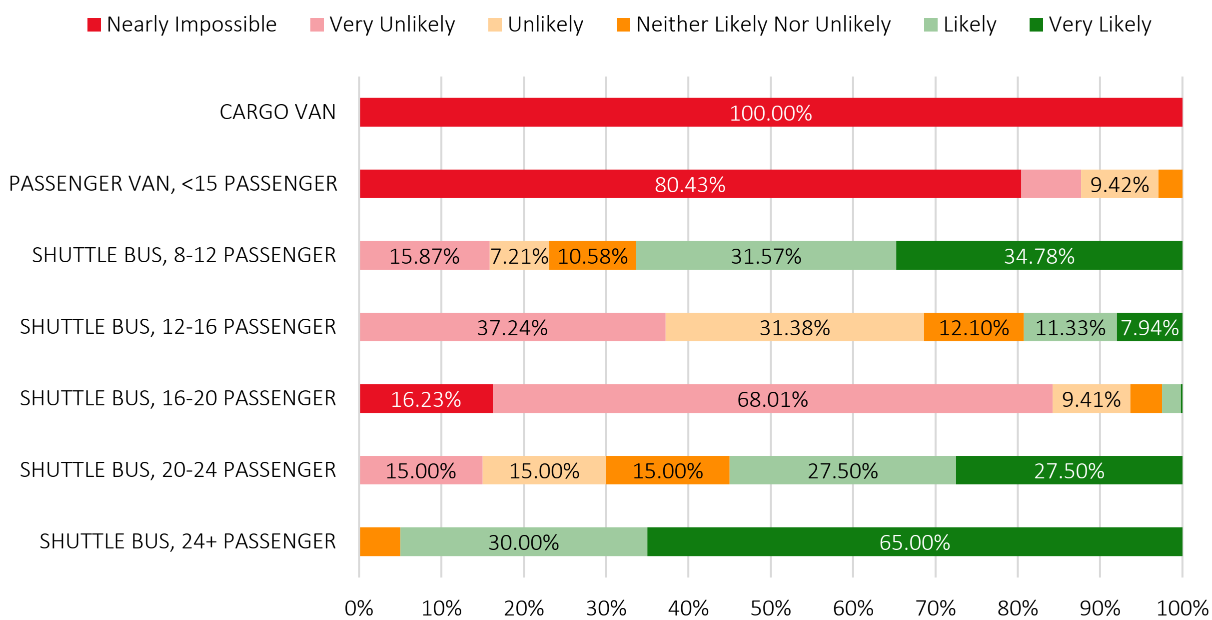
This chart highlights the number of medium-duty vehicles included in the analysis by their average percentage savings from electrification in a subsequent deployment of EVs. One-third of the vehicles analyzed had an EV with a TCO that was within 20 percent higher of an equivalent internal combustion vehicle.

FIGURE 54: CUMULATIVE COST TO ELECTRIFY MEDIUM-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the medium-duty vehicles included in the analysis in a subsequent deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $99 million on average to electrify all of the medium-duty vehicles included in the analysis, though it could electrify 55 percent of vehicles for a cumulative cost of $8.5 million and 46 percent of vehicles for a cumulative savings of over $1.2 million.

FIGURE 55: SUBSEQUENT EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY MEDIUM-DUTY VEHICLES



This figure shows the likelihood results in a subsequent EV deployment for transit agency medium-duty vehicles broken down by use case.

HEAVY-DUTY TRANSIT BUSES

Heavy-duty transit buses accounted for 2,901, or approximately one third, of the 9,376 vehicles included in the transit agency fleet. Transit buses represent the core of service operations for transit agencies in Washington and also account for the bulk of operational and vehicle purchase expenditures. The majority of these vehicles were either 40- or 60-foot transit buses, though several agencies also owned smaller 30- and 35-foot buses in addition to coach buses used for intercity travel. Table 16 breaks down the number of vehicles analyzed by use case.

TABLE 16: TRANSIT AGENCY HEAVY-DUTY BUSES ANALYZED

Use Case	Total Vehicles
COACH BUS	93
TRANSIT BUS, 30’	157
TRANSIT BUS, 35’	318
TRANSIT BUS, 40’	1,231
TRANSIT BUS, 60’	1,102
TOTAL	**2,901**

This table lists the breakdown of heavy-duty buses included in the transit agency analysis by use case

INITIAL EV DEPLOYMENT ANALYSIS RESULTS

The results of the TCO analysis indicate that transit buses were the most cost-effective vehicles to electrify across the entire public fleet in Washington state. In the initial EV deployment scenario which includes the full cost of charging infrastructure equipment and installation, more than 24 percent of buses, or 706, met the five percent threshold for electrification. More than 234 of the vehicles analyzed achieved a savings of greater than 10 percent compared to an internal combustion equivalent. Transit buses are typified by both high upfront and operational costs with buses typically costing in excess of $500,000 and traveling in excess of 30,000 miles per year. Given the high costs associated with these vehicles, even small percentage savings in the TCO can represent large sums of money. Electrifying the 706 vehicles that met the five percent threshold for electrification would result in a savings of $61.6 million on average, ranging from a savings of $141.3 million in the best case to an additional cost of $21.2 million in the worst case. It should be noted that all electric buses included in the analysis met the operational requirements outlined by Washington when soliciting bids for the statewide transit bus contract and that the savings referenced above is not the result of selecting a short range, low-cost buses that may not be able to meet the operational needs of transit agencies in Washington.

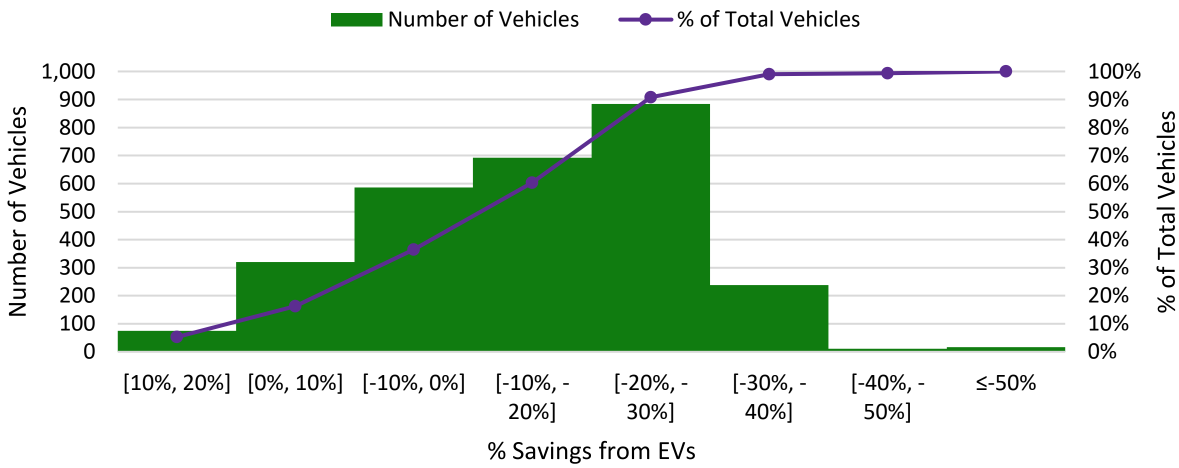
Increasing the threshold to electrify vehicles from five to 20 percent results in the electrification of an additional 1,045 vehicles, bringing the total number of electrified vehicles to 1,751 or more than 60 percent of the fleet. However, electrification of these vehicles would come at a cost of $155.1 million. This figure ranged from $43.6 million in the best case to $264.2 million in the worst case. The high annual mileage for these vehicles contributed to the large range in TCO results as changes in the cost to charge vehicles accumulated into large sums over a vehicle's lifetime. Just as small percentage reductions in vehicle TCO can result in significant savings, small percentage increases in TCO can also result in significant additional costs and expanding the electrification threshold for transit buses beyond five percent carries could result in much higher costs relative to other vehicles analyzed.

The potential cost to electrify all heavy-duty buses included in the analysis is $444.5 million, ranging from a low of a $134.5 million to a high of $750.1 million in additional cost. Figure 56 and Figure 57 show the number of heavy-duty buses by the average percent savings from electrification and the cumulative average cost to electrify heavy-duty buses, respectively.

As stated previously, transit buses were the most cost effective vehicles included in the analysis to electrify and had the highest proportion of vehicles that met the five percent threshold for electrification across all vehicle classes in all fleets included in the analysis. Over 24 percent of transit buses met the threshold for electrification in the present day, more than 50 percent higher than medium-duty transit agency vehicles, the next best segment of vehicles for electrification, and nearly five times the percentage of light-duty state agency vehicles that met the electrification threshold. As mentioned in *0*, the market for electric transit buses is the most well-developed of all heavy-duty EVs and that is reflected in the results of this analysis.

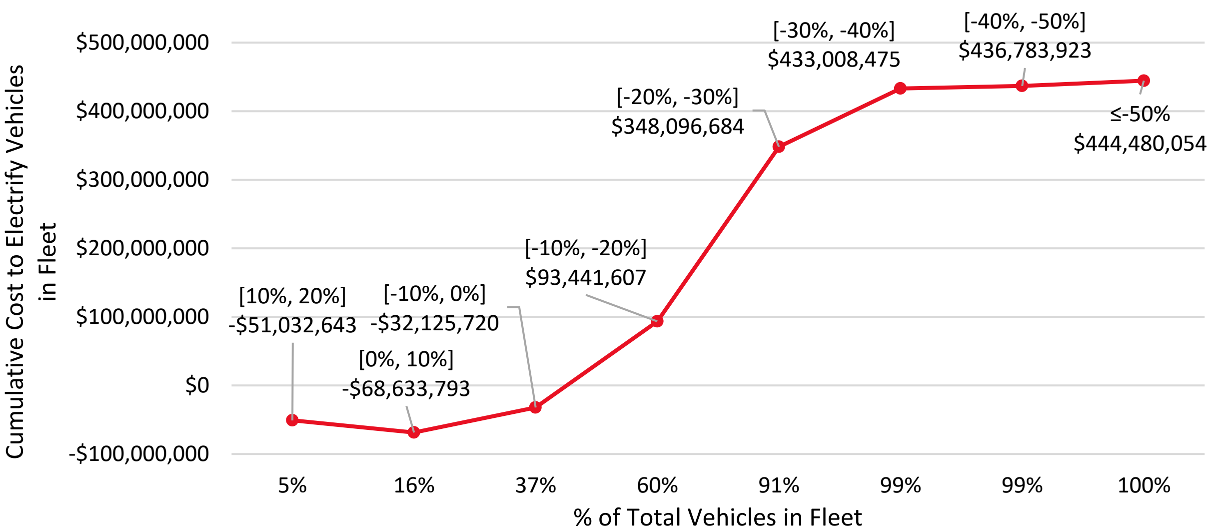
The average price premium for transit buses was less than 50 percent across all use cases, better than even the best case-scenarios for many other medium- and heavy-duty EVs. In some cases, the price of an electric bus was *lower* than an equivalent diesel hybrid bus. The most recent price update for a 35-foot Low Floor Allison Hybrid Diesel bus from Gillig available on the state transit bus contract is $719,875 after tax. The 35-foot battery electric option from BYD available on the state contract is only $672,545 after tax. The same was true for 30-foot transit buses; diesel hybrid models were more expensive than battery electrics.

FIGURE 56: NUMBER OF HEAVY-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN AN INITIAL EV DEPLOYMENT



This chart highlights the number of heavy-duty buses included in the analysis by their average percentage savings from electrification in an initial deployment of EVs. More than 60 percent of the vehicles analyzed had an EV with a TCO that was within 20 percent of an equivalent internal combustion vehicle.

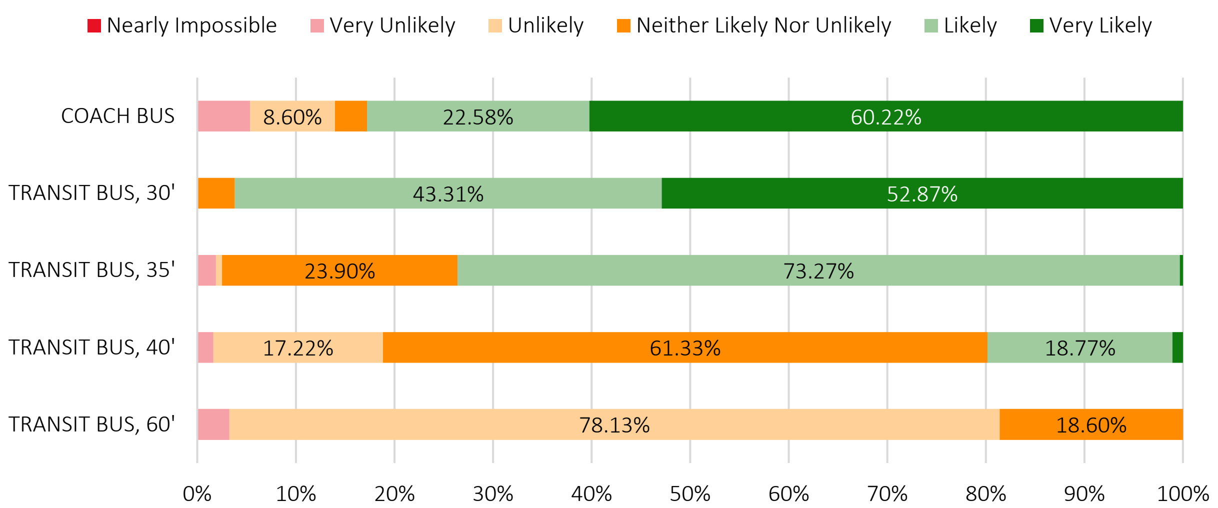
FIGURE 57: CUMULATIVE COST TO ELECTRIFY HEAVY-DUTY VEHICLES IN AN INITIAL EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the heavy-duty buses included in the analysis in an initial deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $444.5 million on average to electrify all of the heavy-duty vehicles included in the analysis, though it could electrify nearly 40 percent of vehicles at an average savings of more than $32.1 million.

Transit agencies across the state have already identified transit buses as a primary target for electrification. As mentioned in *Chapter 1*, several transit agencies in Washington are already in the process of expand electric bus operations with King County alone committing to the purchase of 120 buses. Even assuming that transit agencies have identified and are replacing transit buses that are cost-effective to electrify, only 211 battery electric buses were in operation or on order as of 2019 [13]. That leaves an additional 495 buses that can be electrified at a substantial cost savings. Figure 58 shows the likelihood results for all 2,901 vehicles analyzed under the initial EV deployment scenario.

FIGURE 58: INITIAL EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY HEAVY-DUTY VEHICLES



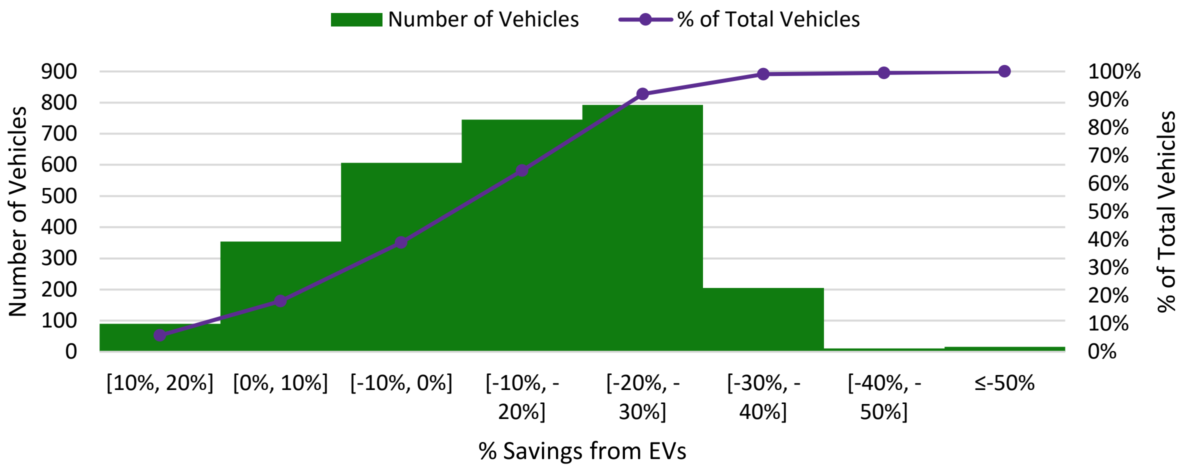
This figure shows the likelihood results in an initial EV deployment for transit agency heavy-duty vehicles broken down by use case.

SUBSEQUENT EV DEPLOYMENT ANALYSIS RESULTS

Under the subsequent EV deployment scenario, the number of buses that met the five percent threshold for electrification increased by nearly 10 percent, rising from 706 to 771. The relatively small increase in the number of EVs meeting the electrification threshold is owed to the cost of charging infrastructure installation relative to the overall TCO for transit buses. Excluding the cost of charging infrastructure installation resulted in an average savings of nearly $11,800 per vehicle which represented about one percent of the average TCO for electric buses. Nonetheless, the potential savings from electrification increased by several million dollars from an average of $61.6 million to $66.5 million. This figure ranged from a savings of $130 million in the best case to an additional cost of $3.2 million in the worst case.

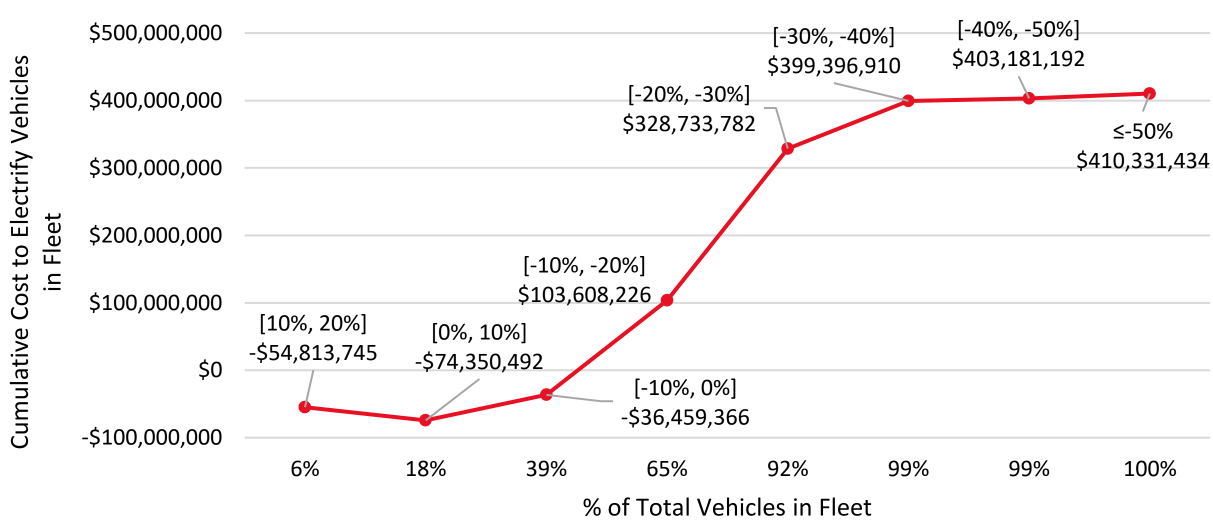
Raising the threshold for electrification beyond five percent resulted in substantial additional costs for transit agencies. Increasing the threshold for electrification to 20 percent resulted in 1,876 vehicles being electrified, but at a cost of $103.6 million on average. As was the case in an initial EV deployment, small percentage differences in total cost of ownership can result in either substantial savings or costs. The cost to electrify all heavy-duty transit vehicles was $410.6 million on average, ranging from $184.5 million in the best case to $643.8 in the worst case. Figure 59 and Figure 60 show the number of heavy-duty buses by the average percent savings from electrification and the cumulative average cost to electrify heavy-duty buses, respectively.

FIGURE 59: NUMBER OF HEAVY-DUTY EVS BY PERCENTAGE SAVINGS FROM AN INTERNAL COMBUSTION EQUIVALENT IN A SUBSEQUENT EV DEPLOYMENT



This chart highlights the number of heavy-duty buses included in the analysis by their average percentage savings from electrification in a subsequent deployment of EVs. About 65 percent of the vehicles analyzed had an EV with a TCO that was within 20 percent of an equivalent internal combustion vehicle.

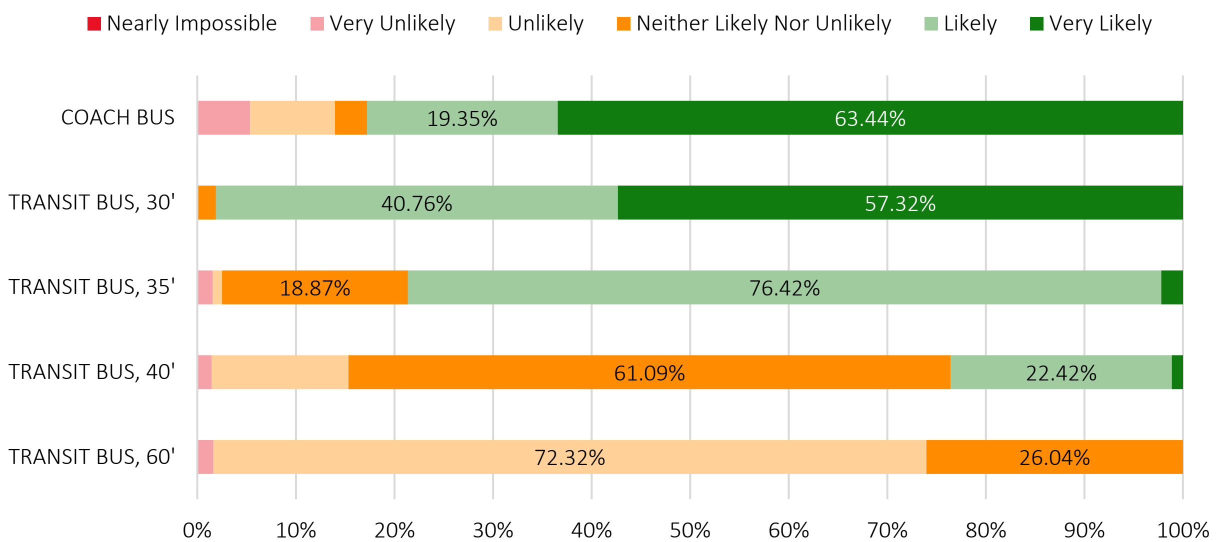
FIGURE 60: CUMULATIVE COST TO ELECTRIFY HEAVY-DUTY VEHICLES IN A SUBSEQUENT EV DEPLOYMENT



This figure shows the cumulative additional cost or savings to electrify the heavy-duty buses included in the analysis in a subsequent deployment of EVs. Negative figures represent savings from vehicle electrification and positive figures represent additional costs from vehicle electrification. Each dot represents a 10-percent range of savings from EVs as denoted in the labels with brackets. It would cost Washington approximately $410.3 million on average to electrify all of the heavy-duty vehicles included in the analysis, though it could electrify nearly 40 percent of vehicles at an average savings of more than $36.5 million.

Transit buses will need to achieve more substantial vehicle cost savings before most of these vehicles meet the five percent threshold for electrification. As mentioned previously, savings on charging infrastructure installation represented less than one percent of EV TCO on average. Even the most expensive charging infrastructure cost included in the analysis for transit buses, that of an on-route charging configuration, only represented five percent of average vehicle TCO. For buses that had no vehicles that met the electrification threshold like 60-foot transit buses, the upfront cost of EVs will need to fall before large numbers of these buses can be electrified cost effectively. Figure 61 shows the likelihood results for all 2,901 vehicles analyzed under the subsequent EV deployment scenario.

FIGURE 61: SUBSEQUENT EV DEPLOYMENT LIKELIHOOD RESULTS FOR TRANSIT AGENCY HEAVY-DUTY VEHICLES



This figure shows the likelihood results in a subsequent EV deployment for transit agency heavy-duty vehicles broken down by use case.

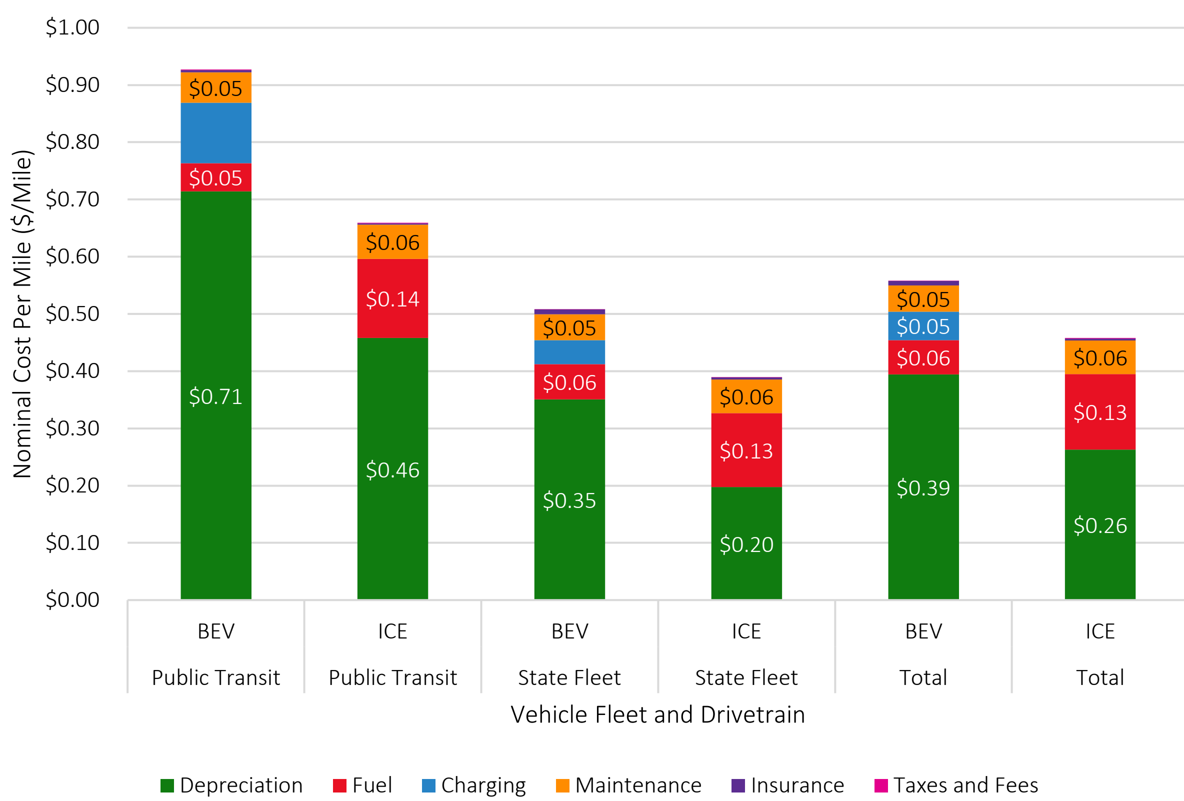
NOMINAL COST PER MILE BREAKDOWN

EVs and internal combustion vehicles offer distinct differences from upfront and operating cost perspectives in the present market, achieving cost savings in some areas while incurring incremental or new costs in others. This section explores the breakdown of operational costs for the battery electric (BEV), plug-in hybrid (PHEV), and internal combustion (ICE) vehicles included in the analysis. Costs are presented on a nominal per-mile basis and separated into six separate categories: charging, depreciation, fuel, insurance, maintenance, and taxes and fees. Charging costs consists of costs for the purchase, installation, and maintenance of charging infrastructure for EVs. Depreciation costs capture both the yearly depreciation for vehicles and differences in upfront vehicle prices. Fuel costs reflect the cost to refuel vehicles with either fossil fuel or electricity. Insurance costs reflect the cost for collision insurance for vehicles. Maintenance costs represent costs for repair and maintenance of vehicles. Taxes and fees cover any initial or recurring taxes for vehicles; in the case of public vehicles this was limited to just a one-time registration fee.

LIGHT-DUTY VEHICLES

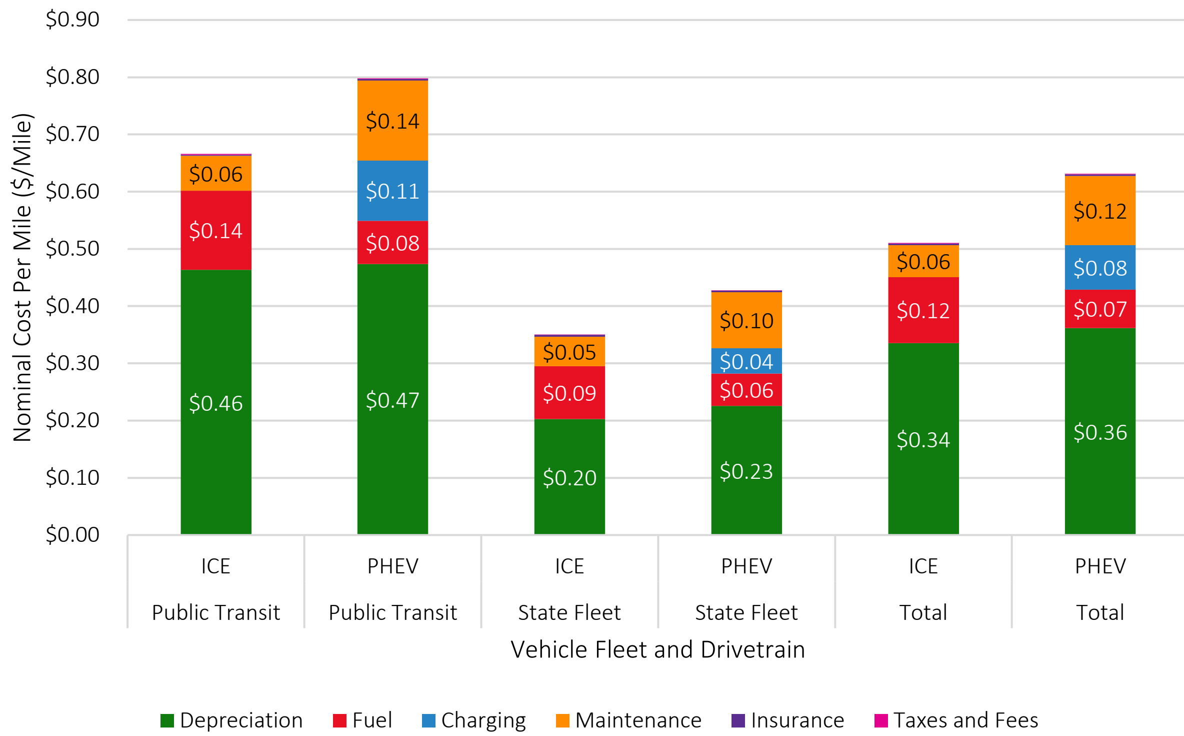
Light-duty EVs typically have higher upfront costs than comparable internal combustion vehicles resulting from more expensive vehicles and the need to purchase and install charging infrastructure. As mentioned above, these differences in upfront costs are captured in the per-mile cost categories of depreciation and charging. However, light-duty EVs are typically two to four times more efficient than internal combustion vehicles and rely on a fuel (electricity) that can be significantly cheaper than gasoline or diesel on an energy equivalent basis. EVs are also less expensive to maintain due to their electric motors having fewer moving parts and lubricants and the lack of a need for a separate transmission. Figure 62 provides a breakdown of the nominal per-mile operating cost categories for the light-duty battery electric and internal combustion vehicles and Figure 63 provides a similar breakdown for plug-in hybrid vehicles and internal combustion vehicles included in the analysis. Not all use cases had an available plug-in hybrid option and the average total cost per mile figures for ICE vehicles in Figure 62 and Figure 63 differ as a result.

FIGURE 62: AVEARGE NOMINAL COST PER MILE BY FLEET FOR LIGHT-DUTY BEV AND ICE VEHICLES



The chart above shows the average nominal cost per mile by cost category for light-duty vehicles included in the analysis.

FIGURE 63: AVEARGE NOMINAL COST PER MILE BY FLEET FOR LIGHT-DUTY PHEV AND ICE VEHICLES



The chart above shows the average nominal cost per mile by cost category for light-duty vehicles included in the analysis for which a plug-in hybrid option was available.

As Figure 62 and Figure 63 demonstrate, battery electric and plug-in hybrid EVs both offer large savings on fuel costs, while having higher depreciation costs and the additional cost of charging infrastructure. Battery electric vehicles offer additional savings on maintenance costs, achieving a 23 percent savings compared to internal combustion vehicles, based on vehicle maintenance records provided by DES. Plug-in hybrids, however, had higher maintenance costs than internal combustion vehicles based also on records from DES. Importantly, a recent study by Consumer Reports puts the average maintenance cost savings for the first 100,000 miles traveled for battery electric vehicles and plug-in hybrid vehicles at 55 percent and 40 percent, respectively [126]. While the study team sought to use real world data from Washington where possible and the DES maintenance data covered nearly 100 PHEVs, none of the vehicles had accumulated more than 50,000 total miles and it is possible that average maintenance costs for DES will come down over time to more closely align with existing studies of vehicle maintenance costs.

The more significant savings for EVs come from reduced fuel costs. On a per-mile basis, the cost to fuel battery and plug-in hybrid EVs was less than half that of equivalent ICE vehicles. Fuel costs accounted for more than 28 percent of the average total operating costs for light-duty ICE vehicles, but only 10 percent of operating costs for BEVs and PHEVs. Even when including the cost of charging infrastructure, the total cost per mile for both BEVs and PHEVs still accounted for a lower share of total operating cost. Combining the per-mile costs for fuel and charging infrastructure for BEVs resulted in an average per mile cost of just under $0.11 which was still lower than the average per-mile costs to fuel ICE vehicles of over $0.13. These figures represent the average cost per mile across all scenarios, but BEVs and PHEVs perform considerably better under optimal charging scenarios. When charging vehicles at the base commercial electricity rate, the average per-mile fuel costs for BEVs drops by more than 30 percent to just over $0.04, nearly 70 percent lower than the average per-mile fuel costs for ICE vehicles. PHEVs saw similar savings when being charged at the base commercial rate, dropping from an average of $0.067 to $0.048 per mile.

Areas where battery electric vehicles were more expensive on a per-mile basis were depreciation and insurance. Insurance costs for light-duty vehicles were determined based on a vehicle's depreciation value and hence more expensive for EVs, though the difference in insurance costs was insignificant at less four-tenths of a cent. Higher depreciation costs reflect the higher upfront costs for battery electric and plug-in hybrid EVs. For battery electric vehicles, increased upfront costs nearly outweighed the savings from lower fuel and maintenance costs. For plug-in hybrids, higher upfront vehicle costs were not as significant, though still higher on average than equivalent internal combustion vehicles by just under one cent per mile. On top of higher depreciation costs, the costs for the charging infrastructure necessary to charge these vehicles accounted for approximately 10 percent of the total operating costs per mile for both battery electric and plug-in hybrid vehicles.

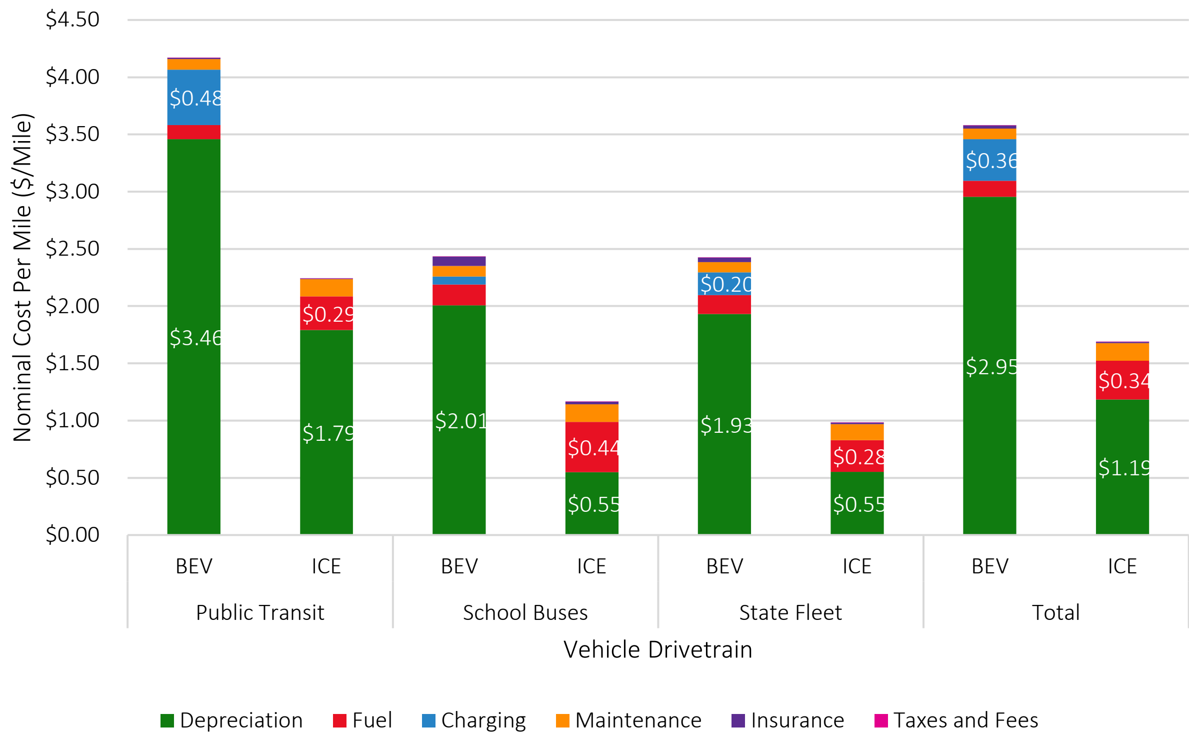
Overall, the increased depreciation and charging costs for BEVs and PHEVs outweighed operational cost savings. The incremental per-mile costs for depreciation and charging for BEVs and PHEVs were $0.18 and $0.10, respectively, well in excess of per-mile fuel and maintenance costs savings of $0.08 and $0.01.

MEDIUM-DUTY VEHICLES

As demonstrated in the total cost of ownership results, the medium-duty EV alternatives included in the analysis were substantially more expensive on average than their internal combustion counterparts. These findings are also borne out in the breakdown of the vehicle cost per mile results. As was the case for light-duty vehicles, EVs offered savings on fuel and maintenance costs while having higher depreciation and insurance costs along with the additional expense associated with purchase and installation of charging infrastructure. The average cost per mile for depreciation, the cost category that captures differences in upfront price, was nearly 150 percent higher for EVs on average across all vehicles. Even for medium-duty transit buses, the medium-duty segment that was most cost-effective to electrify, the average cost per mile for depreciation was more than 90 percent higher for EVs. This disparity, along with the additional cost for charging infrastructure, more than outweighed savings from lower fuel and maintenance costs for most medium-duty vehicles. Figure 64 highlights the high price premium for medium-duty electric vehicles compared to their internal combustion counterparts.

Medium-duty EVs saw even greater fuel cost savings than light-duty EVs, achieving a savings of nearly 60 percent compare to their ICE counterparts. Estimated maintenance cost savings were also higher for medium-duty EVs at more than 39 percent. However, these cost categories represented smaller shares of the total operating costs compared to light-duty vehicles, representing 20 and nine percent of the total operating costs for ICE vehicles, respectively. Any savings for EVs in these cost categories were diluted as a result. On average, the per-mile depreciation costs for medium-duty BEVs were higher than the *total* per-mile costs for medium-duty ICE vehicles and until the upfront prices of medium-duty battery electric and internal combustion vehicles are more closely aligned, most medium-duty vehicles will not be cost-effective to electrify.

FIGURE 64: AVERAGE NOMINAL COST PER MILE BY DRIVETRAIN AND FLEET FOR MEDIUM-DUTY VEHICLES

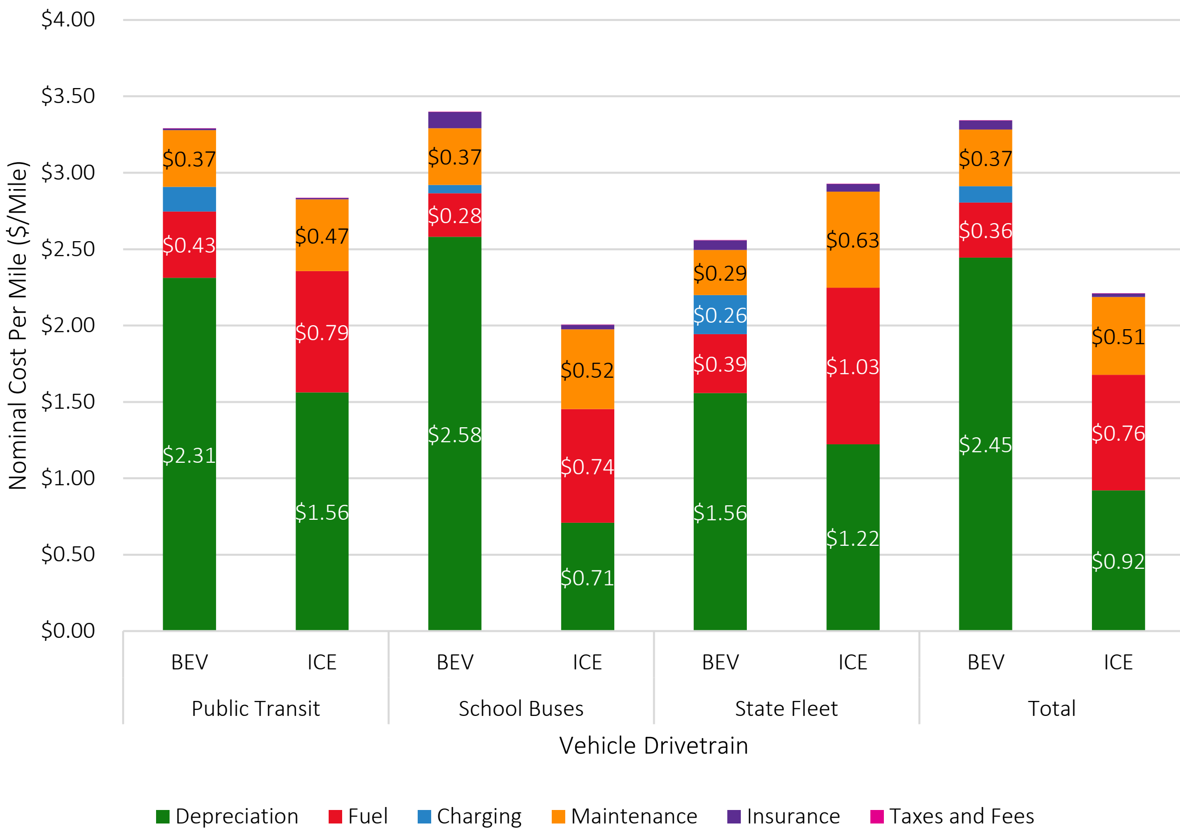


The chart above shows the average cost per mile by category for all medium-duty vehicles included in the state agency analysis.

HEAVY-DUTY VEHICLES

The heavy-duty vehicles included in the analysis, outside of heavy-duty school buses, were among the most cost competitive vehicles to electrify across the entire public fleet in Washington. These vehicles offered substantial fuel cost and maintenance cost savings compared to their internal combustion counterparts while often having price premiums comparable to, and in some cases more favorable than light-duty EVs. Although the total average cost per mile figures for heavy-duty EVs are weighed down by heavy-duty school buses, the data for heavy-duty vehicles from both the state agency and transit agency fleet demonstrate the electrification potential of these vehicles. Figure 65 shows the cost per mile breakdown for heavy-duty vehicles across the state agency, school bus, and transit agency fleets as well as the total average cost per mile results across all heavy-duty vehicles included in the analysis.

FIGURE 65: AVERAGE NOMINAL COST PER MILE BY DRIVETRAIN AND FLEET FOR HEAVY-DUTY VEHICLES



The chart above shows the average cost per mile by category for all heavy-duty vehicles included in the state agency analysis.

The average difference in per-mile depreciation costs for heavy-duty BEVs and ICE vehicles in the state fleet and public transit fleet were the lowest across all vehicles included in the analysis at only 27 and 48 percent, respectively. For comparison, the average difference in depreciation costs for light-duty vehicles in the state fleet and public transit fleet were 56 and 78 percent, respectively. These figures reflect not only the relatively low price premiums for heavy-duty EVs, but also the high mileage for heavy-duty vehicles in the state agency and transit agency fleets. Even though heavy-duty electric transit buses often cost several hundred thousand dollars more than their internal combustion counterparts, this disparity was diluted over the total mileage traveled by a vehicle over its lifetime which could exceed one-half million miles for many transit buses. This relatively low depreciation cost coupled with fuel and maintenance cost savings resulted in heavy-duty vehicles in the state agency and public transit agency fleet having the highest proportion of vehicles that met the five percent electrification threshold.

Electric school buses, however, showed extremely high depreciation costs on a per-mile basis compared to their internal combustion equivalents. Electric school buses averaged more than $1.80 in additional depreciation costs per mile over the lifetime of a bus, more than 260 percent higher than internal combustion buses. Even though these buses offered some of the highest fuel cost savings compared to their internal combustion counterparts at more than 61 percent, the overwhelming disparity in upfront cost resulted in almost no school buses meeting the threshold for electrification.

One additional area of note for heavy-duty EVs is the relatively small cost of charging infrastructure compared to the total cost of ownership for these vehicles. Although heavy-duty EVs had the highest average charging infrastructure costs at more than $30,000 (more than $50,000 if excluding school buses), these costs only represented three percent of the total average EV per-mile operating costs. In comparison, charging infrastructure costs accounted for nine and ten percent of total average per-mile operating costs for light- and medium-duty EVs, respectively. As a result, variations in charging configurations had a relatively small effect on the electrification potential of these vehicles as demonstrated by the slight increase in the number of heavy-duty EVs that met the electrification potential in subsequent EV deployment scenarios.

VEHICLE CHARACTERISTICS

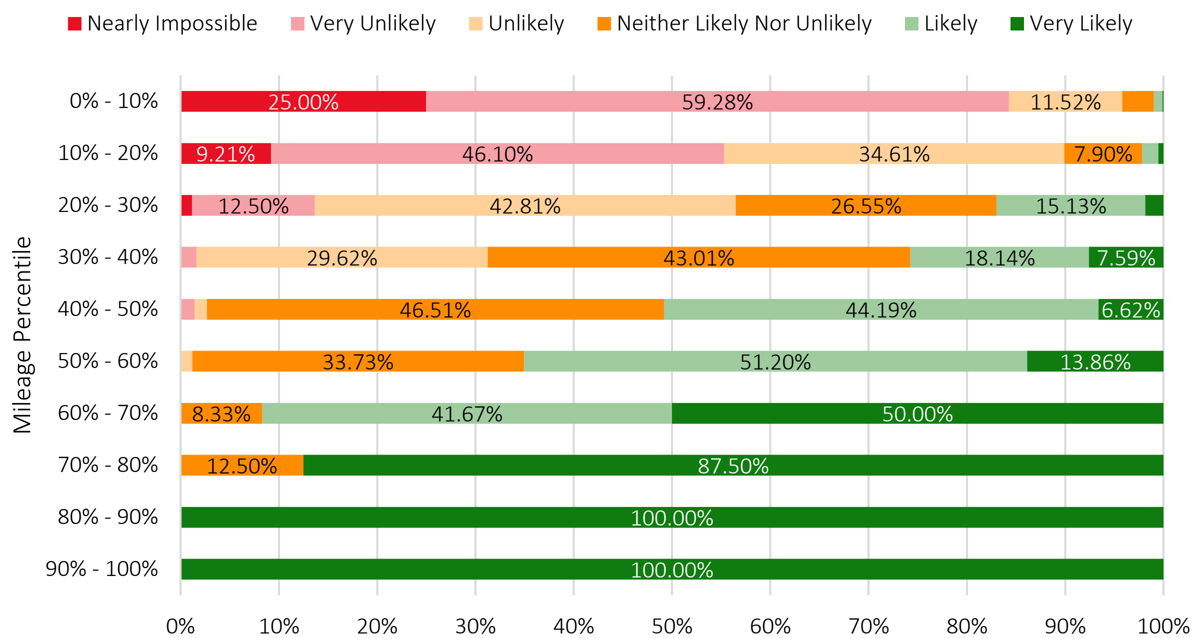
As covered at the start of the chapter, the study team completed an individualized total cost of ownership analysis covering the unique set of characteristics for each of 28,913 vehicles analyzed. These characteristics include individualized data for annual vehicle mileage, useful life, and electricity, gasoline or diesel price. Additionally, the study team included a range of potential EV alternatives and charging configurations for each vehicle. This section explores the effect of each of these vehicle characteristics on the electrification potential of public vehicles in Washington state.

ANNUAL MILEAGE

The primary financial advantage offered by EVs is lower operating costs from reduced fuel and maintenance costs. The primary financial disadvantage for an EV is typically higher upfront costs for vehicles and charging infrastructure. The higher the annual mileage for an EV, the more opportunity it has to accumulate the cost savings from lower fuel and maintenance costs and offset high upfront costs. As such, the most important aspect outside of EV price for determining the electrification potential of a vehicle was annual mileage.

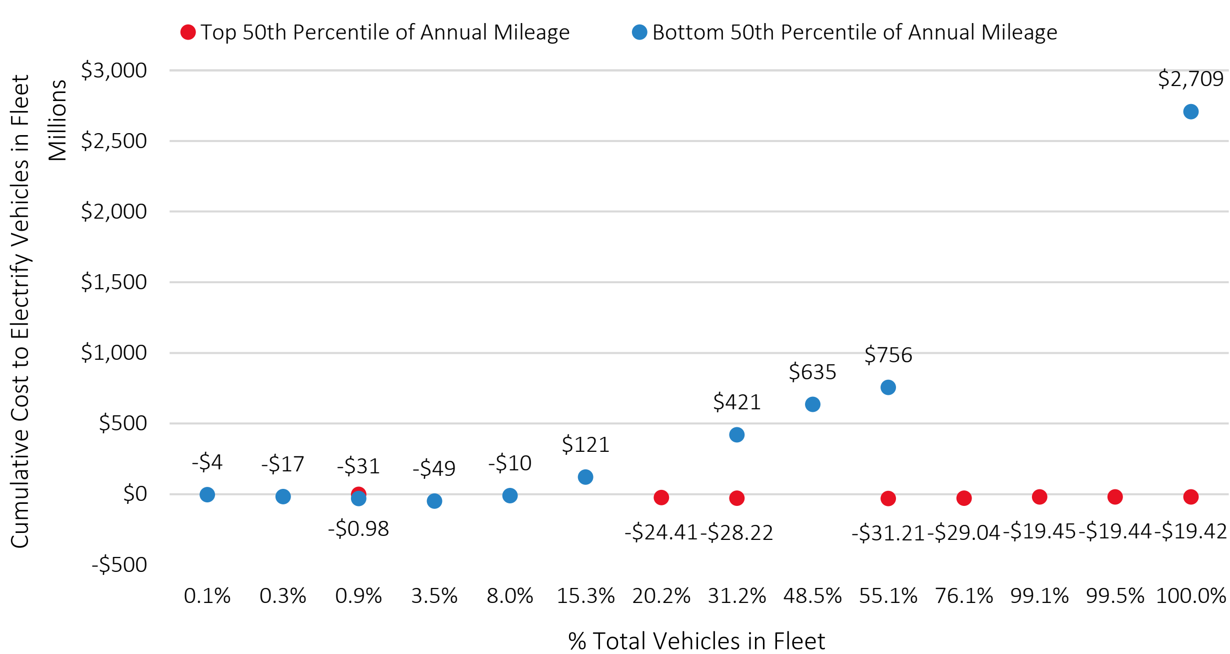
The difference in electrification potential between low and high mileage vehicles was stark. Vehicles in the top 50 percent of annual mileage across the entire public fleet, meaning they traveled more than 52,000 miles per year, were more than 10 times more likely to meet the threshold for electrification than vehicles in the bottom 50 percent. Even small shifts in annual mileage resulted in large changes in the number of vehicles that met the threshold for electrification. Moving from the 10th to the 20th mileage percentile, representing an increase from 10,460 to 20,900 annual miles, nearly tripled the number of vehicles that met the threshold for electrification from 133 to 358. Moving to the 30th percentile for annual mileage more than doubled the number of vehicles that met the electrification threshold again to 764. Importantly, vehicles in the bottom 30th percentile in terms of annual mileage account for more than 90 percent of the entire fleet, largely due to the low annual mileages for school buses. Figure 66 shows the likelihood results for all vehicles broken down by mileage percentile.

FIGURE 66: LIKELIHOOD RESULTS FOR ALL VEHICLES BY ANNUAL MILEAGE



This figure shows the likelihood results for all 28,913 vehicles included in the analysis by their annual mileage percentile where 0-10% are vehicles that traveled 10,460 or less miles per year and 90%-100% are vehicles that traveled 94,000 or more miles per year.

FIGURE 67: CUMULATIVE COST TO ELECTRIFY VEHICLES BY ANNUAL MILEAGE



The average savings from electrification also increases dramatically with more annual miles traveled. The average per-vehicle savings from electrifying vehicles in the 10th percentile of annual mileage was just under $1,600. The average per-vehicle savings from electrifying vehicles in the 90th percentile of annual mileage was more than $620,000. On average, per-vehicle savings increased by 134 percent for each of the percentile bands in Figure 66. Figure 67 show the cumulative cost to electrify all vehicles in the bottom and top 50th percentile of annual mileage.

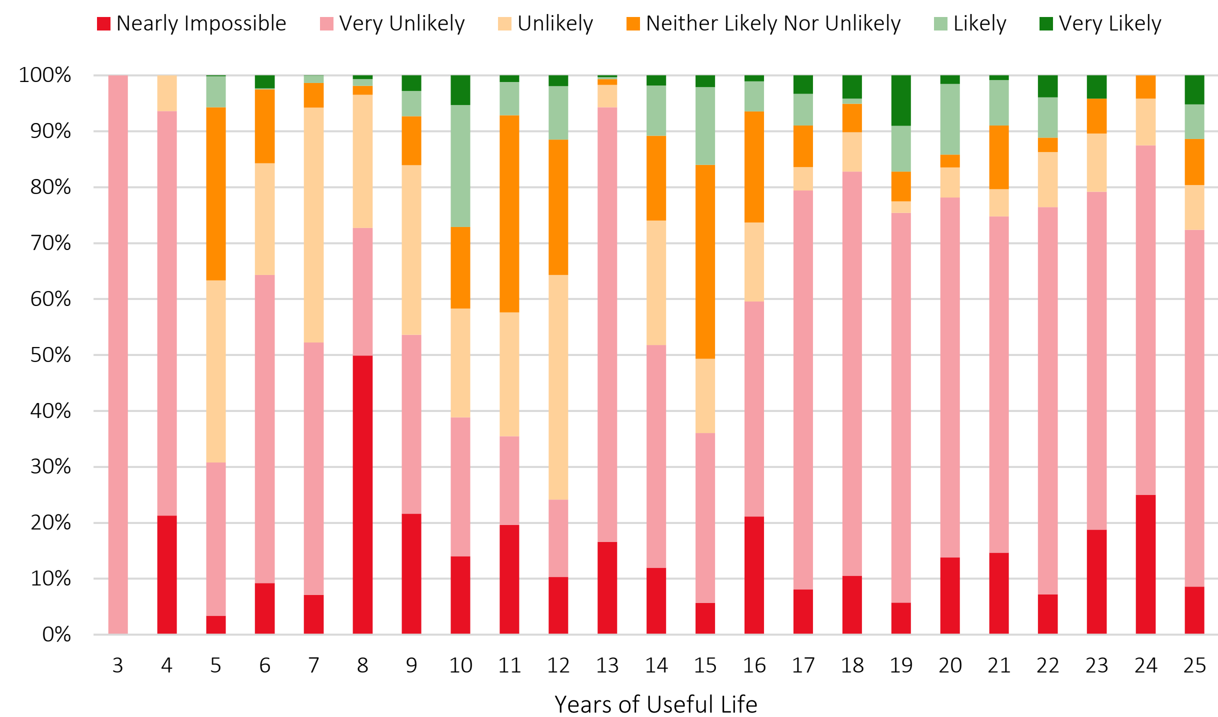
USEFUL LIFE

For this analysis, vehicle useful life determined the number of years of operation for each vehicle. As detailed in *Chapter 3*, all vehicles that were below their planned useful life were assumed to only operate for their planned useful life and all vehicles operating beyond their planned useful life were assumed to operate for the period of time equivalent to the vehicle's current age, capped at a maximum of 25 years. As of the date the study team compiled the fleet inventory, 38 percent of public vehicles in Washington had exceeded their planned useful life, with many vehicles exceeding their planned useful life by more than 50 percent.

The results of the TCO analysis across all vehicles indicates that holding onto a vehicle for a longer period does not necessarily improve their electrification potential since the annual mileage for each vehicle varied widely. The primary determinant of savings for EVs is the total number of miles they travel and a vehicle's useful life was only relevant if the vehicle also drove a sufficient number of miles per year; in short, if a vehicle was not driven often, it did not matter how many years it was used. Additionally, older models in the public fleet tended to have lower annual mileages (as would be expected) with the average mileage decreasing by approximately 1,200 miles for each additional year of useful life. As a result, keeping vehicles longer did not have a noticeable effect on electrification potential for public vehicles in Washington. When compared across similar annual mileages, however, the longer the useful life, the more likely a vehicle was to meet the five percent threshold for electrification. For vehicles traveling more than 31,000 miles per year (the 30th percentile for annual mileage), each additional year of useful life corresponded with an increase in average savings from electrification of more than 2 percent.[4] Figure 68 shows the likelihood results by years of useful life across all light-, medium-, and heavy-duty vehicles included in the analysis.

[4] Excluding vehicles that traveled less than 31,000 miles per year compared to the average savings from an EV yielded a regression equation of $y = 0.0234x-0.3779$ with a correlation of 0.67, where x is years of ownership and y is the percent savings from an EV.

FIGURE 68: LIKELIHOOD RESULTS BY YEARS OF USEFUL LIFE FOR ALL VEHICLES



This figure shows the likelihood results for all vehicles by years of useful life. Vehicles included in the analysis had a useful life of between three and 25 years.

ELECTRICITY, GASOLINE AND DIESEL PRICES

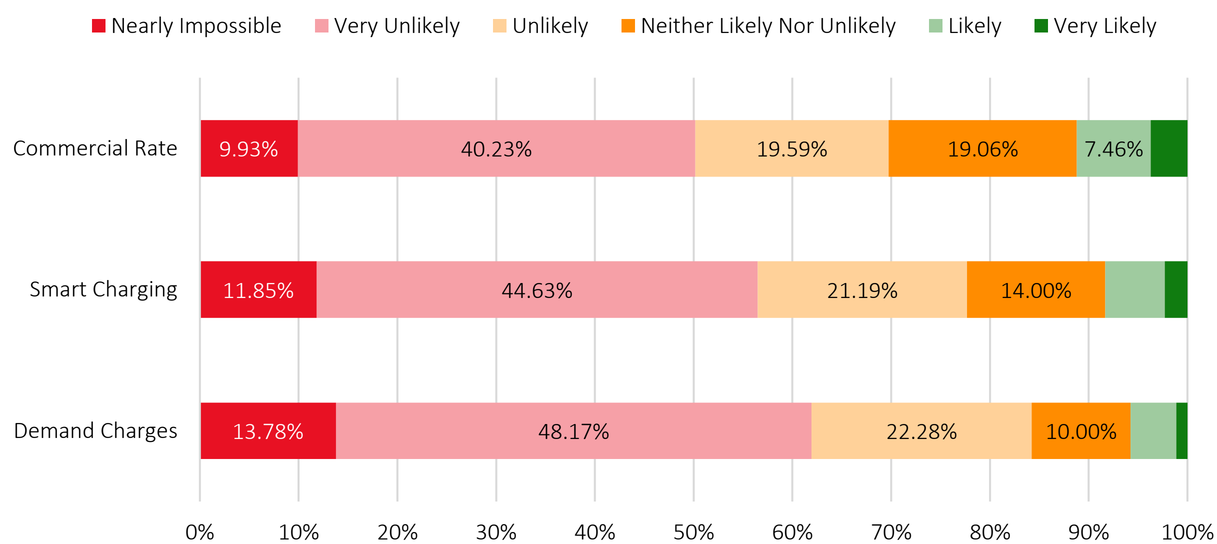
Along with annual mileage, the price of fuel, both for electricity and fossil fuels, plays an important role in the electrification potential of a given vehicle. Fuel prices play a large role in determining how much savings EVs, a far more energy efficient technology compared to conventional vehicles, accrue for each mile. Explored in the sections below are the effect of variations in electricity, gasoline, and diesel price on the electrification potential for public vehicles in Washington.

ELECTRICITY PRICE

The overall TCO results indicate that average electricity price across all scenarios for a given vehicle had an minor role in determining a vehicle's electrification potential. However, this is primarily due to the large prevalence of a single utility rate – that for Puget Sound Energy, the largest electric utility in Washington by customer base. Puget Sound Energy was assumed to be the likely electricity provider for all vehicles located in the counties of Island, Jefferson, King, Kitsap, Kittitas, Lewis, Pierce, Skagit, Snohomish, Thurston, and Whatcom. Collectively, the vehicles in these counties accounted for nearly 64 percent of the total fleet included in the analysis. While certain electric utilities in Washington such as PUD 1 of Chelan County and PUD 1 of Douglas County offer some of the lowest electricity prices in the nation due to an abundance of clean, hydroelectric power, the number of vehicles served by these utilities accounted for less than two percent of all vehicles analyzed.

The study team included a range of electricity prices for each utility included in the analysis including the base commercial rate, base residential rate, the commercial rate including estimated demand charges, and the commercial rate including smart charging. The rates including demand charges and smart charging were modeled as modifiers to the base commercial rate with demand charges being modeled as twice the commercial rate and smart charging modeled as 1.5 times the commercial rate. Also modeled was the residential electricity rate, but this rate was limited to the small share of light-duty vehicles which could charge at a private residence and is not discussed here. Figure 69 shows the likelihood results for all 28,913 vehicles included in the analysis when charging at the commercial, smart charging, and demand charging rates.

FIGURE 69: LIKELIHOOD RESULTS FOR ALL VEHICLES UNDER THREE DIFFERENT ELECTRICITY RATE SCENARIOS



This figure shows the likelihood results for all vehicles when charging at the base commercial rate, the commercial rate that includes the cost of smart charging, and the commercial rate when including demand charges. Also modeled was the residential electricity rate, but this was limited to only light-duty vehicles which could charge at a private residence which represent a small share of the overall fleet and is not shown here.

Moving from the commercial rate to the smart charging rate, representing an increase in the electricity rate of 50 percent for each vehicle to account for the smart charging technology costs (see *Chapter 3*), reduced the number of vehicles that met the threshold for electrification by 840, or approximately 34 percent, from 2,455 to 1,615. Under the Demand Charges scenario, the number of vehicles that met the threshold for electrification was more than 50 percent lower than under the Commercial Rate scenario, dropping from 2,455 to 1,090. The savings from electrification under the Commercial Electrification scenario were $174 million on average. This figure dropped to $113.5 million and $77.6 million under the Smart Charging and Demand Charges scenarios, respectively.

Demand charges are a potential issue fleet managers must address when planning for electrification of several vehicles in the current market. Even moderately sized charging Level 2 charging installations can incur demand charges when multiple vehicles are all charging simultaneously. As demonstrated in the results above, unmanaged charging of EVs that results in demand charges can significantly limit the electrification potential of vehicles and the potential savings they can generate. Demand charges can be mitigated by smart charging software which can limit the total electricity draw across multiple charging stations and was shown to reduce the costs associate with demand charges by 50 percent in a study by the National Renewable Energy Laboratory [7].

GASOLINE AND DIESEL PRICE

The effect of variations in gasoline or diesel price on the electrification potential for a given vehicle were inconclusive. Unlike electricity rates, the study team did not vary the gasoline or diesel price for each vehicle. As a result, isolating the effect of variations in fuel price via an apples-to-apples comparison was not possible as no two vehicles had exactly the same characteristics except for fuel prices. Any effect of fuel price variations on TCO could not be isolated from variations in other factors like annual mileage, useful life, or EV selection. Further complicating the analysis of fuel prices in Washington was the relatively low variation in prices across vehicles. There was only a 21 percent difference between the maximum and minimum prices for diesel of $3.09 and $2.55. The range for gasoline was even smaller with a maximum and minimum price of $2.79 and $2.42. In comparison, the study team varied the cost of electricity for EVs by 50 and 100 percent.

However, variations in fuel price do have a noticeable effect on the TCO of internal combustion vehicles when all other factors are held equal. To demonstrate this, the study team ran a sample analysis which varied the fuel price for a Ford Escape and Goshen shuttle bus. For the Escape, which averaged 10,417 miles per year with a useful life of 12 years, every 10 percent increase in the price of gasoline caused a two percent increase in TCO. For the Goshen, a large vehicle traveling 31,4440 miles per year with a useful life of 10 years that was considerably less fuel efficient, the effect of variations in fuel price was more dramatic with a 10 percent increase in fuel price leading to a four percent increase in TCO. As demonstrated in the analysis results covered previously, even small changes in vehicle TCO can result in large swings in the number of vehicles that meet the threshold for electrification and the savings that electrification can generate.

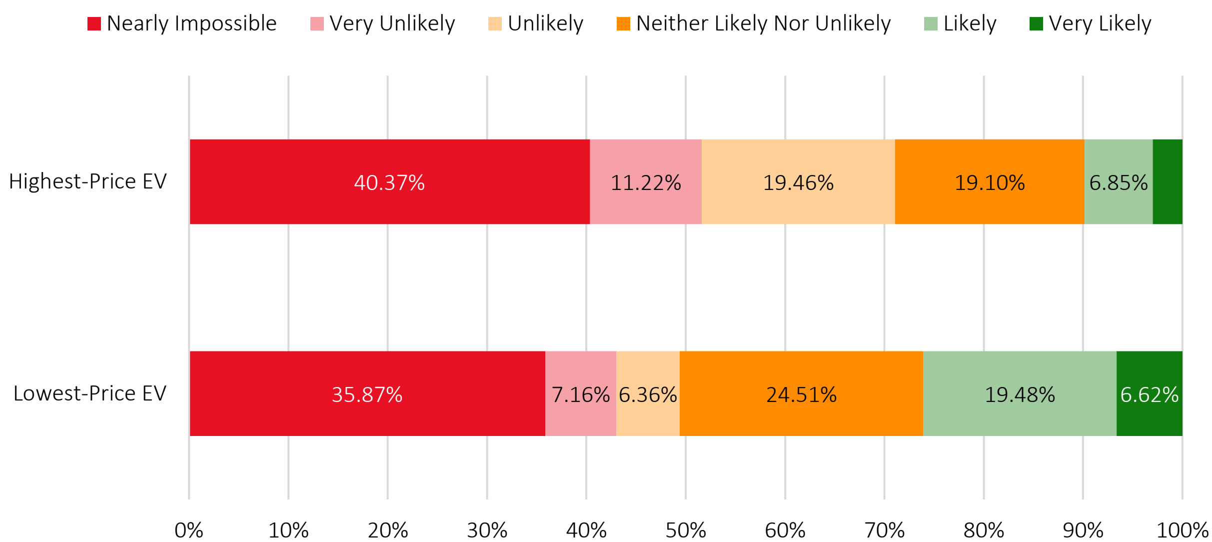
Although the study team did not vary the gas or diesel price for vehicles, a policy analysis was performed to model the effect of introducing a price on carbon in Washington. A carbon price functions in the same manner as an increase in the price of fossil fuels and the results of that analysis are explored in *Chapter 8*.

VEHICLE SELECTION

A primary barrier to electrification is the disparity in upfront costs of EVs and their internal combustion counterparts. When selecting EV alternatives for each vehicle, the study team included up to three EV alternatives which were intended to cover a range of both operational capacity and vehicle price. As referenced in the subsequent EV deployment scenarios examined in the *State Agency Analysis Results*, *School Bus Analysis Results*, and *Transit Agency Analysis Results* sections of this chapter, even small decreases in EV TCO can result in substantial swings in the number of vehicles that meet the five percent threshold for electrification. This was particularly true for light-duty vehicles, which saw an increasing of over 1,000 vehicles that met the five percent threshold for electrification after achieving an average savings of just $3,500 in a subsequent deployment scenario. In some cases, this $3,500 savings paled compared to the difference between upfront costs for the EV alternatives considered for a given vehicle. As was highlighted in the *State Agency Analysis Results* section of this chapter, the difference between the lowest and highest priced EV alternative for light-duty pickup trucks was nearly $30,000. In those cases, choosing the lower-priced option was critical for a vehicle to meet the five percent electrification threshold. To demonstrate the effect of only choosing the lowest cost EV alternative for each vehicle,

Figure 70 shows the difference in the number of vehicles that met five percent electrification threshold when considering the lowest and highest-priced EV alternative. To create an apples-to-apples comparison, only a subsequent EV deployment was considered where vehicles would be charged only at the base commercial rate.

FIGURE 70: LIKELIHOOD RESULTS FOR ALL VEHICLES WHEN SELECTING THE LOWEST AND HIGHEST-PRICE EV ALTERNATIVE



This figure shows the likelihood results for all vehicles when choosing the highest- and lowest-price EV alternative.

Choosing the lowest price EV alternative had a notable effect on the electrification potential of vehicles. When all other factors for a given vehicle were held equal, including electricity price and charging configuration, the number of vehicles across the entire fleet that met the threshold for electrification increased by more than 160 percent from 2,846 to 7,547, representing an increase of 16 percent of the total fleet. Not only does this represent a near tripling of the number of vehicles that would meet the five percent threshold for electrification, electrifying these vehicles would result in substantial additional savings for the state. When selecting the highest-price EV alternative for each vehicle, the average savings from electrifying all 2,846 vehicles that met the electrification threshold was $102.5 million. When selecting the lowest-price EV alternative for each vehicle, the state could electrify an additional 4,701 vehicles at a savings of $61.8 million, bringing the total cumulative savings to more than $164.3 million. Of all procurement aspects considered in this analysis, vehicle selection had the largest effect on the electrification potential of public vehicles in Washington state. Without changing any state policy or allocation of additional funds, fleet managers could generate substantial additional savings and electrify more vehicles by only targeting lower priced EVs when replacing internal combustion vehicles. It should be noted, however, that some lower-priced vehicles may not meet the operational needs of a given vehicle and the lowest-priced EV alternative may not be a viable option in all cases.

BATTERY ELECTRIC AND PLUG IN HYBRID VEHICLES

An additional consideration for light-duty EV selection is the choice between full battery electric and plug-in hybrid vehicles. As detailed in the *Nominal Cost Per Mile Breakdown* section of this chapter, battery electrics offer large savings on fuel and vehicle maintenance costs compared to comparable internal combustion vehicles while plug-in hybrids offer slightly smaller fuel cost savings and require additional maintenance compared to comparable internal combustion vehicles. While PHEVs typically cost less than comparable BEVs, the savings in upfront costs between these two vehicles was not always significant, ranging between an average of four percent for SUVs to 18 percent for sedans. A primary reason for choosing a PHEV is their ability to run solely on gasoline, alleviating any concern over battery ranges and recharge times for BEVs. Limited range of BEVs was a commonly cited barrier to electrification among fleet managers in Washington. Many vehicles in the fleet are required to make occasional long daily trips in excess of 200 miles to areas where there is limited or no charging infrastructure.

The savings from lower upfront costs and additional maintenance costs for PHEVs resulted in these EVs demonstrating similar electrification potential to BEVs in the present-day TCO analysis. PHEVs met the five percent electrification threshold for just over 21 percent of vehicles while comparable BEVs met the electrification threshold for those same vehicles in nearly 20 percent of cases. However, it is important to note that the fuel cost savings from PHEVs are highly dependent on how often vehicles are charged. The study team assumed that PHEVs would be driven using electricity to the greatest extent possible and that they would be charged daily. Under a worst-case scenario, vehicle operators would pay the initial premium for a plug-in hybrid along with associated charging infrastructure, but rarely charge the vehicle and rely primarily on gasoline or diesel to power their plug-in hybrid. This poses a significant risk to not only financial but environmental goals and should be considered when pursuing a PHEV procurement.

CHARGING CONFIGURATIONS

One of the most commonly cited barriers to electrification by fleet managers in Washington was lack of charging infrastructure. This included lack of currently existing charging infrastructure and the difficulty of planning, procurement, and installation of new charging infrastructure. The choice of charging configuration for a given vehicle depends on a range of factors including vehicle operational needs, where the vehicle is parked when not in use, site requirements for the installation of charging infrastructure, and funding. As explained in *Chapter 1*, the study team did not have insight into the specific operational needs of the vehicles included in the analysis and included a range of possible charging configurations to cover likely variations in charging strategy. These configurations ranged from expensive, high-powered DC fast charging solutions to relatively inexpensive Level 2 charging solutions, including a configuration which set the cost of installation and site upgrades to zero in order to model replacement of existing charging infrastructure for a subsequent EV purchase. The sections below explore the effect of choosing different charging configurations for light-, medium-, and heavy-duty vehicles.

LIGHT-DUTY VEHICLES

As shown in the analysis results for state and transit agencies, variations in charging infrastructure cost could have significant impacts on the electrification potential of light-duty vehicles. Lowering the average cost of charging infrastructure for light-duty vehicles by approximately $3,500, or 89 percent, more than doubled the number of state agency vehicles that met the five percent threshold for electrification. Depending on an agencies' choice of charging configuration, even greater savings could be achieved if vehicle charging was optimized. Costs for charging configurations for light-duty vehicles ranged from $6,105 for the most expensive configuration to $1,520 for the least expensive configuration. Table 17 shows the total costs for the charging configurations for light-duty vehicles included in the analysis.

TABLE 17: LIGHT-DUTY CHARGING CONFIGURATIONS

Charging Configuration; Vehicle to Charging Ratio	Total Cost of Equipment + Installation (per vehicle)
Level 2 public depot at 7.6 kW; 1:1	$6,105
DCFC private depot at 50 kW; 10:1	$5,914
Level 2 private depot at 11.5 kW; 1:1	$3,039
Level 2 residential at 7.6 kW; 1:1	$1,853
Level 2 private depot at 11.5 kW; 2:1	$1,520

This table shows the cost for each charging configuration for light-duty vehicles included in the analysis. The ratios represent the number of vehicles being supported by each charging station.

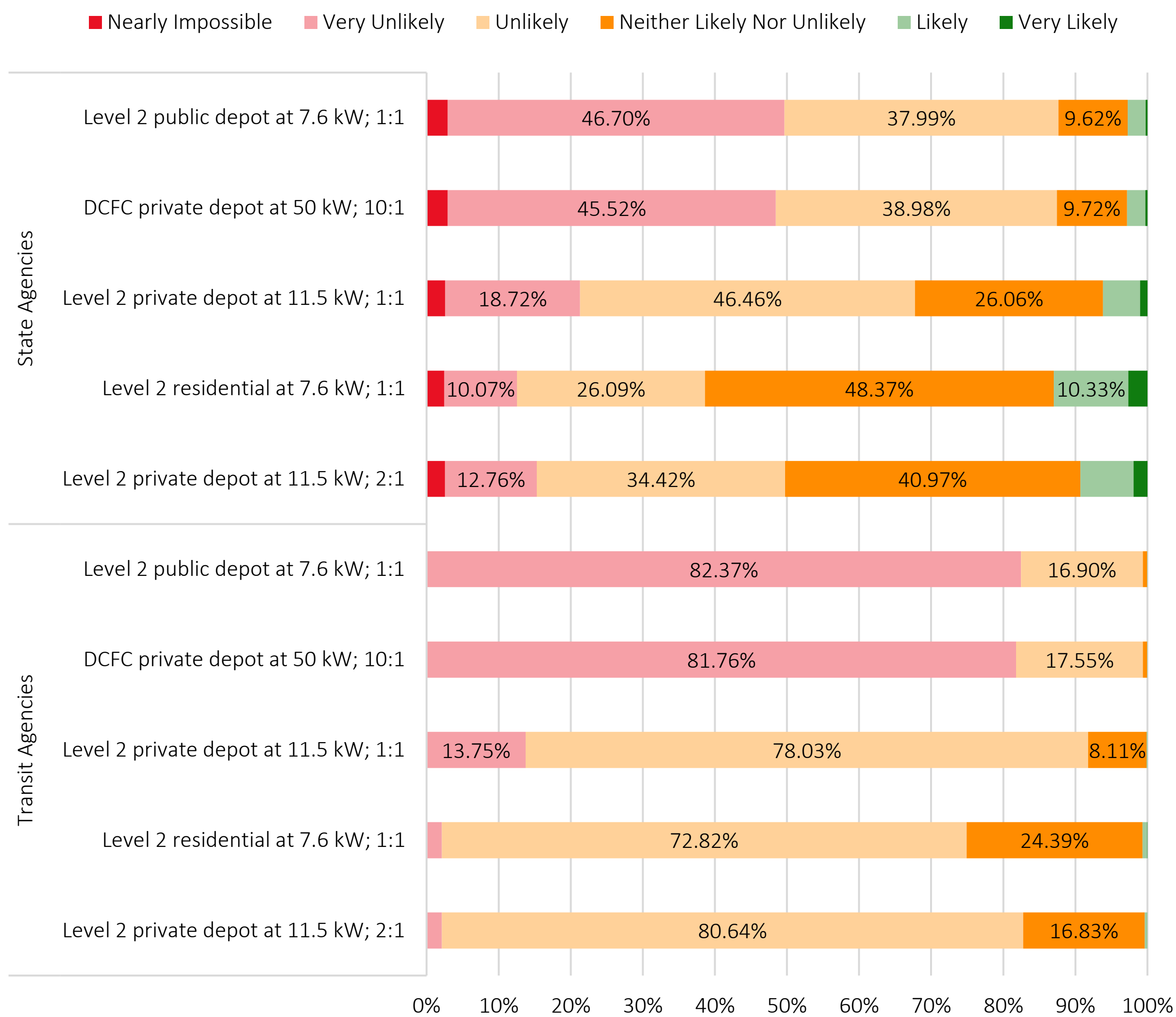
The difference between the highest and lowest-cost charging configuration, a public Level 2 charging station with each charging station supporting one vehicle and a private Level 2 charging station with each charging station supporting two vehicles, was more than $4,500 and the TCO results for these two configurations differed substantially. Moving from the highest- to lowest-cost charging configuration resulted in an additional 548 vehicles meeting the threshold for electrification, more than tripling from 226 to 774. State agencies accounted for 99 percent of these vehicles in both cases. As discussed previously, high price premiums for electric minivans limited their electrification potential and these vehicles represented nearly 95 percent of all light-duty vehicles owned by transit agencies. The difference in savings from electrification was similarly stark, ranging from an average of $362,769 under the highest-cost charging configuration to nearly $1.5 million under the lowest-cost charging configuration.

An even greater difference was seen between the highest- and lowest-cost configurations when increasing the threshold for electrification from five to twenty percent. Raising the threshold to 20 percent resulted in an additional 806 vehicles being electrified under the highest-cost configuration, bringing the total number of vehicles to 1,032 or just under 10 percent of all light-duty vehicles analyzed. The same threshold increase under the lowest-cost configuration increased the number of vehicles meeting the threshold by 3,284, bringing the total number of electrified vehicles to 4,598 or nearly 42 percent of all light-duty vehicles analyzed. The incremental cost to electrify these vehicles would be $6 million and $21.7 million under the highest- and lowest-cost configurations, respectively. Figure 71 shows the likelihood results for all light-duty vehicles by charging configuration. Results are broken down by fleet and presented in descending order of charging configuration cost.

Two additional findings from the analysis of charging configurations were the limited number of vehicles that could be electrified cost effectively when choosing a charging option that installs stations that are also publicly accessible and the benefits of residential charging. Making charging stations accessible to the public comes with considerable additional costs for extra site work for accessibility and more expensive equipment that supports additional features like credit card readers. Washington has in some cases sought to tie charging infrastructure funding to public accessibility, but the results of this analysis indicate that expanding charging station access would come at a considerable additional cost and limit the number of vehicles that could be electrified cost effectively.

Residential charging, alternatively, comes with a relatively low cost compared to other configurations and has the added benefit of charging vehicles only at the base residential rate which is lower than the commercial rate in many cases and does not incur costly demand charges. DES has already tested a home-charging solution in which employees are paid a flat fee each month to cover average vehicle charging costs. This charging configuration had the best results for EVs of all configurations included in the analysis and, although several fleet managers in Washington raised concerns regarding the logistics of pursuing a home-charging solution for vehicles that are not on home assignment.

FIGURE 71: LIKELIHOOD RESULTS FOR ALL LIGHT-DUTY EVS BY CHARGING CONFIGURATION



This figure shows the likelihood results for all light-duty vehicles under various charging configurations broken down by fleet. Charging configurations are listed in descending order by total cost.

MEDIUM-DUTY VEHICLES

As covered in the analysis results for state agencies, school buses, and transit agencies, savings from reduced charging infrastructure costs had a small overall effect on the number of vehicles that met the five percent electrification threshold. Relative to the average TCO for medium-duty EVs, charging infrastructure costs were small, accounting for seven percent of a vehicle's TCO on average. These costs ranged from $29,570 for the most expensive charging configuration to $3,220 for the least expensive configuration. Table 18 shows the total costs for the charging configurations for medium-duty vehicles included in the analysis.

TABLE 18: MEDIUM-DUTY CHARGING CONFIGURATIONS

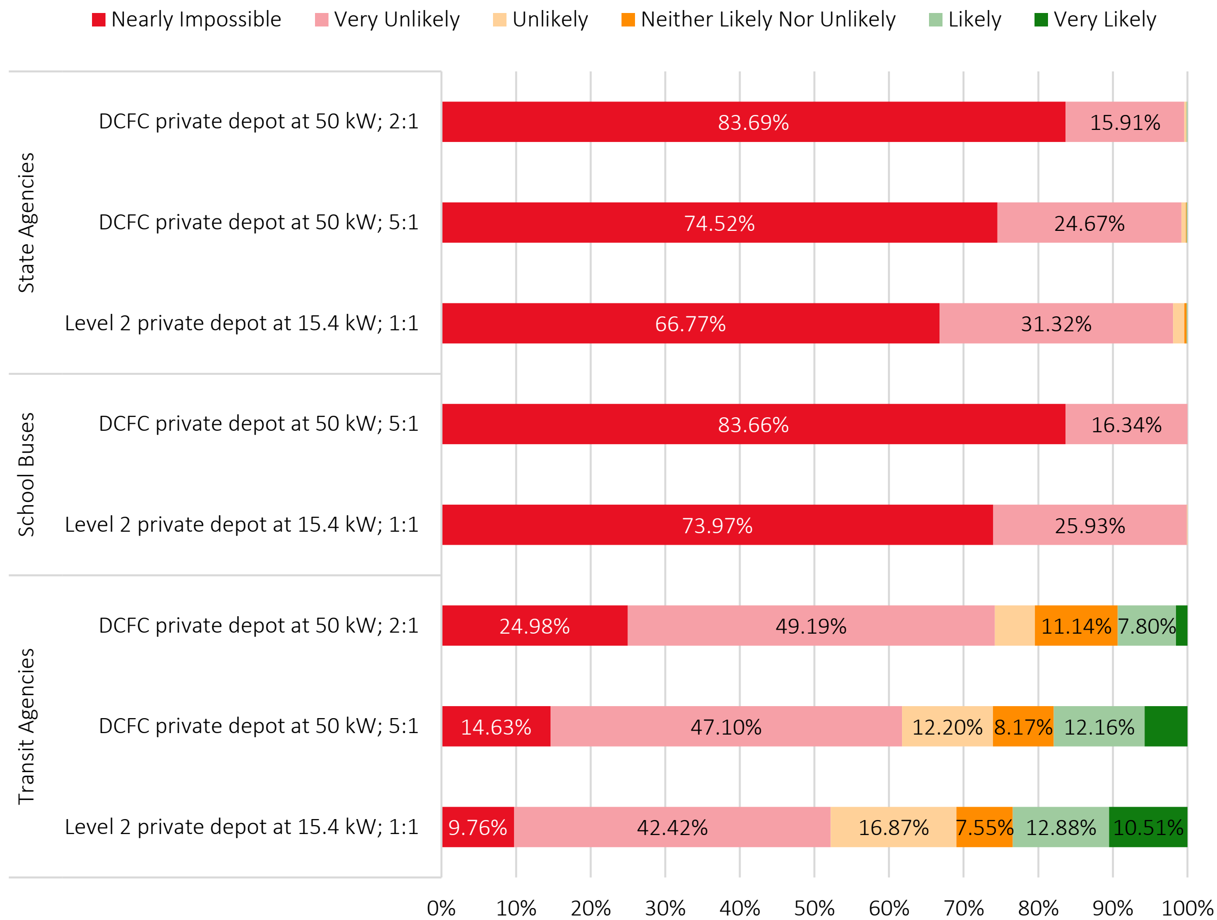
Charging Configuration; Vehicle to Charging Ratio	**Total Cost of Equipment + Installation (per vehicle)**
DCFC private depot at 50 kW; 2:1	$29,570
DCFC private depot at 50 kW; 5:1	$11,828
Level 2 private depot at 15.4 kW; 1:1	$3,220

This table shows the cost for each charging configuration for medium-duty vehicles included in the analysis. The ratios represent the number of vehicles being supported by each charging station.

Given that charging infrastructure costs constitute a relatively low share of a medium-duty vehicle's TCO compared to other cost categories like depreciation, choice of charging configuration across all medium-duty EVs had a less noticeable effect on electrification potential compared to light-duty EVs. However, this was not uniform across all medium-duty vehicles. Choice of charging configuration had no effect on the number of vehicles that met the five percent threshold for electrification for state agencies and school buses, with no additional vehicles meeting the threshold when moving from the highest- to lowest-cost charging configuration. For medium-duty transit buses, moving from the highest- to lowest-cost charging configuration more than doubled the number of vehicles that met the five-percent threshold for electrification, increasing from 299 to 750. Across all medium-duty vehicles, the savings from electrifying all vehicles that met the five percent threshold when including the with the highest-cost charging configuration was $4.7 million on average. These savings increased to an average of $16.9 million when including the lowest-cost charging configuration. Increasing the threshold for electrification to 20 percent resulted in an additional 357 vehicles meeting the electrification threshold at an additional incremental cost of $8.2 million under the highest-cost configuration and an additional 245 vehicles meeting the threshold at an incremental cost of $4.4 million under the lowest-cost configuration. Figure 72 shows the likelihood results for all medium-duty vehicles included in the analysis by charging configuration. Results are broken down by fleet and presented in descending order of charging configuration cost.

The overall results for medium-duty vehicles indicate that choice of charging configuration was unimportant for determining a vehicle's electrification potential, this was largely due to the high price premiums for many of the medium-duty EVs included in the analysis. As detailed in the state agency and school bus analysis results sections of this chapter, medium-duty EV alternatives were considerably more expensive than their internal combustion counterparts such that these price differences outweighed nearly every other factor in an EV procurement, including choice of charging infrastructure. While savings from low-cost charging configurations lowered the average TCO for these vehicles by more than 10 percent on average when compared to high-cost charging configurations, this decrease was insufficient to improve the electrification potential of these vehicles.

FIGURE 72: LIKELIHOOD RESULTS FOR ALL MEDIUM-DUTY VEHICLES BY CHARGING CONFIGURATION



This figure shows the likelihood results for all medium-duty vehicles under various charging configurations broken down by fleet. Charging configurations are listed in descending order by total cost.

The TCO results for medium-duty transit vehicles, however, demonstrate the importance of charging configuration optimization. These vehicles were more competitively priced than school buses and medium-duty state agency EV alternatives and also had higher annual mileages. As a result, their TCOs were much closer to their internal combustion counterparts and the savings from low-cost charging infrastructure were more significant in determining the electrification potential of a given vehicle. As the medium-duty EV market continues to evolve, charging configuration planning will become a more significant factor for determining electrification potential across the entire medium-duty fleet and best practices should be adopted as part of a broader electrification strategy even for vehicles which currently do not meet the five percent threshold for electrification.

HEAVY-DUTY VEHICLES

Similar to medium-duty vehicles, savings from reduced charging infrastructure costs had a smaller effect on the number of vehicles that met the five percent electrification threshold compared to other vehicle classes. Charging infrastructure costs represented a small percentage of average TCO for heavy-duty EVs, accounting for only three percent of a vehicle's TCO on average. Costs for the charging configurations included in the analysis costs ranged from $71,332 for the most expensive charging configuration to $3,220 for the least expensive configuration. It should be noted, however, that heavy-duty vehicles had the greatest diversity in charging configurations of all vehicles with state agency vehicles, school buses, and transit buses all having unique sets of potential configurations. Table 19 shows the total costs for the charging configurations for heavy-duty vehicles included in the analysis.

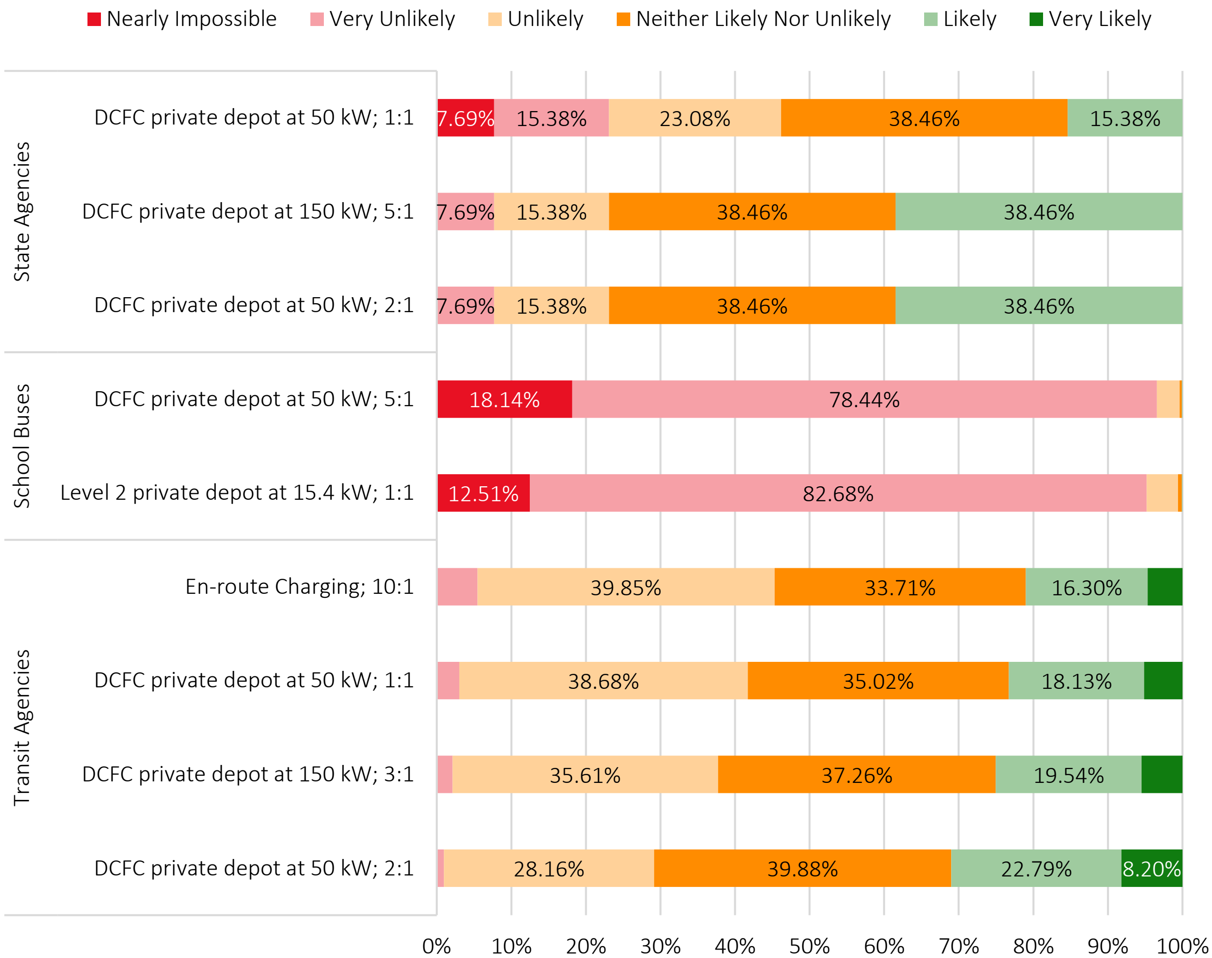
TABLE 19: HEAVY-DUTY CHARGING CONFIGURATIONS

Charging Configuration; Vehicle to Charging Ratio	Total Cost of Equipment + Installation (per vehicle)
En-route Charging; 10:1	$71,332
DCFC private depot at 50 kW; 1:1	$59,140
DCFC private depot at 150 kW; 3:1	$50,145
DCFC private depot at 150 kW; 5:1	$30,087
DCFC private depot at 50 kW; 2:1	$29,570
DCFC private depot at 50 kW; 5:1	$11,828
Level 2 private depot at 15.4 kW; 1:1	$3,220

This table shows the cost for each charging configuration for heavy-duty vehicles included in the analysis. The ratios represent the number of vehicles being supported by each charging station.

The effect of choosing the lowest-cost charging configuration for heavy-duty vehicles on the electrification potential of vehicles was highly dependent on which type of heavy-duty vehicle was being considered. For school buses, only one additional vehicle met the five percent threshold for electrification when choosing the lowest-cost instead of the highest-cost charging configuration. For heavy-duty state agency vehicles, the number of vehicles that met the five percent threshold more than doubled when moving from the highest- to lowest-cost charging configuration, though the increase in the actual number of vehicles was low – increasing from two vehicles to five. For transit heavy-duty transit buses, moving from the highest to lowest-cost charging configuration resulted in an additional 290 buses meeting the five percent threshold for electrification, a nearly 50 percent increase from 609 to 899 vehicles.

FIGURE 73: LIKELIHOOD RESULTS FOR HEAVY-DUTY VEHICLES BY CHARGING CONFIGURATION



This figure shows the likelihood results for all heavy-duty vehicles under various charging configurations broken down by fleet. Charging configurations are listed in descending order by total cost.

The savings from electrifying all vehicles that met the five percent electrification threshold when choosing the highest-cost charging configuration was $50.4 million, with all positive savings coming from the electrification of transit buses (both school buses and state agency vehicles yielded slight additional costs from electrification). When choosing the lowest-cost charging configuration, the savings from electrification rose to $74.3 million, again with all positive savings coming from the electrification of transit buses. Increasing the threshold for electrification to 20 percent resulted in an additional 1,009 vehicles meeting the threshold at an incremental cost of $146.2 million under the highest-cost configuration and an additional 1,208 vehicles at an incremental cost of $191 million under the lowest-cost configuration. Figure 73 shows the likelihood results for all heavy-duty vehicles included in the analysis by charging configuration. Results are broken down by fleet and presented in descending order of charging configuration cost.

As was the case for medium-duty transit buses, heavy-duty transit buses demonstrated significant shifts in electrification potential with even relatively small decreases in TCO resulting from lower-cost charging configurations. While the difference between the most and least expensive charging configuration for transit buses was more than $41,000, this represented a difference of less than four percent in total average TCO. Nonetheless, this four percent TCO savings resulted in a nearly 50 percent increase in the number of vehicles that could be electrified cost-effectively. Electric transit buses were the most cost-competitive group of EV alternatives included in this analysis and even slight changes in TCO had the potential to significantly increase the number of vehicles that could be electrified and dramatically increase the average savings from electrification. As the results of *Chapter 5* indicate, planning around charging infrastructure will become an increasingly important determinant of a vehicle's electrification potential as the market for heavy-duty EVs continues to develop and more vehicles become as competitive as heavy-duty transit buses.

PUBLIC CHARGING

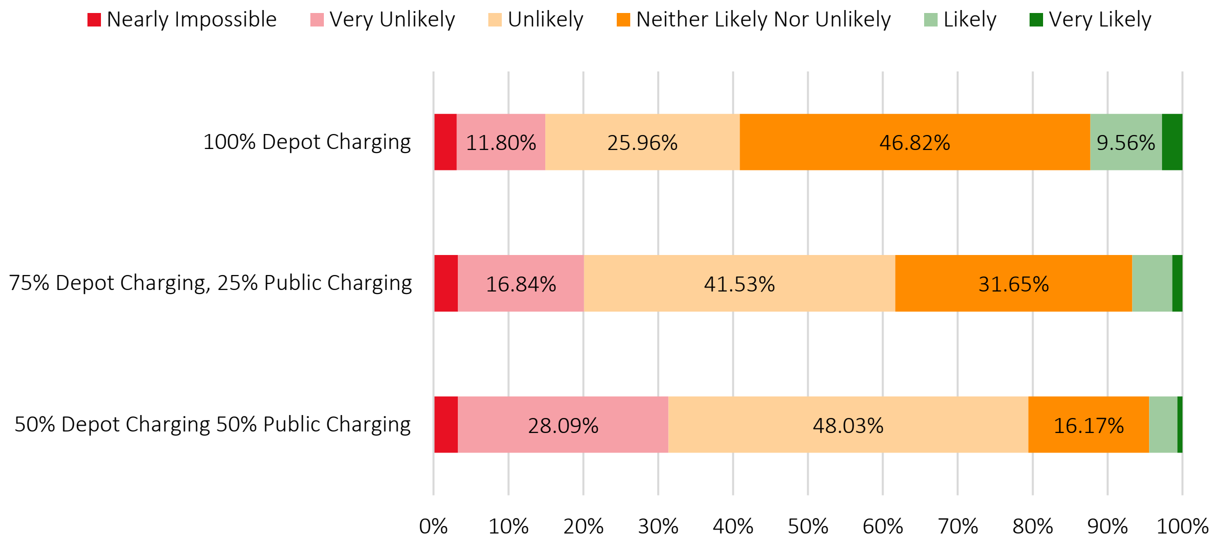
Although not explicitly modeled in the study, an alternative charging configuration which fleet managers may choose to pursue is partial or full reliance on a public charging network. As mentioned previously, a common barrier to electrification cited by fleet managers in Washington is the need for many vehicles to make intermittent long trips that exceed the range of most EVs. These vehicles would likely rely on a public charging network to complete these trips, similar to how many internal combustion vehicles rely on commercial gas stations for refueling. To model the electrification potential of vehicles that rely either partially or entirely on a public charging network, the study team chose to use the variations in electricity rates a proxy. As reliance on public charging would be unlikely for transit vehicles and school buses which normally operate on predetermined routes, this analysis only focused on state agency vehicles.

To ensure an apples-to-apples comparison, the study team only focused on the 66 percent of state agency vehicles served by either Puget Sound Energy or Avista, both of which had the same average commercial electricity rate as of 2020. The smart charging rate for these utilities is equivalent to the average electricity price for a vehicle that charges 75 percent at the base commercial rate at a private depot and 25 percent at a public charging station where the price of electricity is $0.30, the average public charging price at EVgo stations in Washington. Similarly, the demand charges rate for these utilities is exactly equivalent to the average electricity price for a vehicle that charges 50 percent at the base commercial rate at a private depot and 50 percent at a public charging station. Figure 74 shows the analysis results for all state agency vehicles when charging 100 percent at a private deport using Level 2 charging stations, relying on a public charging network for 25 percent of charging, and relying on a public charging network for 50 percent of charging.

As demonstrated in the section on *Electricity, Gasoline and Diesel Prices,* increasing the average electricity price by relying on a public charging network resulted in a considerable decrease in the number of vehicles that met the five percent threshold for electrification. Relying on a public charging network for 25 percent of a vehicle's charging needs decreased the number of vehicles that met the five percent electrification threshold by 46 percent from 659 to 359. Relying on a public charging network for 50 percent of charging lowered the number of vehicles that met the electrification threshold by more than 64 percent when compared to charging only at a private depot, dropping from 659 to 237. The average savings from electrification in the 100 percent depot, 75 percent depot, and 50 percent depot scenarios was $1.7 million, $874,900 and $490,469, respectively.

These results highlight the importance of low-price electricity for EVs to be cost competitive with conventional vehicles on a TCO basis. The increased reliance on higher priced public charging outweighed the upfront costs of installing depot Level 2 charging over the life of the vehicles.

FIGURE 74: LIKELIHOOD RESULTS FOR STATE AGENCY VEHICLES WHEN RELYING ON A PUBLIC CHARGING NETWORK



This figure shows the likelihood results for state agency vehicles when relying charged only at a private depot, when charged 25 percent of the time at a public charging station, and when charged 50 percent of the time at a public charging station.

However, full reliance on a public charging option could result in more vehicles meeting the threshold for electrification depending on the public charging price and the cost of charging infrastructure. A primary reason for the decreases in vehicles that met the electrification threshold in the scenarios above was that vehicles were still burdened by the full cost of charging infrastructure. Eliminating charging infrastructure costs from the 50 percent depot scenario nearly triples the number of vehicles that met the electrification threshold from 237 to 700. Although this scenario assumes an average public charging price of just $0.20 per kilowatt-hour, approximately $0.10 below the current market rate, there is potential for the state to negotiate bulk discounts with major public charging providers.

CHAPTER 5: TOTAL COST OF OWNERSHIP ANALYSES (2020-2035)

Under near-term conditions, the present-day analysis of total cost of ownership (TCO) reveals that many vehicles in Washington state's public fleet did not meet the five percent threshold for electrification. However, the market is changing rapidly, and several factors point toward the potential for EVs to become more cost competitive this decade. Increasing model options, decreasing battery and other production costs, tightening fuel economy and emission regulations, and increasing consumer demand all signal potential for growth in the EV market [127, 128, 129, 130].

To prepare for the future, it is useful to estimate how the difference in TCO between EVs and the incumbent technology may evolve in the medium- to long-term. This chapter attempts to estimate the future of electrification economics by running additional multivariate TCO analyses that account for potential evolution of automotive technology costs using the methodology detailed in *Chapter 3*.

This chapter presents the results of the multivariate analysis, which considered evolving technology and fuel costs, approaches for evaluating the cost and benefits of investment in charging infrastructure, and multiple approaches to vehicle adoption. The analysis includes the complete set of possible scenario combinations for each vehicle from the inventory described in *Chapter 4* and 4,345,253 scenarios in total were analyzed for the analysis of vehicle electrification from the present day through 2035. This included 28,913 vehicles separated into 30 use cases. Given the large volume of scenarios generated, the study team took care to organize the analysis in a thoughtful manner. This analysis will consider the four policy scenarios included in Table 20.

TABLE 20: ELECTRIFICATION POLICY SCENARIOS

Scenario Name	Electrification Criteria
Electrify Nothing	None of the vehicles in the public fleet are electrified.
Electrify Selectively	Vehicles that meet the "Likely" or "Very Likely" TCO criteria are electrified.
Electrify Substantially	Vehicles that meet the "Neither Likely nor Unlikely", "Likely", or "Very Likely" TCO criteria are electrified.
Electrify Everything	All the vehicles in the public fleet are electrified.

The Electrify Nothing and Electrify Everything scenarios are intended to serve as bookends for the analysis, each representing a vehicle procurement approach that is blind to TCO considerations. The Electrify Selectively scenario is intended to represent Washington's existing strategy as spelled out under WAC 194-28 wherein all vehicles for which an EV is within five percent of the TCO meet the threshold for electrification. The Electrify Substantially scenario is a more aggressive scenario in which vehicles where the EV alternative has a TCO within 20 percent of the incumbent technology are assumed to be replaced with an EV.

This inspection will carry forward the previously described scenarios: EV Deployment (Initial EV and Subsequent EV) and Technology Development (BAU Tech and R&D Success). The combination of these two dimensions represent a total of four scenarios as shown in Table 21.

TABLE 21: PROJECTED TCO SCENARIO MATRIX

		Technology Scenario	
		Business as Usual Technology	R&D Success
Deployment Scenario	Initial EV	BAU Tech + Initial EV	R&D Success + Initial EV
	Subsequent EV	BAU Tech + Subsequent EV	R&D Success + Subsequent EV

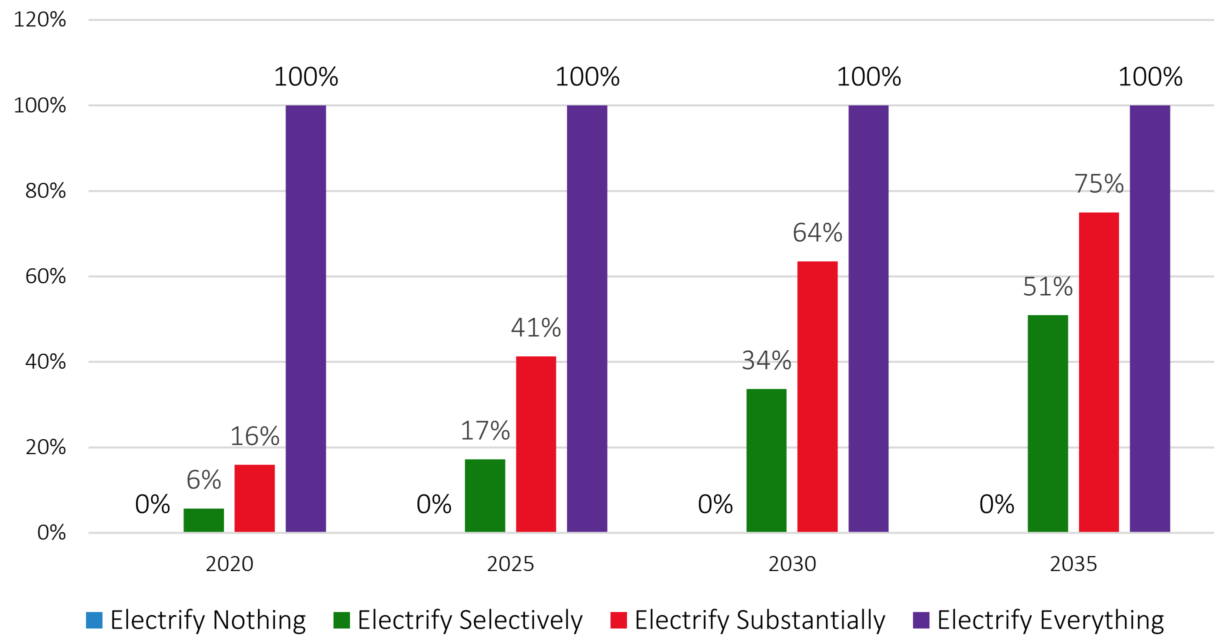
The first dimension, EV deployment, includes two options: 1) an initial EV deployment scenario and 2) a subsequent EV deployment scenario. Under the initial deployment scenario, the study team averaged the TCO results for EVs across all scenarios under consideration, including various charging configurations, EV models, and electricity rates. Under the subsequent deployment scenario, the study team limited the scenarios under consideration to just those that modeled no cost for construction or electrical grid upgrades for charging infrastructure. The subsequent scenario is intended to reflect the long-term savings potential of EVs once the upfront investments in charging infrastructure have already been made.

The second dimension, technology development, also includes two options: 1) a business as usual (BAU Tech) scenario in which existing trends in automotive technology (performance, efficiency, cost) persist into the future and 2) a research and development success (R&D Success) scenario in which aspirational technology targets are met. These scenarios are described in more detail in *Chapter 3*.

PROJECTED TCO ANALYSIS RESULTS

Analysis results are first presented by year for the entire fleet, focusing only on the BAU Tech and Initial EV Deployment scenarios. Figure 75 shows the share of qualifying fleet vehicles from 2020 to 2035 under the four policy scenarios. By definition, the Electrify Nothing and Electrify Everything scenarios features 0 percent and 100 percent EV shares, respectively. The Electrify Selectively and Electrify Substantially scenarios result in EV market share that are determined by the EV and incumbent technology cost assumptions and EV deployment scenario. While EV shares under both the Electrify Selectively and Electrify Substantially scenarios increase over time, the Electrify Substantially scenario is more aggressive with EV shares up to 30 percentage points higher than the Electrify Selectively scenario. In the near-term (2020-2025) EV shares under the Electrify Selectively scenario remain modest at less than 20 percent, while in the long-term (2035) EV shares under the Electrify Substantially scenario reach 75 percent.

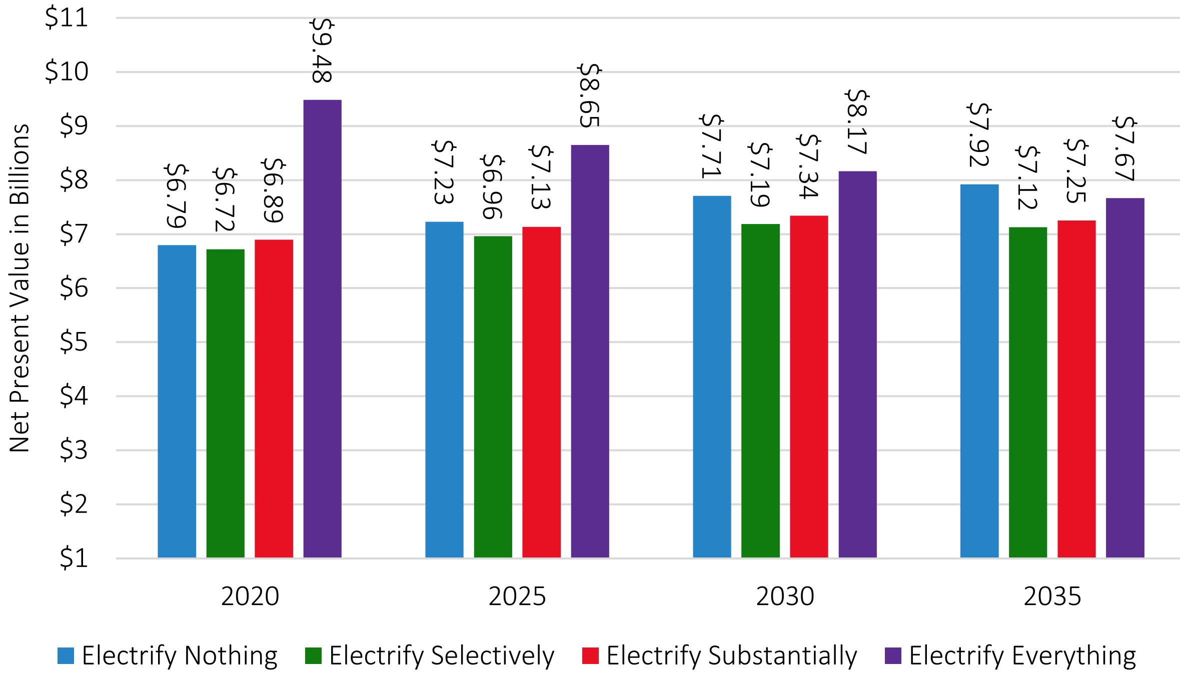
FIGURE 75: 2020-2035 ELECTRIFICATION SHARES BY YEAR UNDER VARIOUS POLICY SCENARIOS FOR AN INITIAL DEPLOYMENT OF EVS UNDER A BAU TECH SCENARIO



This chart shows the share of fleet vehicles that would be electrified under four different policy scenarios from 2020 to 2035. The results presented are for an initial EV deployment under a BAU Tech scenario.

The cost of each of these scenarios is presented in Figure 76 as the sum of the lifetime fleet costs for all vehicles included in the analysis (28,913 vehicles) assuming a purchase year equal to the scenario year. In the near-term, the Electrify Everything scenario is prohibitively expensive with fleet costs 33 percent ($2.4 billion) higher than the Electrify Nothing scenario. However, as the capital cost of EVs is projected to come down over time in both the R&D Success and BAU Tech scenarios, the Electrify Everything scenario results in lower fleet costs than the Electrify Nothing scenario for both technology scenarios by 2035. Also note that the Electrify Nothing scenario increases in cost through time as the BAU Tech forecast assumes conventional gasoline and diesel vehicles become more expensive due to requirements for these vehicles to improve efficiency and decrease emissions.

FIGURE 76: LIFETIME FLEET COSTS IN YEAR 2020, 2025, 2030, AND 2035 UNDER VARIOUS POLICY SCENARIOS FOR AN INITIAL DEPLOYMENT OF EVS UNDER A BAU TECH SCENARIO

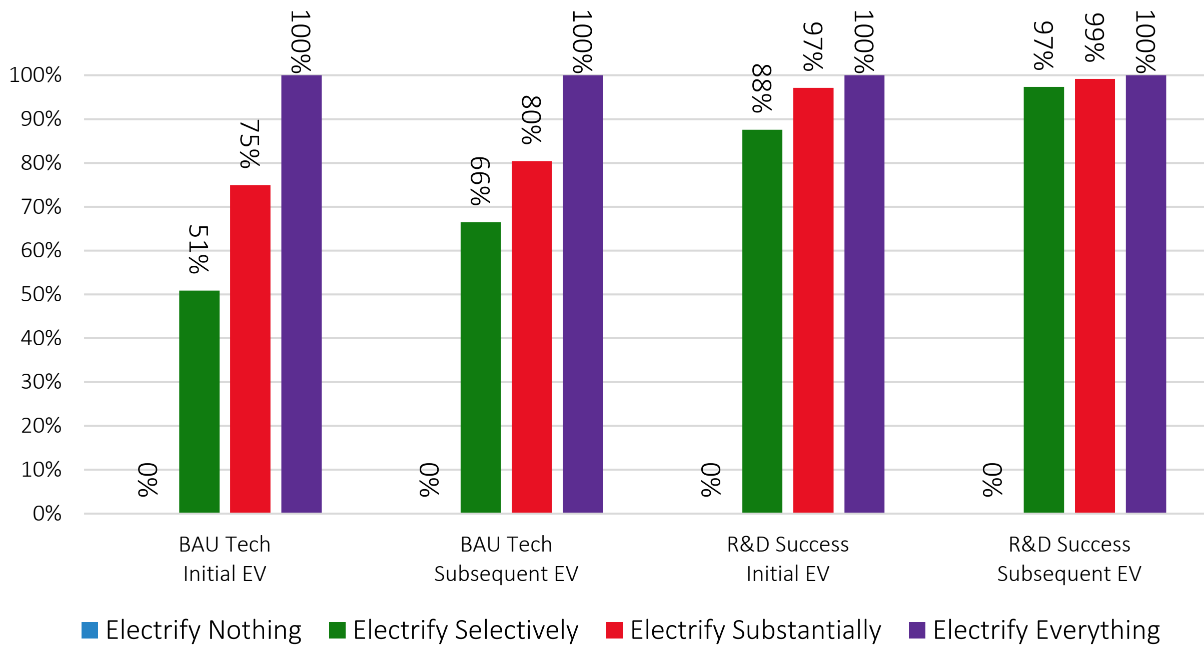


This chart shows the total lifetime fleet costs (in billions of U.S. dollars) for all vehicles under different policy scenarios from 2020 to 2035. The results presented are for an initial EV deployment under a BAU Tech scenario. As technology improves and EV costs come down, the cost of the Electrify Everything scenario decreases considerably over time.

Across all scenarios in Figure 76, the Electrify Selectively scenario results in the lowest fleet lifetime costs. This is a natural result of this scenario's design to electrify only those vehicles with the most compelling TCO projections. However, the Electrify Substantially scenario produces similar results (2-3 percent higher costs) while enabling the fleet EV share to exceed that of the Electrify Selectively scenario by up to 30 percent. Recall that these results assume the most cautious set of technology and EV deployment assumptions.

Focusing on the long-term scenario of 2035, the EV share of the public fleet in each of 16 scenarios (two technology scenarios, two EV deployment scenarios, and four policy scenarios) is shown below in Figure 77. A policy objective to Electrify Selectively combined with a BAU Tech progression results in a majority of EVs in the fleet by 2035, (51-66 percent depending on EV deployment scenario). On the other end of the spectrum, a policy objective to Electrify Substantially combined with a R&D Success environment results in nearly all fleet vehicles being converted to EVs (97-99 percent depending on EV deployment scenario).

FIGURE 77: ELECTRIFICATION SHARES IN 2035 UNDER VARIOUS TECHNOLOGY, INFRASTRUCTURE, AND POLICY SCENARIOS

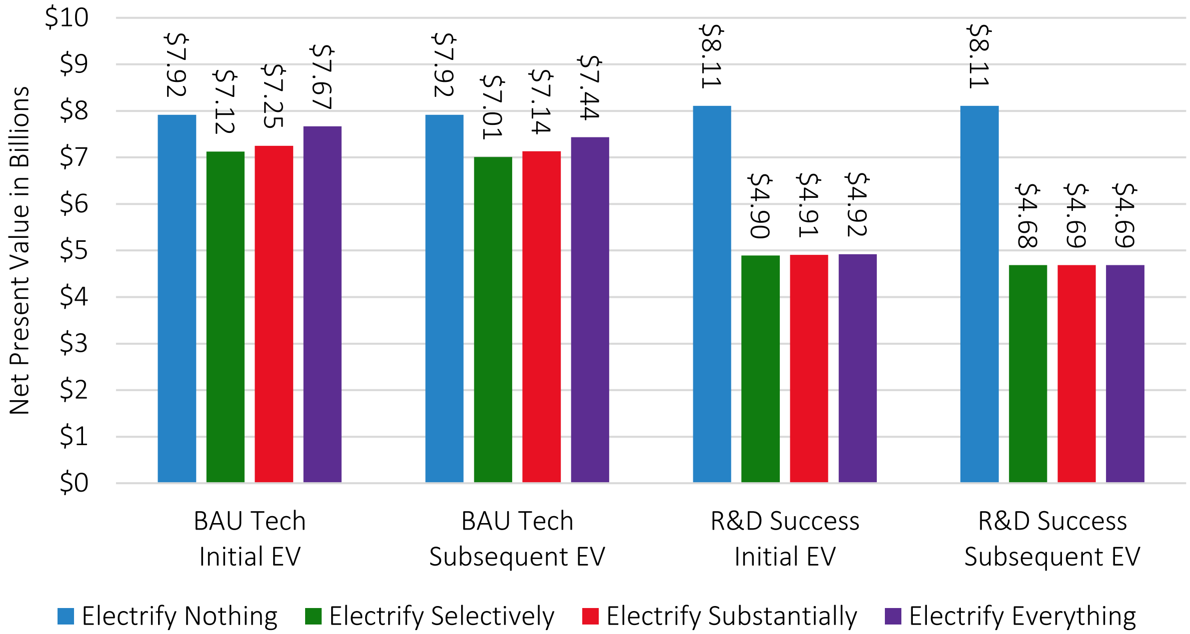


This chart shows the share of fleet vehicles electrified under various technology, infrastructure, and policy scenarios from 2020 to 2035.

The cost of each of these scenarios is presented in Figure 78 as the sum of the lifetime fleet costs for all vehicles included in the analysis (28,913 vehicles) assuming a purchase year of 2035. The fleet costs are observed to vary most dramatically under different technology scenarios. In the BAU Tech scenarios, fleet costs in the Electrify Nothing scenario total $7.9 billion. This cost drops by approximately 10 percent in the Electrify Selectively scenarios, to $7.1 billion and $7.0 billion in the Initial EV and Subsequent EV Deployment scenarios, respectively.

A clear trend emerges from the BAU Tech scenarios where fleet costs remain high in the Electrify Nothing scenario and are only marginally improved in the Electrify Everything scenario. Costs reductions are found to be most significant in scenarios where electrification is deployed strategically using a TCO-based approach.

FIGURE 78: LIFETIME FLEET COSTS IN 2035 UNDER VARIOUS TECHNOLOGY, INFRASTRUCTURE, AND POLICY SCENARIOS



This chart shows the total lifetime fleet costs (in billions of U.S. dollars) for all vehicles under various technology, infrastructure, and policy scenarios from 2020 to 2035.

The R&D Success scenarios show a similar trend, however the benefits of electrification at any level are much more significant. Fleet costs of Electrifying Nothing are estimated to be slightly higher in an R&D Success scenario ($8.1 billion) as a result of emission reduction technologies with high capital costs. Estimated cost differences between the remaining three levels of electrification become much less significant, on the order of 1 percent. Relative to the Electrify Nothing scenario, all three of the remaining electrification scenarios are estimated to result in TCO reductions of approximately 40 percent, bringing fleet costs down to $4.9 billion in the Initial EV scenarios and $4.7 billion in the Subsequent EV scenarios. This result demonstrates the significance of the potential for R&D to dramatically bring down the capital costs of electrification while simultaneously improving fleetwide energy efficiency. Low capital costs resulting from technological innovation combined with high efficiency vehicles provides the opportunity for significant TCO savings across the fleet. These savings are especially evident in the medium- and heavy-duty vehicle markets where significant R&D innovations remain necessary before competitive products can be brought to market.

PROJECTED TCO ANALYSIS RESULTS BY FLEET AND WEIGHT CLASS

Having inspected projected TCO results across all public vehicles in Washington state, results are now presented by fleet and vehicle weight class. Consistent with *Chapter 4*, results are broken down by the three fleets for which the project team received detailed vehicle data: the state agency fleet, the school bus fleet, and the transit agency fleet. Within each section, the overall TCO results for electric and internal combustion engine vehicle procurements are compared to determine the likelihood that a given vehicle is a suitable candidate for electrification as described in *Chapter 3*.

Given the large number of variable combinations (state fleet, weight class, technology scenario, EV deployment scenario, policy scenario), figures in the following sections are presented to focus on the variable combinations shown in Table 22 to highlight the key findings from the analysis.

TABLE 22: SELECTED SCENARIOS FOR PRESENTATION OF PROJECTED TCO RESULTS BY STATE FLEET AND WEIGHT CLASS

Scenario Name	Policy Scenario	Technology Scenario	Deployment Scenario
Electrify Selectively	Electrify Selectively	BAU Tech	Initial EV
Electrify Substantially	Electrify Substantially	BAU Tech	Initial EV
Electrify Substantially + Subsequent EV	Electrify Substantially	BAU Tech	Subsequent EV
Electrify Substantially + R&D Success	Electrify Substantially	R&D Success	Initial EV

STATE AGENCY ANALYSIS RESULTS

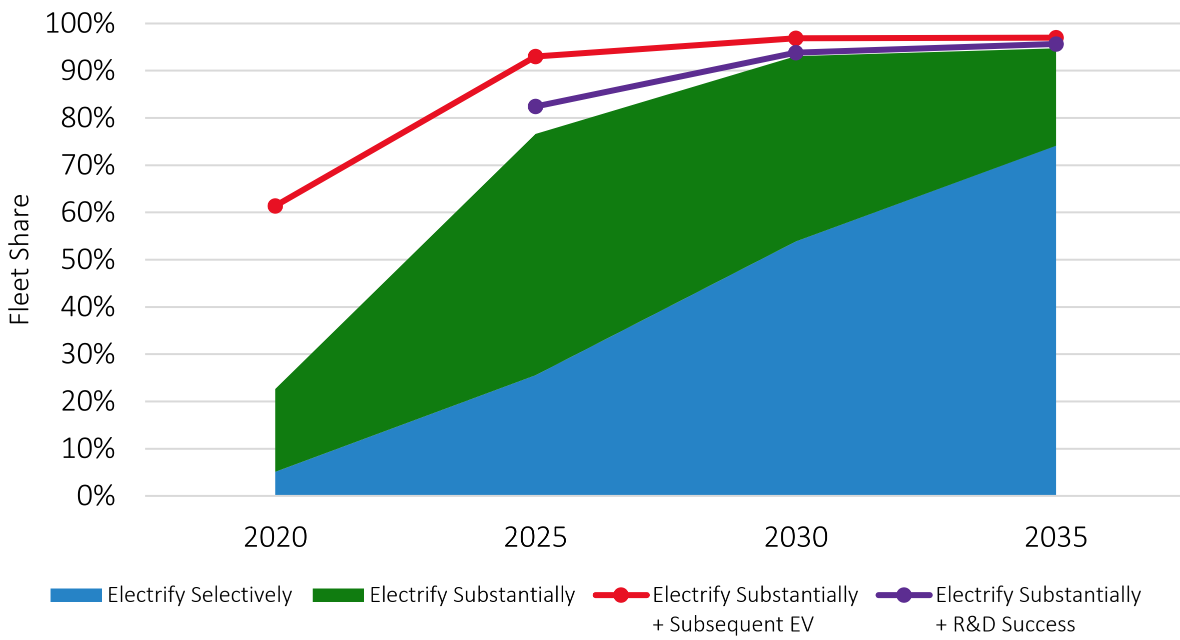
As shown in *Chapter 4*, the largest set of fleet data collected by the study team was for vehicles owned by state agencies. In total, the state agency fleet included information on over 13,000 vehicles. Of these vehicles, the study team identified 9,205 for which sufficient detailed vehicle data existed and for which there was at least one EV alternative and included them in the analysis. The sections below explore the results for light-, medium-, and heavy-duty vehicles.

LIGHT-DUTY VEHICLES

Light-duty vehicles owned by state agencies consist of passenger vehicles, including sedans, SUVs, and vans, as well as utility vehicles, including light-duty pickup trucks, police vehicles, and motorcycles. Of the 9,205 state agency vehicles analyzed, light-duty vehicles accounted for 8,199, or nearly 90 percent. Among light-duty vehicles, SUVs were the most common, followed by pickups, sedans, police pursuit vehicles, vans, and finally motorcycles.

Consistent with present-day analysis results shown in *Chapter 4*, less than 10 percent of light-duty vehicles in 2020 met Electrify Selectively criteria under the BAU Tech scenario. However, as EV technology costs are expected to decrease over time (particularly vehicle battery costs), EVs become a competitive alternative for over 70 percent of this fleet segment by 2035. The more aggressive policy approach of Electrify Substantially results in over 90 percent of the fleet meeting the threshold for electrification by 2035. Results of the projected TCO analysis for light-duty vehicles in state fleets are shown below in Figure 79.

FIGURE 79: PERCENT OF LIGHT-DUTY VEHICLES IN STATE AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (BAU TECH SCENARIO)



This figure shows the share of light-duty fleet vehicles that would be electrified when the TCO threshold for electrification is met.

Across all scenario years, EV TCO becomes more competitive in the Subsequent EV Deployment scenario, particularly in the near-term. By discounting the installation cost of charging infrastructure, the share of vehicles meeting the electrification TCO threshold increases to over 90 percent as early as 2025. These results highlight the significance of charging infrastructure capital costs in determining whether light-duty electric vehicles meet the TCO threshold necessary for consideration by state agencies in Washington state.

A less impactful variable for state agency light-duty vehicles is how technology costs will evolve over the next 15 years. Under the R&D Success scenario, the fleet share meeting Electrify Substantially criteria increased by less than 10 percentage points across all scenario years.

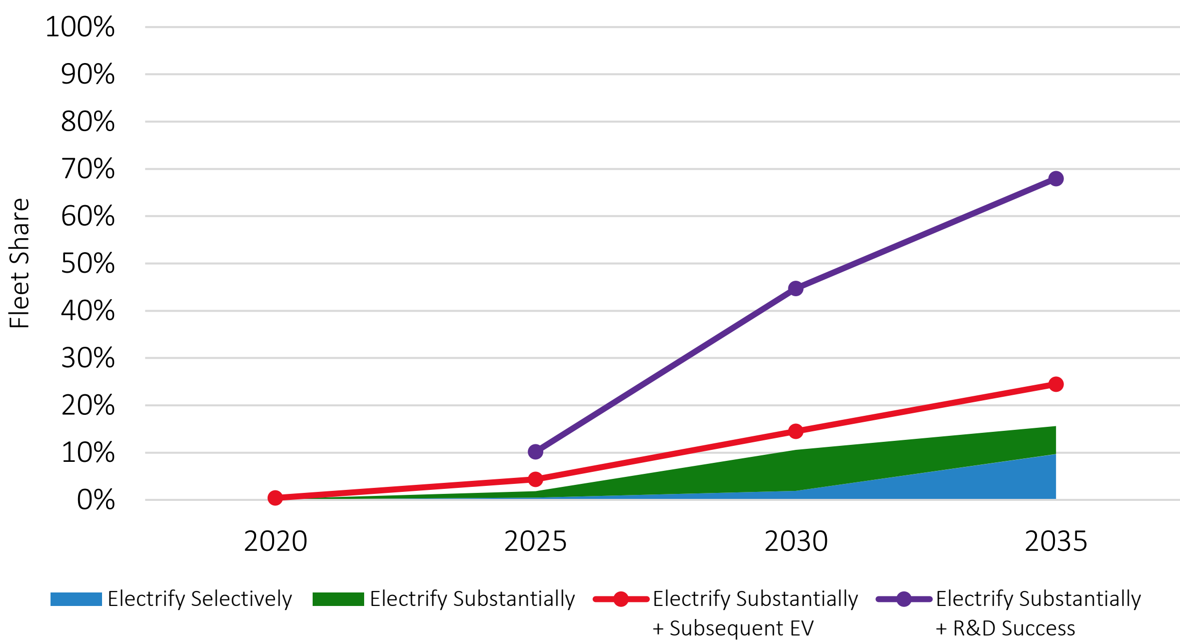
MEDIUM-DUTY AND HEAVY-DUTY VEHICLES

In addition to light-duty vehicles, state agency fleets were found to include over 3,000 medium- and heavy-duty vehicles. As discussed in the previous chapter, only approximately 1,000 of these vehicles were included in the TCO analysis due to lack of existing EV model options capable of providing equivalent (or better) utility compared to the incumbent technology and/or lack of sufficient data for the purpose of modeling TCO. Of the approximately 1,000 vehicles analyzed, nearly 99 percent were medium-duty vehicles.

While this analysis does consider the potential for technology costs to evolve over the next 15 years, no considerations were made for the potential of new models that may be brought to market between 2020 and 2035. As such, vehicles within the state fleet for which no EV alternative currently exists are omitted from the present-day analysis and the 2020-2035 TCO projections.

Relative to light-duty vehicles within state agency fleets, a much smaller share of vehicles within the medium-duty state agency fleets are projected to meet the TCO electrification threshold, as shown in Figure 80. In the BAU Tech scenario, only about 10 percent and 15 percent of the fleet meets the Electrify Selectively and Electrify Substantially criteria by 2035, respectively. While this result is not impacted significantly by the installation cost of infrastructure, the share of vehicles meeting the Electrify Substantially criteria is projected to reach nearly 70 percent by 2035 under the R&D Success scenario. While the majority of vehicles in this segment fail to meet electrification criteria under BAU Tech scenarios, the R&D Success results indicate that a large number vehicles are close and would qualify for Substantial Electrification if R&D targets are reached and resulting decreases in upfront vehicle costs are realized.

FIGURE 80: PERCENT OF MEDIUM-DUTY VEHICLES IN STATE AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECH SCENARIO)



This figure shows the share of medium-duty fleet vehicles that would be electrified when the TCO threshold for electrification is met.

The TCO analysis for State Agency heavy-duty vehicles was extremely limited due to a lack of data from existing vehicles and lack of present-day electric alternatives. A total of 13 vehicles were considered in the analysis. While the limited sample size makes it difficult to draw definitive conclusions, TCO results were favorable for this segment with approximately 25 percent of heavy-duty vehicles meeting the Selective Electrification criteria in 2020. This share climbs to 90 percent by 2030 in the Selective Electrification scenario while the Substantial Electrification scenario reaches a 90 percent share by 2025.

SCHOOL BUS ANALYSIS RESULTS

The second largest set of fleet data collected by the study team was for school buses owned by school districts in Washington state. The school bus data included information on over 10,838 vehicles, all of which were included in the analysis. Each of these vehicles was mapped to up to two electric alternatives, depending on estimated average daily mileage.

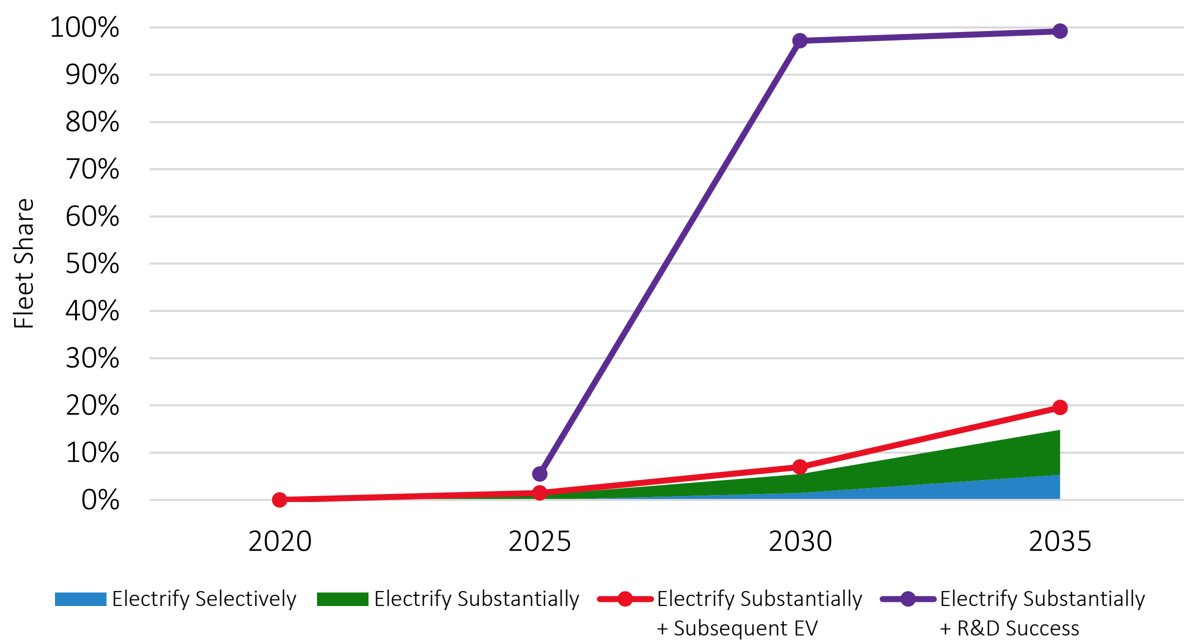
All categories of school bus, Type A, B, C, and D were included in the analysis. All bus types analyzed shared similar operational characteristics such as VMT and fuel price and had similar EV alternative offerings from a price and operational capability standpoint.

MEDIUM-DUTY BUSES: TYPE A AND B

Medium-duty Type A and B school buses accounted for 19 percent of Washington state's school bus fleet, including over 2,000 Type A buses and less than 40 Type B buses. Very few buses analyzed in this segment were able to meet either the Selective or Substantial Electrification criteria. As shown in Figure 81, while the share of buses meeting the TCO threshold is projected to improve between 2020 and 2035, less than 20 percent of this segment meets the Substantial Electrification criteria by 2035, even in the Subsequent EV Deployment scenario.

However, results are forecasted to change dramatically in scenarios where R&D success is achieved. The R&D success scenarios result in a dramatic increase in vehicles meeting the Substantial Electrification threshold after 2030 due to decreases in upfront vehicle cost, achieving nearly 100 percent of this segment by 2035. These results highlight the critical need for innovation in the medium-duty school bus category for fleet electrification to become a more financially viable option.

FIGURE 81: PERCENT OF MEDIUM-DUTY BUSES (TYPES A AND B) MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECH SCENARIO)

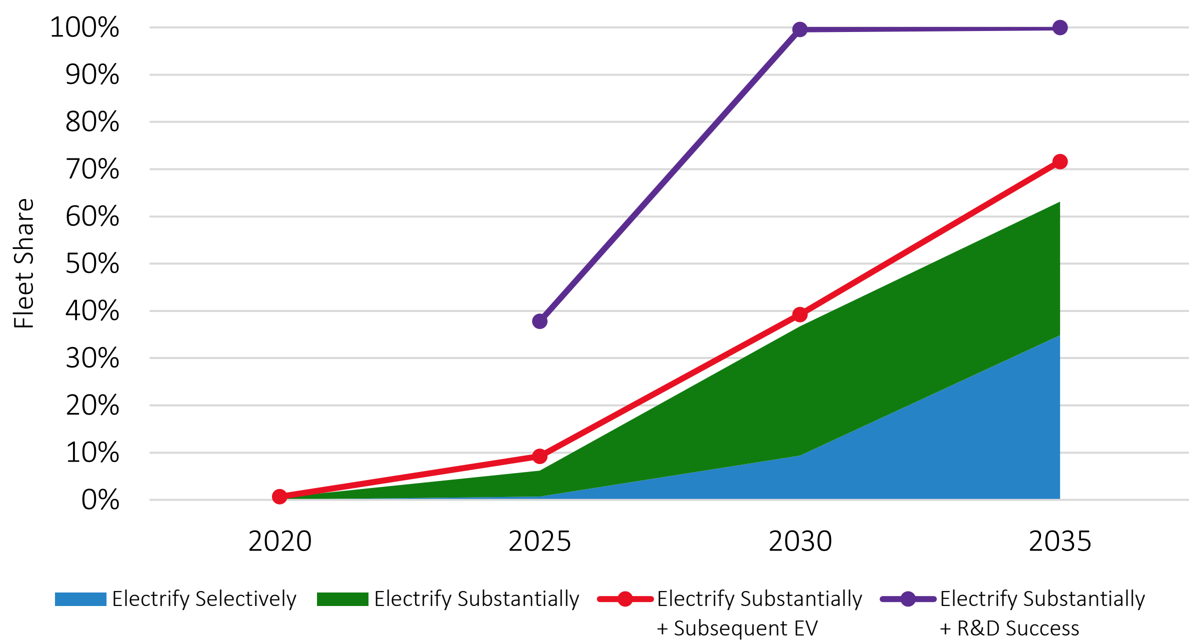


This figure shows the share of medium-duty buses (Type A and B) where the TCO threshold for electrification is met.

HEAVY-DUTY BUSES: TYPE C AND D

Heavy-duty Type D and C school buses represented the majority of the school bus fleet in Washington state, accounting for 47 percent and 37 percent of the total fleet, respectively, for a total of 8,700 vehicles. Of these, nearly none of the heavy-duty buses qualified for electrification on the merit of TCO in 2020 using either Selective or Substantial Electrification criteria (see Figure 82). However, the number of qualifying vehicles in this segment increases dramatically by 2030. The share of heavy-duty school buses meeting the Substantial Electrification criteria in 2035 is over 60 percent in the BAU Tech scenario and nearly 100 percent in the R&D success scenario. This result reflects projections for the manufacturing cost of heavy-duty electric school buses to decrease significantly over the next decade as a result of innovations in battery technology and manufacturing volumes. As with other medium- and heavy-duty segments, the EV deployment scenario has a relatively insignificant impact on vehicle TCO.

FIGURE 82: PERCENT OF HEAVY-DUTY BUSES (TYPES C AND D) MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECH SCENARIO)



This figure shows the share of heavy-duty buses (Type C and D) that would be electrified when the TCO threshold for electrification is met.

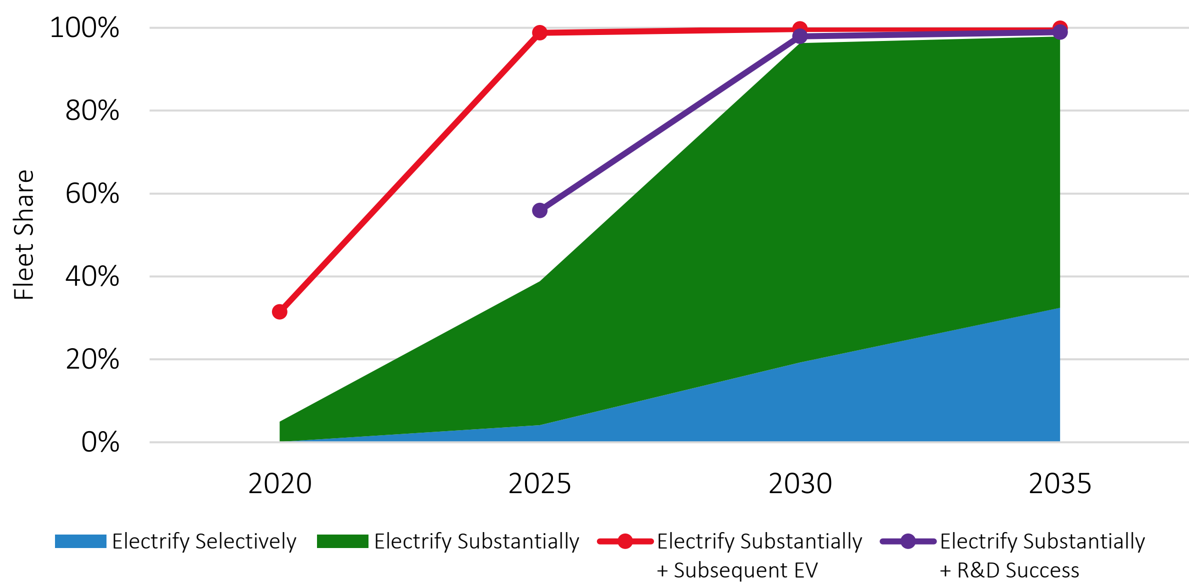
TRANSIT AGENCY ANALYSIS RESULTS

The study team identified over 9,000 vehicles owned by 29 public transit agencies in Washington state. Nearly half of these vehicles are operated by King County Metro. Transit agency vehicles in Washington state are split roughly in thirds among light-duty vans, medium-duty shuttle buses, and heavy-duty transit buses. This section presents results by these weight classes, including light-, medium-, and heavy-duty.

LIGHT-DUTY VEHICLES

Among the approximately 3,000 light-duty vehicles used within transit agencies, the majority of vehicles are minivans used for passenger service, while just over 350 vehicles are passenger cars used for administration or maintenance purposes. Within this segment, the study team found that almost none of these vehicles met the Selective Electrification threshold in 2020, as shown in Figure 83. In addition to having relatively low VMT (annual average of 8,700 miles), and therefore having low potential for fuel cost savings electric minivan options included in the TCO analysis are currently being offered for nearly twice the price of conventional alternatives, making it difficult for EVs to be economically competitive in this segment. However, the share of vehicles meeting the Selective Electrification threshold climbs steadily between 2025 and 2035 where it reaches a value of over 30 percent by 2035. The Substantial Electrification criteria dramatically increases the share of this segment qualifying for electrification from approximately five percent in 2020 to over 95 percent by 2035.

FIGURE 83: PERCENT OF LIGHT-DUTY VEHICLES IN TRANSIT AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECH SCENARIO)



This figure shows the share of light-duty transit vehicles that would be electrified when the TCO threshold for electrification is met.

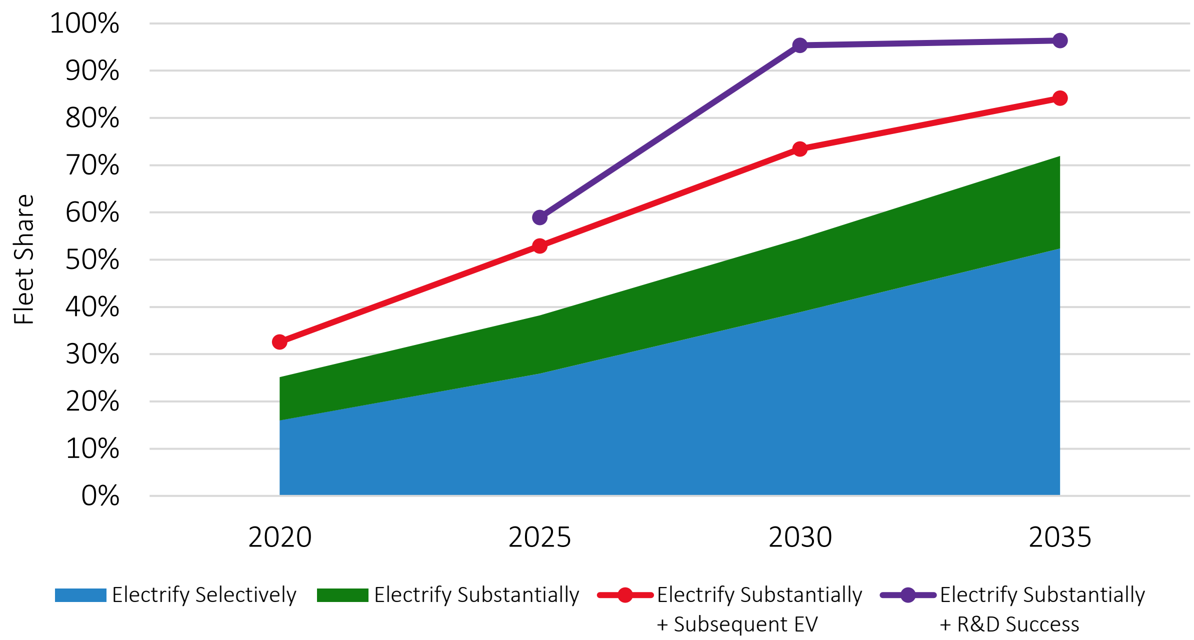
As with other light-duty fleets in this analysis, the impact of the R&D success scenario is found to have a relatively muted impact on the share of vehicles meeting the TCO threshold in any of the scenario years as most vehicles already met the electrification threshold even in the absence of larger price decreases from R&D success. However, the role of charging infrastructure installation costs is shown to be very significant. In a Subsequent EV Deployment scenario, qualifying vehicles in the light-duty transit agency segment reach nearly 100 percent of the fleet as soon as 2025.

MEDIUM-DUTY BUSES

Medium-duty buses accounted for approximately 3,200 vehicles within the transit agency fleet. These vehicles are typically used to provide paratransit, accessibility, or vanpool services to residents across Washington state. Most of these vehicles are shuttle buses with an aftermarket passenger body.

As shown in Figure 84, a significant number of vehicles in this segment (over 15 percent) met the Selective Electrification criteria in 2020. The share of qualifying vehicles steadily increases between 2020 and 2035 with over 50 percent of vehicles within this segment meeting the Selective Electrification criteria in 2035. Application of the Substantial Electrification criteria increases the share qualifying vehicles by 5 to 20 percentage points with over 70 percent of the fleet becoming eligible by 2035.

FIGURE 84: PERCENT OF MEDIUM-DUTY BUSES IN TRANSIT AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECHTECH SCENARIO)



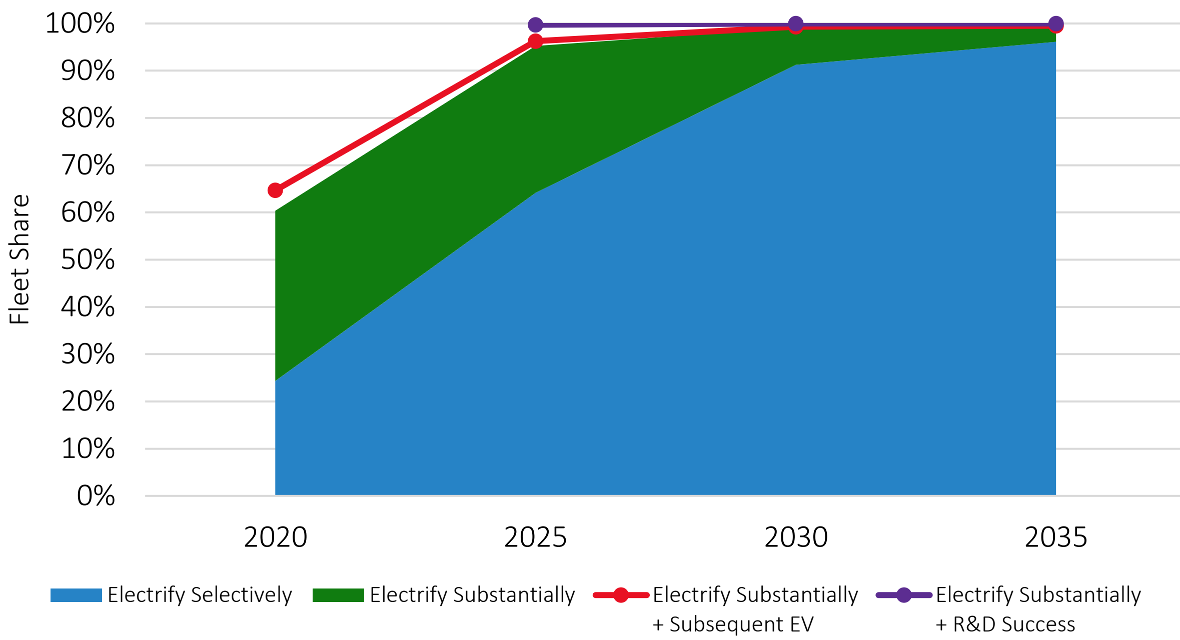
This figure shows the share of medium-duty transit buses that would be electrified when the TCO threshold for electrification is met.

Both the EV deployment and technology development scenarios are shown to be impactful on the share of qualifying medium-duty transit buses. The Subsequent EV Deployment scenario increases the fleet share in this segment by over 10 percentage points across all years, with over 80 percent of vehicles meeting the Substantial Electrification criteria by 2035. Even more impactful is the R&D Success scenario in which over 95 percent of this fleet segment reaches a TCO estimate consistent with the Substantial Electrification criteria by 2030.

HEAVY-DUTY BUSES

Of the nearly 3,200 transit buses found to be in operation in Washington state, the study team found that approximately 25 percent of vehicles in this segment met the Selective Electrification threshold as of 2020 (see Figure 85). This value increases to approximately 60 percent of the fleet when applying the Substantial Electrification criteria. This finding is consistent with the actions of many transit agencies that have begun to investigate the potential for large scale fleet electrification. Transit buses are uniquely suited to take advantage of the low operational costs of EVs based on their high VMT vocation and, in many cases, running on predictable schedules that allow for consistently high utilization of the vehicle's electric range. However, variations in rated electric range, due to battery temperature, battery degradation, and vehicle heating/cooling loads, must be taken into consideration.

FIGURE 85: PERCENT OF HEAVY-DUTY BUSES IN TRANSIT AGENCY FLEETS MEETING THE TCO THRESHOLD FOR ELECTRIFICATION (UNDER THE BAU TECH SCENARIO)



This figure shows the share of heavy-duty transit buses that would be electrified when the TCO threshold for electrification is met.

The share of vehicles meeting the TCO electrification threshold is projected to increase steadily from 2020 to 2030 under the BAU Tech scenario and exceed 95 percent of the fleet by 2035 (in both the Selective and Substantial Electrification scenarios). While the R&D Success scenario paints an even more aggressive picture, the incremental impact is relatively minor due to the extremely high fleet shares already being achieved under a BAU scenario between 2025 and 2035 (in the Substantial Electrification scenario). As with other heavy-duty vocations, the impact of the Subsequent EV Deployment scenario is found to be a minor contributing factor to the overall EV TCO due to relatively low share of TCO accounted for by charging infrastructure.

While the projected TCO analysis provides a positive outlook for the economic viability of battery electric buses, it should be noted that this analysis did not consider vehicle- or route-specific driving requirements or the distribution of daily vehicles miles necessary to accommodate such deep levels of electrification. Based on the data available, EV alternatives were selected based on average, or typical, daily range requirements. Right sizing electric range for agency-specific applications could likely require more aggressive battery capacities (and charging infrastructure) than considered in this analysis, ultimately impacting the study findings.

CHAPTER 6: CHARGING INFRASTRUCTURE

As part of the public fleet electrification analysis, the study team estimated the size and composition of the statewide charging network needed to support the various electrification scenarios. This evaluation leverages the detailed present-day fleet inventory presented in *Chapter 1*, the charging technologies and costs presented in *Chapter 3*, and the TCO-based electrification scenarios presented in *Chapter 4* and *Chapter 5*. While the previously presented vehicle TCO results were inclusive of charging infrastructure, including installation and equipment costs, this chapter provides standalone infrastructure cost estimates for select electrification scenarios and additional discussion regarding potential tradeoffs between charging infrastructure alternatives. The chapter concludes with a brief discussion of the suitability of the electrical grid to meet the demand associated with the fleet electrification in Washington.

BALANCING VEHICLE AND CHARGING DEPLOYMENT

A long-standing dilemma that has plagued alternative fuel vehicles has been the inability to co-develop a vehicle market with a cost-effective network of fueling stations. The lack of economic incentive to deploy alternative fuel vehicles without the prerequisite network of fueling stations, and vice versa, is often analogized to the classic “chicken or the egg” paradox.

Over the last decade, EVs have achieved notable success in breaking this cycle. EV charging stations account for more than 80 percent of all alternative fueling stations in the United States tracked by the Alternative Fuels Data Center [98]. One advantage of EVs relative to other alternative fuel vehicles is that they benefit from electricity being a transportation fuel already produced at scale with a mature network of transmission and distribution infrastructure that enables convenient, affordable fueling in many households. Residential charging or home charging is often thought of as the foundation of charging infrastructure for personally owned EVs (see Figure 86).

Expansion of residential charging has facilitated growth in the EV market, which has increased the demand for charging services away from home at workplaces, destinations, and along highways. Publicly accessible charging networks have grown considerably since 2018 by companies like ChargePoint, EVgo, Greenlots, Tesla, and most recently, Electrify America. These public networks help EV drivers achieve the mobility offered by internal combustion vehicles already supported by a broad network of gasoline and diesel fueling stations.

The need for charging infrastructure away from a vehicle's primary charging location can be described using concepts of charging coverage and charging demand. Charging coverage is defined as geographically dispersed networks of charging stations that provide EV drivers with a full range of mobility. This level of infrastructure availability is necessary for allowing long distance travel, such as cross-county road trips, even if rarely used. Infrastructure coverage needs are generally independent of the EV fleet size, meaning that the same availability of infrastructure is necessary for fleets of all sizes. However, fleet size is a determining factor influencing the level of infrastructure required to meet charging demand. In addition to having full coverage, meeting cumulative fleet charging demand required that sufficient capacity is available to recharge vehicles at will. This prevents queuing (or waiting in line) to charge, something relatively rare to experience at a gasoline or diesel fueling station. The International Council on Clean Transportation provides a recent example of estimating national demand for charging infrastructure [131].

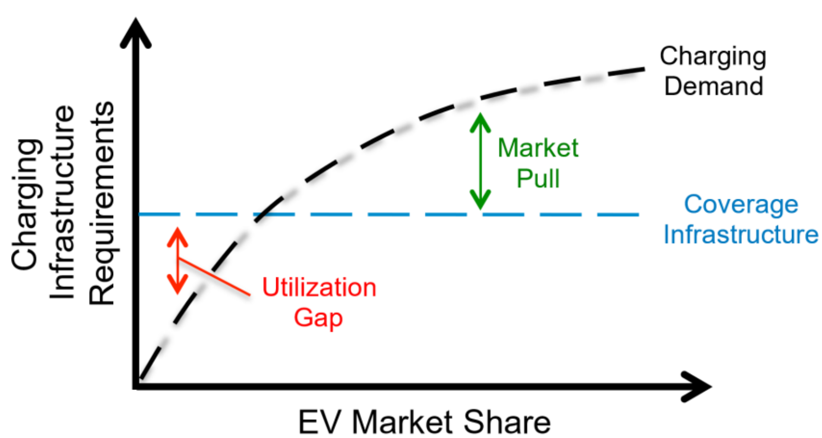
FIGURE 86: EV CHARGING PYRAMID

This figure offers the relative frequency and cost of charging at different locations.

Source: [132]

At initial stages of EV deployment, coverage requirements outweigh the total demand for charging. This mismatch results in low station utilization that can limit the business case for some charging stations without increased demand or other revenue streams. However, as the EV market matures and more vehicles are brought into the system, the need for charging infrastructure increases and eventually exceeds the minimum coverage requirements. This transition is expected to create a "market pull" or natural demand for charging where networks can monitor the utilization of existing assets and make expansion decisions as necessary (see Figure 87).

FIGURE 87: EV CHARGING REQUIREMENT EVOLUTION AS A FUNCTION OF EV MARKET SHARE



This figure shows how charging demand changes with increases in EV market share and charging infrastructure requirements.

Source: [133]

UNIQUE CONSIDERATIONS FOR PUBLIC FLEETS

The concepts outlined in the section above were foundational to the study team's approach to estimating the statewide charging network necessary to enable the substantial electrification of Washington state's public fleet. Just as residential charging is foundational to the electrification of the passenger vehicle fleet, overnight depot charging is the cornerstone of charging for public fleet vehicles. By surveying public fleets in Washington state, the study team estimates that 90 percent of public light-duty vehicles are parked at depot facilities overnight, with the remaining 10 percent of vehicles being taken home by public employees and parked at a private residence. The study team further estimated that nearly all medium- and heavy-duty vehicles within public fleets are parked at depot locations overnight. As such, the analysis of statewide charging needs focuses on overnight depot charging at depots for light-, medium-, and heavy-duty vehicles.

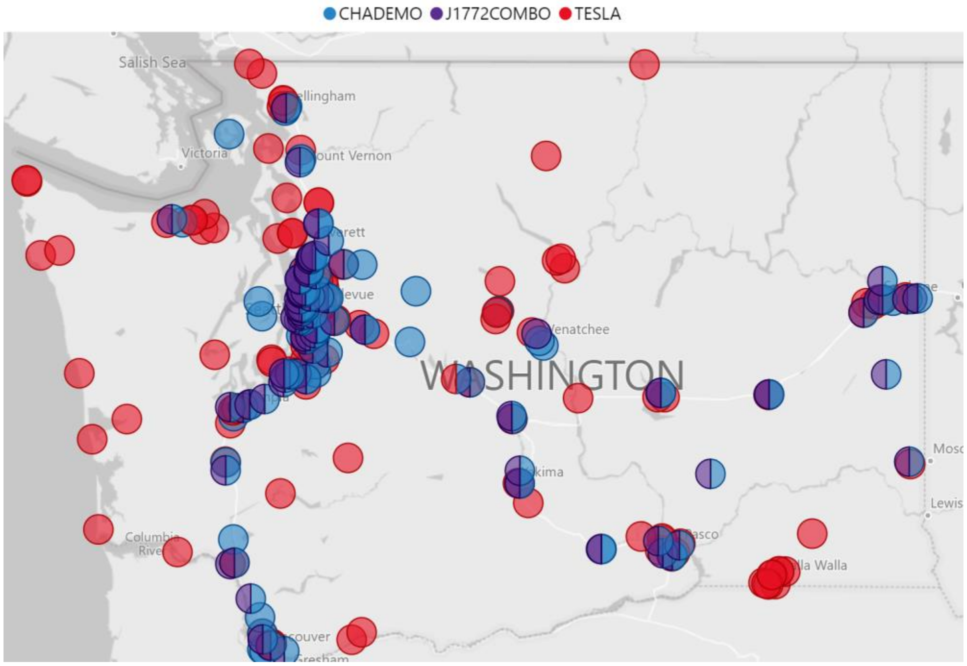
Revisiting the concepts of coverage and demand for public charging infrastructure, the study team evaluated current coverage and projected future demand for charging across the state. There are currently over 1,000 publicly accessible charging stations in Washington state with an average of more than three ports at each station. Approximately 78 percent of these ports are Level 2 charging stations capable of replenishing 10 to 20 miles of range per hour of charging for a light-duty EV. The remaining ports are DC (fast) charging stations capable of replenishing 60 to 80 miles of range per 20 minutes of charging for a light-duty EV. These DC charging stations consist of three unique (and largely non-compatible) connector types: combined charging system (CCS, the most common standard adopted by manufacturers in the United States, Europe, Asia), CHAdeMO (mainly used by Nissan[5] and some Asian manufacturers), and Tesla.

Overall coverage for DC charging supporting light-duty EVs in Washington state is assessed to be sufficient for travel across much of the state, especially within urban areas and across the interstate highway system (see Figure 88 for a statewide map of CCS stations, maps for CHAdeMO and Tesla stations have similar geographic coverage). However, remaining gaps in the network could make it difficult for rural fleets with long-distance travel needs to consider electrification, particularly in the northeastern counties of Chelan, Douglas, Okanogan, Ferry, Stevens, and Pend Oreille.

Compared to the personal light-duty fleet in Washington state, demand for public charging infrastructure from light-duty vehicles in the public fleet is expected to be relatively minimal. The personal vehicle fleet in Washington state includes roughly 5.9 million vehicles [134]. Based on projections from the US Energy Information Administration's Annual Energy Outlook [135], 925,000 personal light-duty EVs are projected to be on the road in Washington state by 2035, approximately 15 percent of all light-duty vehicles based on Annual Energy Outlook's reference scenario. Assuming all vehicles in the public light-duty fleet were to be electrified by 2035, this would account for an additional 22,000 EVs, representing approximately two percent of the projected private light-duty EV fleet. As such, personal EVs are assumed to drive the majority of demand for public charging infrastructure expansion along major highways and in urban areas. No detailed forecast for publicly accessible charging infrastructure supporting public light-duty vehicles is included in this evaluation.

[5] Nissan, the largest EV manufacturer that support CHAdeMO announced in July 2020 that they would move to the CCS charging connector in the United States and Europe, effectively setting a sunset date for this connector in the U.S. market. See https://www.nissanusa.com/ariya.html.

FIGURE 88: STATEWIDE MAP OF EXISTING DC CHARGING STATIONS



This map shows the location of DC charging sites by connector type throughout the state of Washington as of July 2020.

Source: [102]

Dedicated public charging infrastructure designed to support the electrification of medium- and heavy-duty vehicles remains a nascent subject. While three connector standards have emerged for DC charging serving light-duty vehicles (CCS, CHAdeMO, Tesla), design standards for DC charging serving medium- and heavy-duty EVs are still in the early development phase. Presently, medium- and heavy-duty vehicles are using the light-duty DC charging standards, which result in longer charging times in overnight, depot settings. To mitigate this limitation, the CharIN Association is currently leading the development of a DC charging for stations serving medium- and heavy-duty EVs at high power levels on the order of one or more megawatts per connector. The CharIn Association is a non-profit organization that brings together industry stakeholders from the automotive, charging, and electric utility sectors to collaborate on technology development and standard-making activities. Given that these standards are still under development and assuming that investment in public charging infrastructure for medium- and heavy-duty EVs is likely to be motivated by demand from privately-owned vehicles (similar to the light-duty sector), this analysis makes no explicit forecast for publicly accessible charging infrastructure supporting these vehicles in the Washington state fleet.

ASSESSMENT OF DEPOT-BASED CHARGING INFRASTRUCTURE

Charging infrastructure volume and cost estimates were performed for each of the charging scenarios (see Table 8) and the electrification scenarios considered for this analysis. Each charging scenario was developed after taking into consideration the planned and existing charging infrastructure in Washington.

Each charging scenario is configured as a combination of possible infrastructure configurations that can be used for each vehicle type. Table 8 shows the available type of charging station, respective power rating, and vehicle-to-charger ratio in formulating charging scenarios. These charging configurations and related costs of charging infrastructure were accounted for in all TCO estimates and subsequent electrification scenarios. To estimate the charging infrastructure cost, an additional Combined Charging Configuration was devised.

TABLE 23: CHARGING SCENARIOS BY VEHICLE CLASS

Vehicle Class	Charging Equipment	Charger Power (Kilowatts)	Vehicle to Charger Ratio
Light-Duty Vehicles	Level 2 Residential	7.6	1 to 1
	Level 2 Private Depot	11.5	1 to 1
	Level 2 Private Depot	11.5	2 to 1
	DC Private Depot	50	10 to 1
	Level 2 Private Depot	7.6	1 to 1
	Replace Level 2 at Private Depot	11.5	2 to 1
Medium-Duty Vehicles	Level 2 Depot	15.4	1 to 1
	DC Depot	50	5 to 1
	DC Depot	50	2 to 1
	Replace Level 2 at Private Depot	15.4	1 to 1
Heavy-Duty Trucks	DC Depot	150	5 to 1
	DC Depot	50	2 to 1
	DC Depot	50	1 to 1
	Replace DC	50	2 to 1
School Buses	Level 2 Depot	15.4	1 to 1
	DC Depot	50	5 to 1
	Replace Level 2 at Private Depot	15.4	1 to 1
Transit Buses	DC Depot	150	3 to 1
	DC Depot	50	1 to 1
	DC	50	2 to 1
	On-Route	N/A	10 to 1
	Replace DC at Private Depot	50	1 to 1

This table details the charging scenarios considered for each vehicle in the analysis. Different charging scenarios were considered for the different weight classes of light-, medium-, and heavy-duty. Within medium-duty vehicles, school buses were assigned separate charging scenarios. Within heavy-duty vehicles, school buses, transit buses, and trucks were all separately identified.

The Combined Charging Configuration assumes 10 percent—estimated as a weighted average from fleet operators survey responses—of the light-duty EVs rely on home charging. Furthermore, the study team estimated that 20 percent of light-duty EVs would require quick depot recharging using 50-kilowatt DC charging stations with a ten to one vehicle-to-charger ratio. The remaining 70 percent of the light-duty EV fleet was assumed to use high power (11.5 kilowatts) Level 2 charging stations at a depot.

Medium-duty EVs have larger batteries compared to light-duty EVs and often require higher-powered charging solutions to meet operational needs. To model this, the study team assumed medium-duty EVs would rely primarily on 50-kilowatt DC charging stations with a five to one vehicle-to-charger ratio. A similar charging configuration was assumed for electric school buses. Transit buses typically have larger batteries compared to school and shuttle buses as a result of operational requirements for these vehicles. The consistent routes of transit buses, which can place high demands on the range of these vehicles, making it plausible for them to charge at both the depot and on-route. The volume of the charging infrastructure for electric transit buses was estimated considering 80 percent of transit buses are expected to charge at a depot; these charging needs included 50-kilowatt charging stations with a two-to-one vehicle-to-charger ratio and wired on-route charging stations with a ten-to-one vehicle-to-charger ratio.

Figure 89 and Figure 90 show the estimated volume of charging infrastructure for each of the electrification scenarios incorporated in the Combined Charging Configuration. The volume of charging infrastructure increases as the size of the electrified fleet increases for each electrification scenario. As light-duty vehicles are the largest component of the public fleet in Washington, each electrification scenario also results in a higher number of charging stations serving light-duty EVs. Overall, the 50-kilowatt DC charging stations have the highest share of stations, because in the Combined Charging Configuration, each vehicle class uses them at depot facilities. In 2035, the highest level of fleet electrification results from the R&D Success and Subsequent EV scenario with close to 28,000 vehicles meeting the five-percent threshold for electrification. Consequently, the volume of charging infrastructure is the largest in this scenario with 50-kilowatt DC charging stations accounting to 53 percent of the more than 9,500 charging stations included in this estimate. On the contrary, the BAU Tech scenario leads to more than 23,000 EVs in the fleet by 2035 and would require around 8,700 charging stations with 44 percent of the total being 50-kilowatt DC charging stations.

After reviewing the literature and case studies covering charging equipment and installation costs for fleet installations, the study team produced charging infrastructure costs (see Table 9 in *Chapter 3*). As discussed in Chapter 3, the available sources reveal that the cost of installing charging stations decreases with an increase in the number of charging stations installed at a respective location.

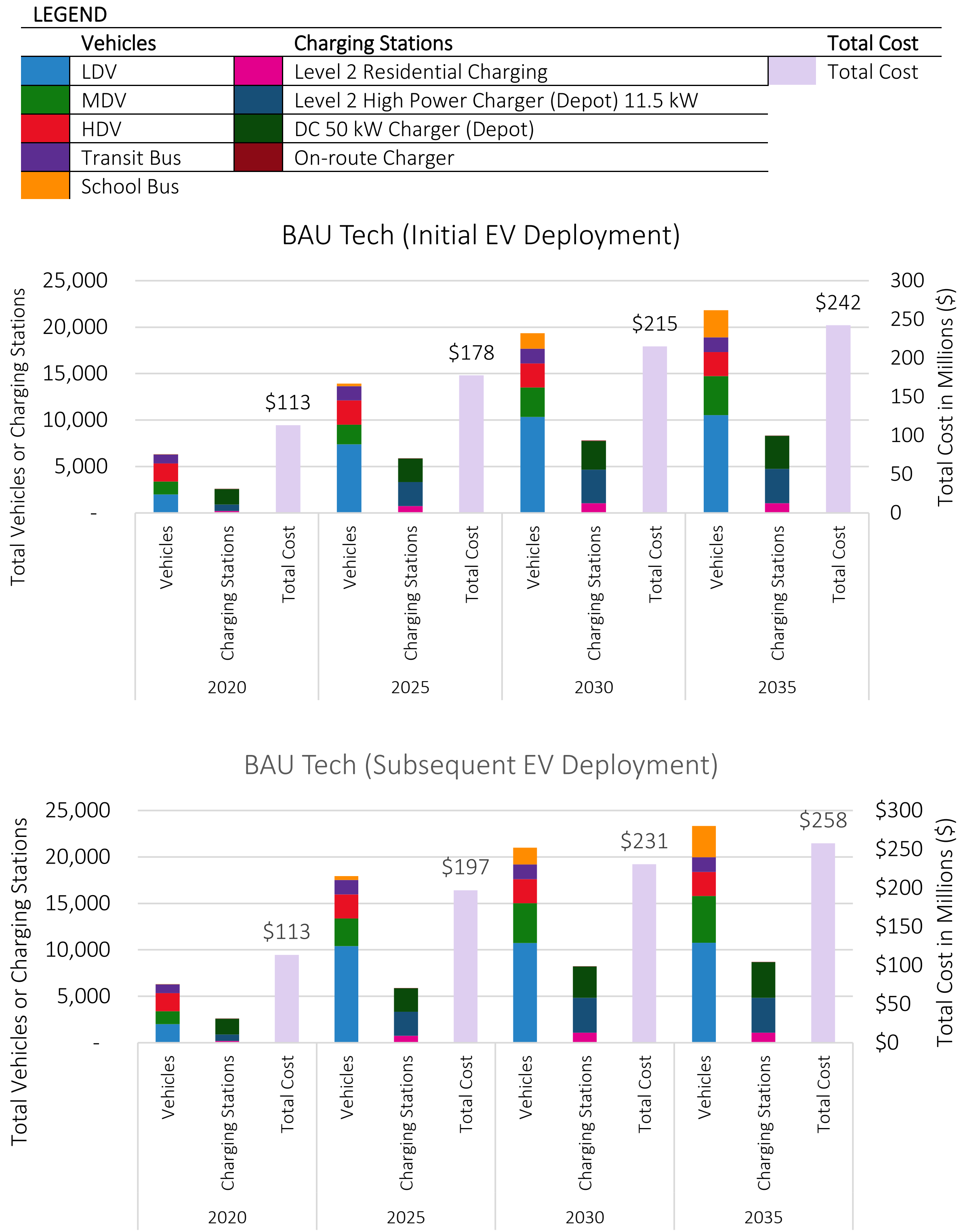
The total costs and deployment for the charging infrastructure are similar across scenarios with respect to the total cost for all EV deployment. The share of costs for charging is between 3 percent and 5.4 percent of the costs for vehicles and charging regardless of the scenario or deployment year. This estimate highlights that charging while in absolute terms is significant (between $100 and $300 million), it is not a high share of the total cost of owning EVs. See Table 24 for a complete summary.

TABLE 24: CHARGING COST AND DEPLOYMENT SUMMARY

Scenario	2020		2025		2030		2035	
	Charging Cost (% of Total)	Total Charging Ports	Charging Cost (% of Total)	Total Charging Ports	Charging Cost (% of Total)	Total Charging Ports	Charging Cost (% of Total)	Total Charging Ports
BAU Tech (Initial EV)	$113m (4.8%)	2,600	$178m (4.1%)	5,892	$215m (3.7%)	7,790	$242m (3.6%)	8,337
R&D Success (Initial EV)	$113m (4.8%)	2,600	$214m (3.9%)	6,912	$298m (3.8%)	9,258	$304m (3.8%)	9,441
BAU Tech (Subsequent EV)	$113m (4.8%)	2,600	$197m (3.6%)	5,892	$231m (3.0%)	8,228	$258m (3.2%)	8,699
R&D Success (Subsequent EV)	$113m (4.8%)	2,600	$233m (5.4%)	8,207	$305m (5.3%)	9,524	$311m (4.6%)	9,675

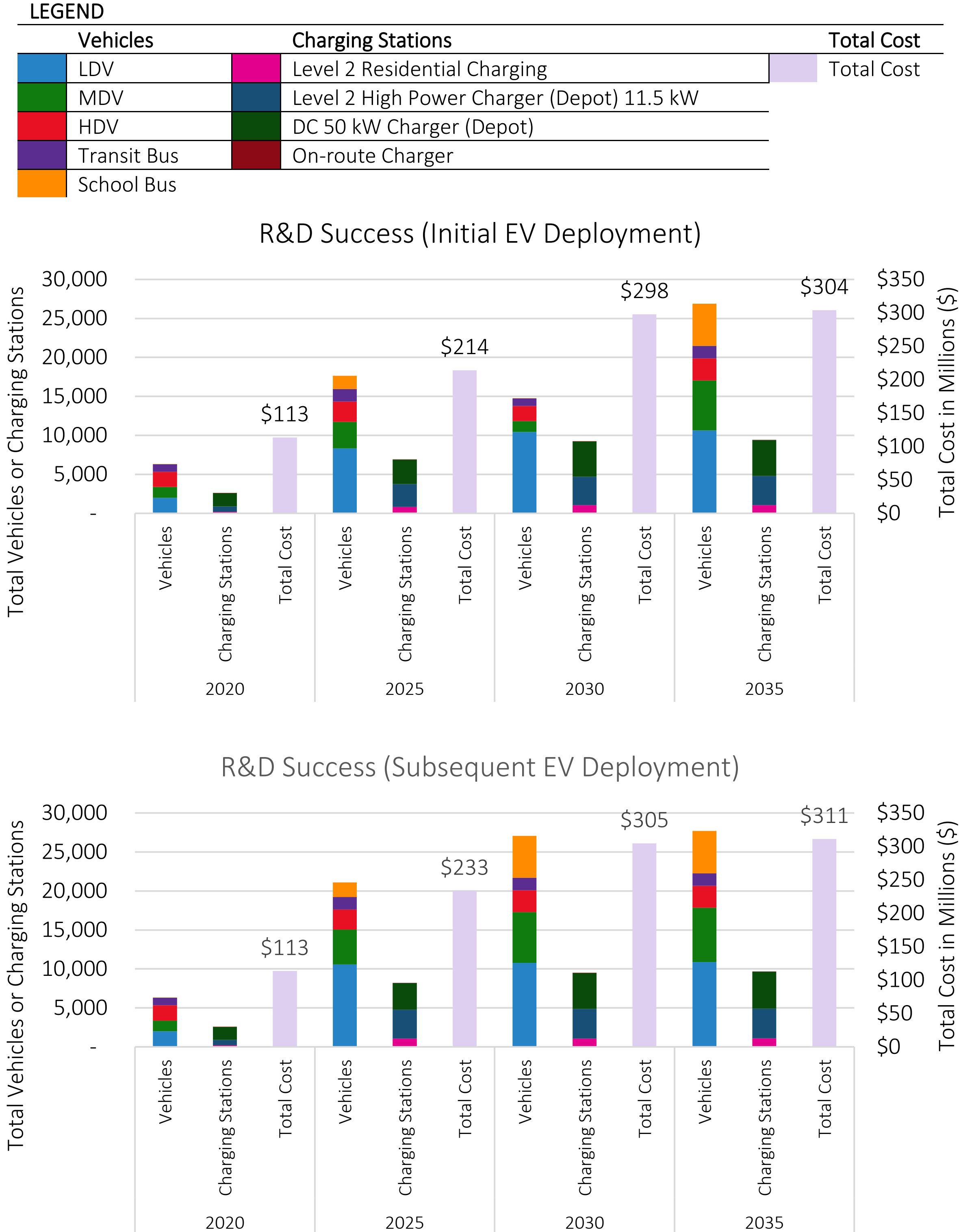
This table summarizes the total charging cost and deployment under the BAU Tech and R&D Success scenarios for an initial and subsequent EV deployments. The EV charging cost share of the total costs (vehicle plus charging) is included.

FIGURE 89:BAU TECH SCENARIO RESULTS



These charts show the total vehicle and charging deployment and total charging costs for an initial EV and subsequent deployment for 2020, 20235, 2030, and 2035 under the BAU Tech scenario.

FIGURE 90:TECH SUCCESS SCENARIO RESULTS



These charts show the total vehicle and charging deployment and total charging costs for an initial EV and subsequent deployment for 2020, 20235, 2030, and 2035 under the BAU Tech scenario.

ELECTRICAL GRID EVALUATION

While not the primary focus of this analysis, the electrical grid's ability to serve new load brought on by transportation electrification is a critical question. The question becomes especially relevant in Washington state, which has committed to 100 percent of electricity generation being greenhouse gas neutral by 2030 as required by the Clean Energy Transformation Act [8]. While this would represent a significant challenge in many parts of the United States, Washington state is fortunate to already enjoy electricity that is generated from 86 percent greenhouse gas free sources, as of 2018 [136].

A useful simplification of the electrical grid is to consider all of the bulk system assets used to generate power independently from the network of transmission and distribution infrastructure used to move power from generating assets to commercial and residential load sources. This section will briefly comment on the suitability of generation and distribution assets to accommodate new load brought on by the substantial electrification of public fleets.

GENERATION IMPACTS

At the bulk system level, the study team has estimated that full electrification of the 56,080 light-, medium, and heavy-duty vehicles in Washington state's public fleet would result in approximately 0.69 terawatt-hours (TWh) of new annual electric load from EV charging. While this is a tremendous amount of energy in an absolute sense, the impact is likely minimal relative to existing electricity generation within Washington state. Considering that in 2018 117 TWh of electricity was generated in Washington state, the public fleet's full electrification would increase electricity demand by about 0.6 percent. Assuming a 0.69 TWh increase in system load over 10-15 years would likely be well within the capacity of the state's electric utilities given that recent electricity generation has varied by tens of TWh from one year to the next (likely due to weather patterns, the economy, population/industry migration, regional electricity imports/exports, etc.).

While a more detailed analysis of generation-level impacts from the public fleet's electrification was not in scope for this analysis, several studies have examined the issue in greater detail at the national and regional levels. The U.S. Department of Energy recently sponsored a study examining the sufficiency of U.S. electricity generating capacity for widespread adoption of light-duty plug-in electric vehicles [137]. One major conclusion of the study was that:

> *"Sufficient energy generation and generation capacity is expected to be available to support a growing EV fleet as it evolves over time, even with high EV market growth."*

While this study did not consider the necessary upgrades to electricity distribution systems or electrification of the medium- and heavy-duty fleet, the study states that:

> *"...[those caveats] do not weaken the overarching conclusion that the adoption of electric vehicles at scale will not pose significantly greater challenges than past evolutions of the U.S. electric power system."*

Additionally, the National Renewable Energy Laboratory led a similar analysis that included a primary scenario with 73 million light-duty electric vehicles on the road nationally by 2035 (in addition to more aggressive scenarios) [138]. They found that:

> *"Electricity demands from light-duty electric vehicles are small in comparison to total installed electric capacity and resulting generation, and the majority of incremental capacity and generation are projected to come from renewable sources by 2035."*

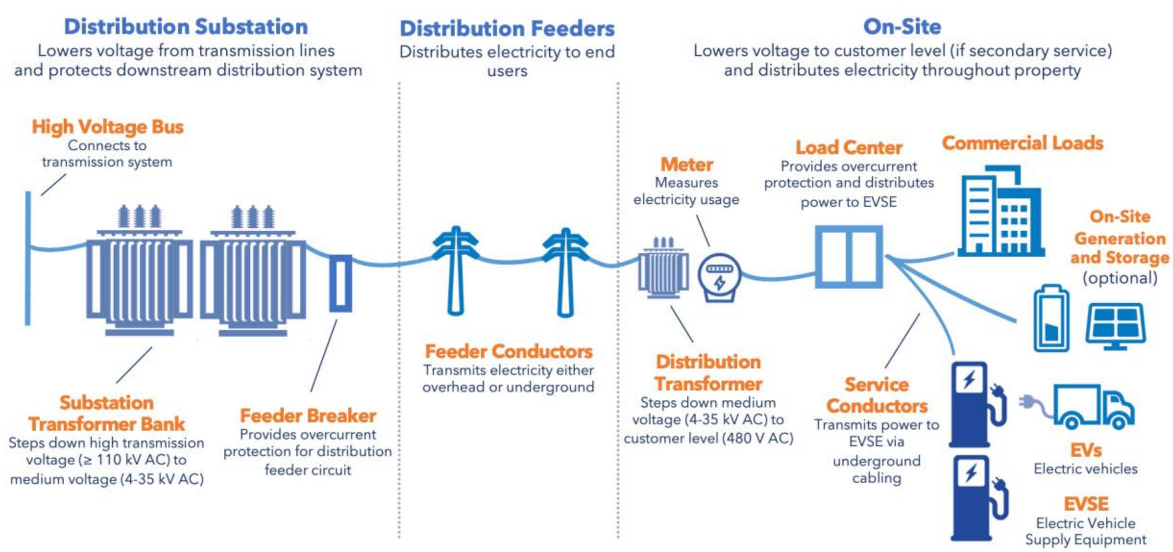
Given the relatively small size of Washington state's public fleet (56,080 vehicles) compared to the state's total vehicle fleet (including nearly six million light-duty vehicles plus commercial medium- and heavy-duty vehicles), the above findings suggest that Washington state's electric utilities appear to be well-positioned to support substantial electrification of the public fleet.

DISTRIBUTION IMPACTS

More so than the grid's capacity to generate additional electricity, a potential barrier to electrifying the public fleet is the ability of distribution infrastructure to provide power to the necessary locations. This analysis has assumed that the majority of EV charging within the public fleet will occur at depots where vehicles are stored overnight. In some cases, these depots may have low levels of existing electrical service, and substantial electrification of their fleets may require significant local service upgrades.

Local upgrades to the distribution system could be necessary "in front of the meter" (typically property of the electric utility) or "behind the meter" (typically a property of the customer). Upgrades in front of the meter could include the on-site transformer or, in extreme cases, upgrades to the upstream substation. Behind the meter, upgrades could include new switchboards, circuit breakers, and on-site wiring. A schematic of the site-level distribution infrastructure as it relates to EV charging is shown in Figure 91.

FIGURE 91: SCHEMATIC OF TYPICAL ELECTRICITY DISTRIBUTION COMPONENTS



Source: [139]

Two critical considerations related to distribution system upgrades are the capital cost and the timeline necessary to complete the installation. Costs associated with upgrades to local distribution systems are site-specific and will vary significantly based on the number and rated power of charging ports being installed, existing hosting capacity available on each leg of the network (the difference between installed capacity and existing peak load), and presence of on-site storage and/or generation.

While the costs of upgrades are perhaps an obvious consideration, the timeline necessary to complete these upgrades can also be a barrier. While it is likely that on-site upgrades behind the meter can be completed relatively quickly (i.e., weeks to months), in the event that a request for new electrical service requires upgrades on the utility side of the meter, projects will need to plan for significantly longer delays (i.e., months to years).

The nature of installing EV charging infrastructure (potentially high costs and long lead times) suggests that fleet operators would be well served to take a long-term perspective on fleet electrification. While the study team's TCO analysis has indicated that there is excellent potential for lifetime cost savings associated with substantial electrification, proactively installing charging infrastructure well in advance of vehicle procurement may be necessary to ensure that fleet managers can take advantage of volumes of scale when installing new charging infrastructure. Scale to decrease charging equipment and installation costs and scale to reduce the cost of upgrades to the depot's electrical infrastructure could all prove efficient in the long run.

CHAPTER 7: QUALITY EMISSIONS SAVINGS

In addition to providing opportunities to provide economic benefits to fleets, EVs also offer considerable societal benefits through reduced transportation emissions. While earlier chapters go into great depth on EV TCO, this chapter focuses on the role of reduced emissions as one of the primary motivations for investment in fleet electrification. Estimates for the emissions savings associated with electrification of Washington state's public fleet and the geographic distribution of savings across the state are outlined below.

STATEWIDE EMISSION BENEFITS

Distance-based emissions rates for light-, medium-, and heavy-duty vehicles were developed for internal combustion engine (ICE) vehicles and their EV alternatives based on the vehicle energy consumption rates and the mix of electricity generating assets across Washington state's power system [140] [141] [142] [143].

For each ICE vehicle, one to three EV alternatives were identified by the study team (as described in *Chapter 3*) with emission rates associated with charging calculated as the average across all the EV alternatives. The electrification of light-duty vehicles in the public fleet reduces CO_2, NO_X, PM_{10}, and $PM_{2.5}$ emissions by 88 to 91 percent per mile. Reductions are even greater for medium-duty vehicles with an emission reduction range for these same pollutants between 90 and 94 percent. Heavy-duty vehicles benefit even more from electrification for all types of emissions. For vehicles of all weight classes, SO_X and VOC emissions are reduced by 96 percent to 99 percent. The estimated emission rates for ICE vehicles and EVs by weight class are shown in Table 25. The emission rates for the EV alternatives of light-duty vehicles are higher than medium- and heavy-duty vehicles in some categories including SO_X and VOC due to the inclusion of PHEVs as potential EV alternatives with the light-duty segment.

Assuming the vehicle miles traveled (VMT) remain the same before and after electrification, the annual emissions savings associated with electrification of each vehicle in the public fleet is calculated as the product of the vehicle-level emissions reductions per mile and annual VMT. The annual VMT distribution and summary statistics of the state agency fleet is shown in Table 25. On average, heavy-duty vehicles accumulate approximately 25% greater distance traveled than both light- and medium-duty vehicles.

While the TCO analysis went to great lengths to examine economic costs under a variety of electrification scenarios, estimations of the emissions benefits have been simplified to consider full electrification of the public fleet. Included in these estimates are the 28,913 vehicles from the TCO analysis originally presented in *Chapter 3*. Approaches for valuing these emission benefits are discussed in *Chapter 8*.

Electrifying all 28,913 vehicles analyzed in Washington state could lead to an annual CO_2 reduction of nearly 750,000 tons (as shown in Table 26). According to the statistics from the Department of Ecology, the transportation sector in Washington state emitted a total of 43.5 million metric tons of carbon dioxide equivalent in 2017 [9]. For reference, the public fleet CO_2 emission savings potential achieved through full electrification of all vehicles analyzed would account for an estimated 1.7 percent of Washington state’s 2017 carbon emissions.

The CO_2 emission savings of heavy-duty vehicles account for approximately 77 percent of the CO_2 and 80 percent of the particulate matter emissions savings of the whole fleet, even though heavy-duty vehicles only account for 40 percent of the vehicles analyzed. While electrification of the heavy-duty fleet is more costly, it also provides greater marginal emissions savings across most emissions categories. Medium-duty vehicles account for roughly 14 percent of the CO_2 and 10 percent of the PM2.5 emissions savings potential. Light-duty vehicles account for nine percent of the CO_2 and PM2.5 emissions savings potential.

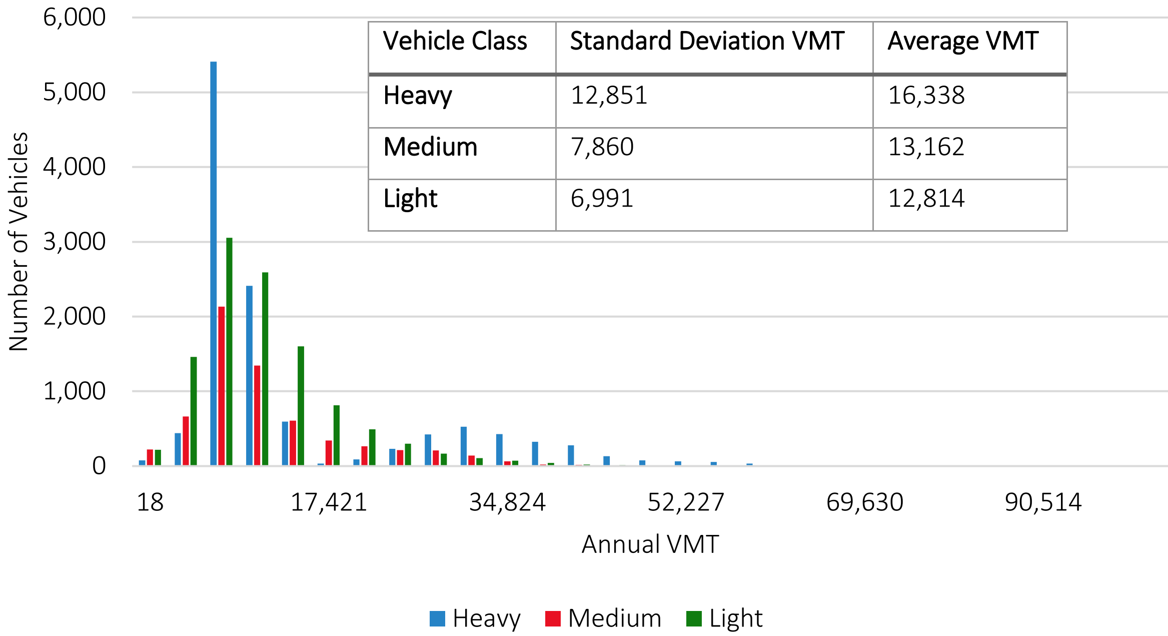
TABLE 25: PER MILE EMISSION RATES FOR ICEVS AND EV ALTERNATIVES

	Vehicle Class	Summary Statistics	CO_2 (lbs/mi)	NOX (mg/mi)	SOX (mg/mi)	VOC (mg/mi)	PM10 (mg/mi)	PM2.5 (mg/mi)
ICEV	HDV	Mean	6.34	6847.02	477.99	867.94	134.01	116.73
		Std Dev	1.33	1.43	99.94	181.48	28.02	24.41
	MDV	Mean	2.84	1128.03	215.96	185.66	40.68	34.16
		Std Dev	0.77	320.12	54.94	60.08	10.10	8.72
	LDV	Mean	1.06	326.81	113.36	309.77	24.19	17.61
		Std Dev	0.30	93.23	32.24	88.16	6.88	5.01
EV alternative	HDV	Mean	0.47	133.33	3.27	1.52	8.81	5.32
		Std Dev	0.12	35.13	0.86	0.40	2.32	1.40
	MDV	Mean	0.22	64.01	1.57	0.73	4.23	2.56
		Std Dev	0.05	13.10	0.32	0.15	0.86	0.52
	LDV	Mean	0.13	36.80	4.35	10.43	2.52	1.62
		Std Dev	0.09	28.00	10.19	27.99	2.08	1.52

TABLE 26: STATEWIDE ANNUAL EMISSION BENEFITS FROM ELECTRIFICATION OF THE PUBLIC FLEET

	Number of vehicles	CO_2 (ton)	NOX (kg)	SOX (kg)	VOC (kg)	PM10 (kg)	PM2.5 (kg)
LDV	10962	68416.7	42160.9	15951.1	43798.3	3179.2	2344.3
MDV	6262	106300.9	86440.9	17353.2	14787.4	2954.5	2562.0
HDV	11689	572020.0	1313003.0	92947.9	169700.4	24409.2	21752.5
TOTAL	28913	746737.5	1441604.8	126252.2	228286.0	30543.0	26658.8

FIGURE 92: ANNUAL VMT DISTRIBUTION OF PUBLIC FLEET BY WEIGHT CLASS



Vehicle Class	Standard Deviation VMT	Average VMT
Heavy	12,851	16,338
Medium	7,860	13,162
Light	6,991	12,814

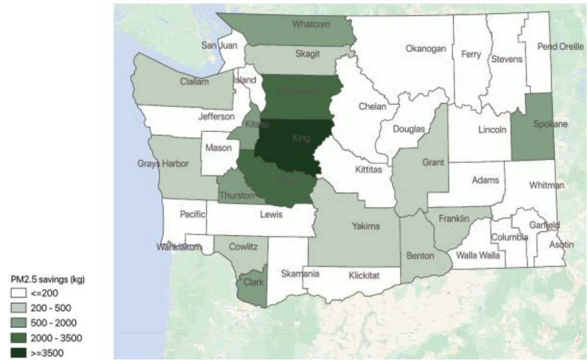
GEOGRAPHIC DISTRIBUTION OF EMISSION BENEFITS

While electrification of the public fleet provides significant statewide emissions benefits, these benefits are not distributed evenly across the state. Areas with relatively large existing public fleets are expected to see the greatest emissions savings from fleet electrification.

Vehicle-level emissions savings are aggregated based on the county that each vehicle serves to generate county-level savings. Figure 93 and Figure 94 how the geographic distribution of emissions benefits related to reductions in CO_2 and PM2.5 at the county-level. For vehicles that serve a region that covers multiple counties such as the South Puget region that includes King, Kitsap, Pierce, and Thurston Counties, it is assumed that the emissions savings are equally distributed among the counties. The geographic distribution of the emission categories reflects relative fleet sizes: Snohomish and King Counties have the highest levels of emissions savings from the fleet electrification, followed closely by Pierce and Thurston Counties.

FIGURE 93: COUNTY-LEVEL ANNUAL CO_2 SAVINGS

FIGURE 94: COUNTY-LEVEL ANNUAL $PM_{2.5}$ SAVINGS



Though heavy-duty vehicles contribute the most to the emissions savings for a large majority of the counties, the ratios of the emissions savings among the three vehicle classes vary greatly by county, as shown in Figure 95, Figure 96, and Figure 97. More than 90 percent of the potential emissions savings for Ferry and Lincoln Counties come from the electrification of heavy-duty vehicles. These vehicles made up about 80 percent of the potential emissions savings for King, Pierce, Snohomish, San Juan, and Walla Walla Counties. Columbia, Skamania, Wahkiakum, and Island Counties saw the highest percentage of their potential emissions savings coming from electrification of medium-duty vehicles. Thurston and Kittitas Counties have more than 25 percent of their potential CO_2 emissions savings coming from electrification of light-duty vehicles, significantly higher than other counties.

FIGURE 95: RELATIVE CO_2 SAVINGS FROM HDV ELECTRIFICATION

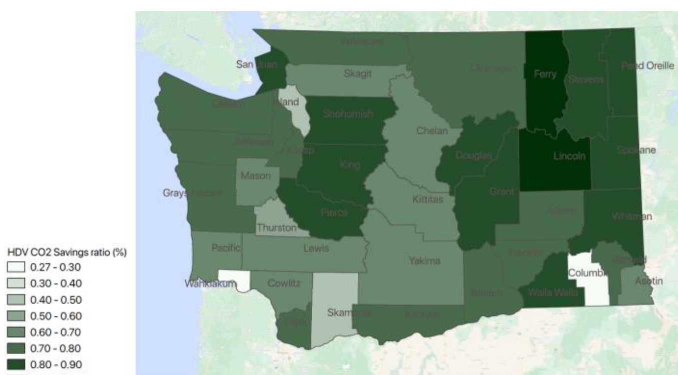


FIGURE 96: RELATIVE CO_2 SAVINGS FROM MEDIUM-DUTY ELECTRIFICATION

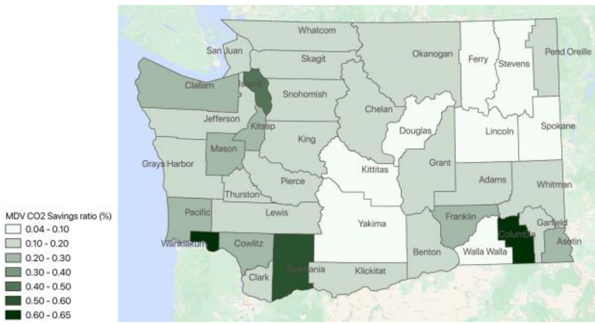
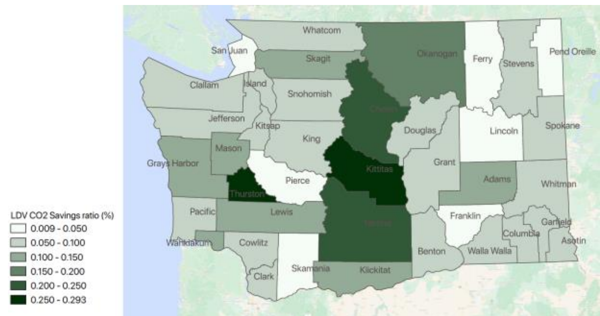


FIGURE 97: RELATIVE CO_2 SAVINGS FROM LIGHT-DUTY ELECTRIFICATION



Though the county-level emissions savings show which counties have the largest emission savings potential by electrifying their public fleets, it does not clearly show the intensity of the emissions changes within the region. Criteria emissions such as NO_X, SO_X, and measures such as PM10 and PM2.5 have the most influence on local air quality. Therefore, emissions benefit estimations have been disaggregated from the county-level to a two-mile grid across the entire state. The disaggregation process leveraged the ratio of the publicly reported annual average daily travel (AADT) on the road network inside each grid compared to the total VMT on the road network within the county. The emissions savings in each grid were calculated according to Equation 4, with the assumption that the VMT distribution of a state agency fleet on the road network is proportional to the road usage considering all vehicles within the county or region it serves.

Equation 4 $$Emission\ Savings_{grid} = Emission\ Savings_{county} \times \frac{Total\ VMT_{grid}}{Total\ VMT_{county}}$$

The 2018 Highway Performance Monitor System (HPMS) dataset is used to calculate the AADT by grid cell. HPMS is a national-level highway information system maintained by the United States Federal Highway Administration that includes data on the use and operating characteristics on all public roads, including AADT estimates for most major road segments. The daily VMT for each road segment is calculated as the product of the segment's AADT value and the segment length. Segment-level VMT is then aggregated to the grid- and county-level. The distribution of grid-level $PM_{2.5}$ and PM_{10} savings are illustrated in Figure 98 and Figure 99, respectively. PM emissions savings are concentrated along a few major corridors and urbanized areas with significant vehicle activity, such as along I-5, I-90, I-82, the greater Seattle region, Olympia, Tacoma, and Spokane.

FIGURE 98: GRID-LEVEL $PM_{2.5}$ EMISSION SAVINGS

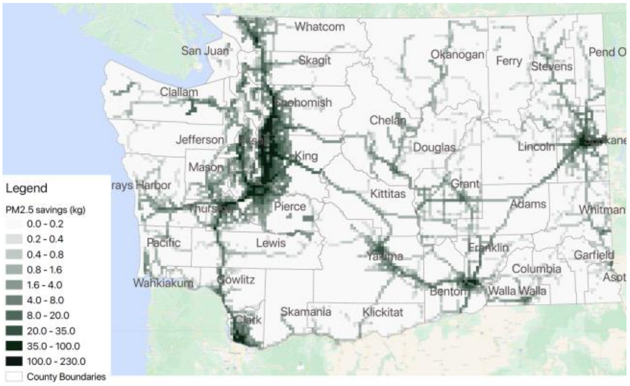
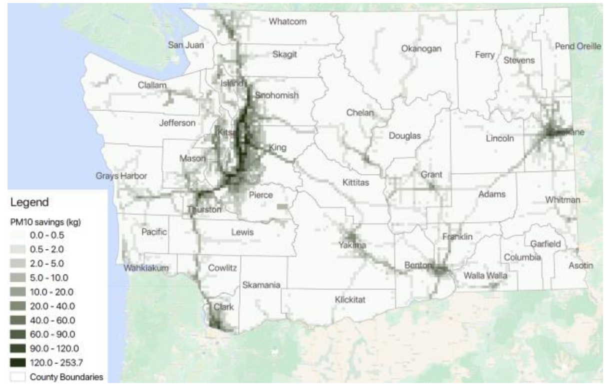


FIGURE 99: GRID-LEVEL PM_{10} EMISSION SAVINGS



CHAPTER 8: FINANCING MECHANISMS AND PUBLIC POLICIES

Assessing the effects of public policies and innovative finance mechanisms on electric vehicle fleet procurements requires a deep understanding of the barriers fleet managers face, including gaining access to capital funds necessary for vehicle purchasing, charging station deployment, and electrical infrastructure upgrades; installing charging infrastructure at leased properties; and determining best practices for vehicle procurement. The previous four chapters of this study describe in great detail the costs and benefits of transitioning Washington's public vehicles to electric with today's market and policy conditions. This chapter explores how financing mechanisms and potential future policies could help accelerate that transition.

Washington has a variety of different funding mechanisms available to help facilitate the electrification of fleet vehicles statewide. As a part of the overall fleet assessment, the study team conducted a review of these approaches by identifying existing examples of financing options and determining how they could be applied to transportation electrification in Washington. The study team identified the following financing mechanisms and policy strategies:

- Energy performance contracting
- Public financing programs
- Vehicle leasing
- Right to charge legislation
- Fleet management services and vehicle use optimization
- Vehicle to grid technology
- Clean fuel standards and credit systems
- Utility grants and rebates
- State grant programs
- Bundled procurements and cooperative purchasing

Fleet electrification is expected to provide considerable benefits to the electrical grid as well as savings for operators [10]. Washington faces challenges and opportunities that can be addressed both by leveraging the state's existing policy framework and exploring new interventions. For example, the lack of ownership of properties where vehicles are located can be circumvented by "right to charge" policies requiring that landlords allow tenants (public agencies in this case) to install charging on the premises [144].

There are several resources Washington can use to determine general best practices for fleet electrification. The Electrification Coalition has produced a number of useful resources from their work on creating fleet electrification roadmaps including a best practices document for financing [145]. The Center for Climate and Energy Solutions has conducted reviews of existing fleet electrification strategies that cover a range of challenges and successes experienced by different city governments [146]. Their report purports that public-private hybrid financing mechanisms can spread out the investment risks while building a stronger business case for EVs by reducing the need to raise funds from outside sources requiring interest payments. The Rocky Mountain Institute found that issuing a request for information from local and regional stakeholders, developing a list of viable alternatives to existing vehicles, and identifying opportunities for pre-planning before any procurements are issued can save time and allow for greater collaboration based on their work electrifying government fleets in Hawaii [147].

This chapter will define various financing mechanisms and policy strategies the state government could pursue and highlight their applications to Washington's fleet managers. Combining some of these mechanisms can help all corners of the state benefit from fleet electrification efforts. For example, the state could use the cost savings from some policies to pursue the electrification of more challenging vehicle use cases.

Generally, this chapter uses TCO thresholds of 10 percent and 20 percent. These figures were chosen for illustrative purposes; the criteria established in WAC 194-28 is that any EV alternative that is within five percent of the TCO of its internal combustion engine counterpart shall be used. A summary of the effects of policies analyzed using a 10 percent TCO threshold are included in Table 27.

TABLE 27: EFFECT OF POLICY OPTIONS ON FLEET ELECTRIFICATION AT THE 10 PERCENT THRESHOLD

Policy Modeled	Number of Additional Vehicles to Electrify	Percent of Fleet Analyzed	Additional Operational Cost Savings from Electrification
Vehicle-grid Integration	468	2%	$17,326,753
Carbon Price	1,725	6%	$84,032,302
Level 2 Infrastructure Grant	1,828	6%	$1,114,852
DC Charging Grant	813	3%	$18,707,575
Truck and Bus Grant Funding Program	12,065	42%	$510,153,977
Bundled Procurements	1,149	4%	$671,420

ENERGY PERFORMANCE CONTRACTING

In conversations with state agency staff and other stakeholders in Washington throughout this study, the most commonly cited barrier to electrification among state agencies was lack of charging infrastructure or lack of funding for charging infrastructure. Washington has implemented rules under Chapter 194-28 and 194 – 29 WAC which establish that state agencies and local governments shall replace existing vehicles with alternative fuel vehicles "to the extent practicable" and lack or difficulty of installing charging infrastructure is a justification often cited by state agencies to not electrify vehicles. This section explores the potential role of energy performance contracting in providing access to funding for charging infrastructure as well as vehicles.

According to the Southwest Energy Efficiency Project, "Energy Performance Contracting (EPC) is a financing mechanism used to pay for energy efficiency improvements all at once that are then paid back through annual energy savings" [148]. These contracts are implemented by Energy Service Companies (ESCOs), private businesses that offer a variety of energy solutions ranging from energy efficiency upgrades to infrastructure supply.

Washington has already seen successful with EPC models and the Washington State Energy Programs has completed more than $1.4 billion in performance contracts since 1985 [149]. Between 2014 and 2015, investment in EPCs increased from $4.8 to $6.7 million and the state received an additional $10 million from the Office of Efficiency and Renewable Energy's State Energy Program between 2010 and 2019 [150]. Throughout the program's history, Washington has avoided more than 300,000 tons of annual carbon dioxide emissions [149].

At the municipal level, the City of Boulder in Colorado leveraged energy performance contracts to achieve 25 percent energy savings across 66 buildings facilitated in part by the implementation of a demand response program using EV batteries. The $16 million program relied on a combination of government grants, utility rebates, and private investment to tie charging infrastructure deployment to facility upgrades. This helped offset the cost of charging as well as leverage the investment to achieve overall goals of reducing carbon emissions and fulfilling climate goals [151].

In Washington, staff members at the Department of Commerce in conversations with the study team have pointed to the opportunity to lump utility upgrades with general building maintenance costs to offset EV charging costs and maximize resources available to expand fleet charging infrastructure. Existing EPC frameworks available in the Washington State Energy program can be expanded to include transportation electrification investment. This could encourage further coordination with the state's electric utilities which could capitalize on the benefits of EV charging if the stations are considered as energy efficiency investments.

While performance contracting has traditionally been applied to energy efficiency upgrades for buildings, some states are beginning to explore this as a viable option for fleet vehicle acquisition [148]. In 2013, Colorado modified previous legislation to explicitly include fleet electrification as an eligible intervention for performance contracts. Specifically, the modified bill expanded the eligibility definition to include fuel and operational cost savings associated with alternative fuel vehicles as viable ways to improve energy efficiency. Fleet operators could then use the savings associated with fleet electrification to pay off loans used to purchase them [152]. Since the original performance contracting legislation was established in the 1990s, more than 152 entities in Colorado have worked with third-party Energy Service Companies (ESCOs) to identify $35 million in annual savings potential. The Colorado Energy Office estimates that these potential savings have led to an investment of $574 million for energy efficiency upgrades [153].

For the multi-variate TCO analysis, no scenarios were evaluated specifically related to ESCOs. However, for charging infrastructure, the effects of an ESCO on TCO calculations could be similar to the effects seen when applying the policy explored in *Utility Grants or Rebates*. Unlike a typical ESCO, however, this approach would be using funds from building energy efficiency projects as opposed to capturing the energy savings from EVs. A project that only captures the direct energy savings from EVs would not have a positive effect on the TCO.

PUBLIC FINANCING PROGRAMS

Government has played a constructive role in accelerating clean energy deployment through several innovative finance programs. This section covers two programs related to EVs: revolving loan funds and loan loss reserve programs. Both programs could improve access to funding for entities looking to purchase EVs and EV charging by reducing risk and lowering the cost of capital. In cases where EVs are already likely to have a favorable TCO, loan programs can help fleets overcome upfront acquisition cost barriers to realize potential savings.

Revolving loan funds are often publicly funded programs that can allow state or local governments to lend money to other public or private entities to acquire goods or services, including alternative fuel vehicles

[145]. The funds are paid back by the borrowers and then re-issued to other borrowers. So long as loans are repaid, the program can be self-sustaining if operating costs associated with administering the loan are covered by interest payments or other means.

A revolving loan fund can provide access to capital for the purchase of EVs and charging equipment in cases where EVs are deemed cost effective. This can be useful for inflexible public budgets that have more funds allocated for operating expenses than capital expenses; this is common for conventional fleet operations because of the high cost of fueling and maintaining a conventional vehicle relative to its acquisition cost. As explained throughout this report, EVs tend to be the opposite, with low operating costs and high acquisition costs. Loan programs can help address EV's high acquisition costs in the near term until fleet operators gain more experience with EVs [154].

Washington has already taken this policy approach and electrification of fleet vehicles is included in the Clean Energy Fund, a statewide revolving loan and grant program established in 2013 to advance clean energy development and deployment in Washington. The Washington Department of Commerce manages the Clean Energy Fund as well as the Electric Drive Washington website which includes a range of resources for state and local governments looking to electrify fleets [155]. While the revolving loan portion of the program only applies to energy projects, the program also includes grants for charging infrastructure for government entities and includes a prioritization of fleets operating in underserved communities. The most recent round of funding made $10.6 million in grants available for eligible projects. Overall, the Clean Energy Fund has already dispersed $152 million across all areas of the program including loans and grants for transportation electrification projects as well as renewable energy and grid modernization [156].

Another way to improve access to capital for borrowers for EV and charging purchases is to lower the risk of lending for private institutions. A loan loss reserve serves a backstop for lenders in case a borrower is unable to payback a loan. This program reduces the risk of default which can result in lower interest rates, an expanded pool of borrowers, or both. The California Capital Access Program (CalCAP) Electric Vehicle Charging Station (EVCS) Financing Program, created in 2015, has a loan loss reserve of $2 million used to encourage private lenders to fund EV charging projects. Borrowers can borrow up to $500,000 and once the funds are paid back, they can receive a rebate from the state for 10 or 15 percent up to $75,000 [157]. Although this program has been around for five years, it only issued two loans through 2019 worth an average of $250,000 [158].

It is important to note that loan programs do not improve the TCO for EVs, making their role in supporting transportation electrification most valuable for cases where the TCO for EVs is favorable but the upfront acquisition cost is a barrier. When EVs result in a net savings, loan programs can open doors to new opportunities for electrification by improving access to the upfront capital to invest in charging infrastructure and acquire new vehicles. In other cases, these programs offer less value. For example, a 2014 case study on Utah's Clean Fuels and Vehicle Technology Grant and Loan Program found that the program was consistently oversubscribed with more applications than there was available funding. It also concluded that more applicants favored the program's grant offerings over the loan component and would often get loans from private financial institutions and use the CFV funding to pay off the third-party loan when capital funds were not available [159]. Utah now offers several tax credits and grant-based programs supporting charging infrastructure and vehicle conversions. This includes a workplace charging rebate program that was allocated $4.9 million in 2019 [160].

Although the limited influence loan programs have on the TCO of EVs resulted in this policy being excluded from the analysis, implementing a loan program could be a key opportunity for Washington by the Department of Commerce, especially if it is expanded to include state agencies. The state is considering a zero percent interest rate to maximize the electrification potential enabled through the program; the current interest rate for the Clean Energy Fund revolving loan program is two percent. Although zero percent interest would certainly be a lower cost to borrowers, a two percent loan program could address capital and operating budget allocation issues. It is also likely that outreach and promotion of such a program would be important to ensure participation based on the low number of loans issued in Utah's program referenced above. When these budgetary issues exist and a net savings is likely for an EV in the present day (see *Chapter 4*) or the near future (see *Chapter 5*), a direct lending program or a program that reduces the cost of borrowing from a private institution (e.g., a loan loss reserve) could have meaningful impact on fleet electrification.

VEHICLE LEASING

Fleet vehicle leasing is a way for governments to have flexibility and avoid being locked into a version of technology that is rapidly changing, like EVs. Leasing can also reduce risk for fleets when adopting new technology by avoiding large upfront capital commitments. Leases also reduce risks associated with vehicle resale value, which can be uncertain in part because of the rapid changes in the technology. Lease contracts can also be designed in a way that allows government ownership at the end of the contract or by establishing a return of the vehicle to the lessor.

Historically, one advantage of vehicle leasing was avoiding having the asset appear on the balance sheet (operating lease). This advantage is no longer possible Under the Generally Accepted Accounting Principles (GAAP). Thus, all leases are considered capital leases today and leases are no longer a way to help address the barriers associated with inflexible public budgets that have more funds allocated for operating expenses than capital expenses. Leases can have two structures, closed-end and open-end, which determines whether the lessor or lessee maintains ownership of the vehicle. In addition, leases can be structured to enable the lessee take ownership of the vehicle at the conclusion of the lease, referred to as a tax-exempt lease purchase [161].

Lease arrangements typically do not lower the TCO for a vehicle because of the involvement of a third party. One exception is a leasing arrangement for the vehicle battery since that is an asset that can have a notable value after at the end of its useful life in a vehicle. Electric bus manufacturer Proterra offers a battery leasing program that allows transit agencies to purchase the bus chassis while leasing the battery. Proterra will replace the depleted batteries and redeploy the battery in a second life application [162]. Through the end of 2019, at least 100 buses had been procured under this program which is funded with at least $200 million through a joint venture with Mitsui [163]. California and Virginia have both taken advantage of this program and have selected Proterra as the supplier for statewide electric transit bus procurement contracts [164, 165].

Several government entities actively use vehicle leasing for fleet procurements. For example, government fleets in the California Bay Area have benefitted from the provision of full-service lease plans where the vehicle owners covers "all costs of acquiring, operating, and monitoring of an EV fleet" and charge the operator a lease payment based on vehicle-miles-traveled. This approach is similar to a conventional electric power purchase agreement and can encourage more effective fleet management [166]. Vehicle providers have also been able to access federal and state level rebates and tax incentives and pass these savings on to the lessee to reduce the cost of the lease [167].

At the time of this study, public fleets in Washington are prohibited from entering into lease agreements for vehicles. This is due to the limitations on encumbering funds required for a multi-year lease.

As mentioned above, leasing programs do not typically lower TCO costs. As such, the study team did not model the effects of procurements. However, the effects of a battery leasing program, like the one offered by Proterra, on a vehicle TCO would be similar to the vehicle incentive programs modeled in the *State Grant Programs* and *Capturing the Full Federal EV Tax Credit* sections.

RIGHT TO CHARGE LEGISLATION

In conversations with stakeholders in Washington for this study, the study team found the most commonly cited barrier to electrification in Washington is that of charging infrastructure. According to a representative from the Washington State Department of Commerce, approximately 90 percent of facilities used by the state are leased rather than owned by the state. These leasing agreements rarely cover the installation of charging infrastructure and, even in the case where landlords are amenable to the addition of charging stations, government entities must consider if there will be a return on investment over the lifetime of the lease.

One emerging policy solution to overcome this barrier and accelerate the pace of electrification in Washington is "right to charge" legislation that applies to renters. The Northeast States for Coordinated Air Use Management (NESCAUM) defined "right to charge" as laws that provide tenants or property residents the right to install charging infrastructure assuming the tenant will cover the associated costs of the infrastructure. As of October 2019, five states, California, Colorado, Hawaii, Florida, and Oregon, have implemented statewide right-to-charge laws. California and Oregon were the only states where these laws applied to renters as well as owners [168].

On August 31, 2020, California legislators passed Assembly Bill 841 authorizing $1 billion in new spending on a package of different energy efficiency measures including dedicated funding for EV charging. The bill includes right-to-charge elements directed towards the state's utilities by requiring them to invest in the distribution infrastructure and utility-side upgrades required to provide charging services to customers throughout the state. This significantly reduces the upfront costs faced by public agencies, businesses, and other groups looking to install EV charging and eliminates the need for regulatory approval for each investment in grid upgrades to service EVs [169].

Right to charge legislation could address a primary barrier cited by officials at the Washington State Department of Commerce, resistance from property owners towards installing EV charging at facilities housing fleet vehicles. Implementing additional policies modeled after California's AB 841 could help fleet managers accelerate electrification by reducing the upfront cost associated with permitting and preparing their sites for rapid expansion of charging infrastructure.

Right to charge legislation was not modeled directly in the study. As it is an enabling policy, it has no discernible effect on the TCO for EVs but could be an essential step to advance public fleet electrification at sites not owned by the government.

FLEET MANAGEMENT SERVICES AND VEHICLE USE OPTIMIZATION

Fleet management refers to any effort to maximize fleet efficiency and cost savings. Outcomes of these services include the streamlining and scheduling of EV charging, reduction of vehicle usage, and determining the optimal fleet vehicle fuel mix. A first step in fleet management often requires fleet assessment, which is the primary goal of this study. In addition to the Fleet Procurement Analysis Tool used for this study, Argonne National Lab has developed the AFLEET tool to help fleet managers optimize fleets and understand differences in total cost of ownership across a range of conventional and alternative fueled vehicles [140].

Many state governments and electric utilities across the country are actively engaged in providing fleet management services to accelerate fleet electrification. The program mentioned in greater detail in the *Utility Grants or Rebates* section from Xcel Energy in Minnesota remains the one of the leading examples of utility engagement in this field [170]. The program is designed to provide tailored services to fleets as they assess the electrification potential of their vehicles and look to optimize charging infrastructure deployment. California utilities like Pacific Gas & Electric and Southern California Edison have developed guidelines and resources for fleet operators. In particular, Pacific Gas & Electric has published a comprehensive guidebook for their customers to explore fleet electrification [171].

At the state level, the Colorado Energy Office offers fleet coaching services for local governments through the ReCharge Colorado program [172]. The coaching service helps local governments identify funding opportunities and build stakeholder support networks. In Washington, Washington State University's Green Transportation Program provides unbiased, up-to-date education and technical assistance to support the transition of public fleets to cleaner fuels. The Department of Commerce also provides information on effective fleet procurement practices via their Drive Electric Washington website [155].

Businesses in the EV sector such as private charging service providers are also actively engaged in providing fleet management services. Charging service providers like ChargePoint offer EV charging management service for EV fleet operators. The company has partnered with the University of California at San Diego to help manage charging of their fleet vehicles and offers a mix of different charging technologies to increase the overall efficiency of the fleet [173]. The market for fleet management services is growing and several private sector entities including GreenLots, Electriphi, and Geotab all offer fleet and charging management services [174, 175, 176]. Another private company Samsara has developed nine core recommendations to help fleet operators maximize efficiency including software solutions to manage dispatching, reducing idle time, and establishing a clear vehicle replacement plan [177].

From a policy perspective, the federal government engages in fleet management by requiring regular reporting from federal fleet managers to ensure they are meeting regulatory requirements established by the EPA [178]. The U.S. Government Accountability Office (GAO) has also established guidelines and recommendations to help fleet managers develop and meet efficiency targets [179].

Effective fleet management covers all aspects of a fleet's operations from procurement through replacement. Highlighted in *Chapter 4* was the relative importance of charging strategy, useful life, and annual VMT in the procurement planning for an EV. Below are some of the key insights gleaned from that research:

- Targeting vehicles with high annual mileage for electrification can substantially increase the savings from electrification. The average per-vehicle savings from electrifying vehicles in the 10th percentile of annual mileage was just under $1,600. The average per-vehicle savings from electrifying vehicles in the 90th percentile of annual mileage was more than $620,000.
- Extending the useful life of vehicles was found to have a relatively minor impact on TCO for EVs and was primarily relevant for vehicles which traveled in excess of 31,000 miles per year.
- Optimizing the charging strategy for light-duty vehicles can result in significant increases in both the number of vehicles that can be electrified cost-effectively and the savings from electrification. The difference between the choosing the highest- and lowest-cost charging configuration included in the analysis was the electrification of an additional 548 vehicles and at a cost savings

of more than $1.1 million. This effect was less significant across all medium- and heavy-duty vehicles, but could be the deciding factor for medium- and heavy-duty EVs that were most cost-competitive with their internal combustion equivalents like transit and shuttle buses.

- The most effective method to increase the electrification potential of vehicles is to target low-cost EVs when selecting an EV alternative. The difference in electrification potential when selecting the highest- and lowest-priced EV was dramatic, resulting in an increase of 160 percent in the number of vehicles that met the threshold for electrification and an additional savings of more than $60 million. A key piece of planning an EV procurement is right-sizing, or selecting the most appropriate vehicle that still meets the needs of the use case. King County Metro is already doing this as part of the MetroPool program which uses cheaper Nissan Leaf vehicles instead of minivans to provide carpooling services to residents.

VEHICLE-TO-GRID TECHNOLOGY

Vehicle-grid integration (VGI) is defined by the California legislature as “any method of altering the time, charging level, or location at which grid-connected electric vehicles charge or discharge, in a manner that optimizes plug-in electric vehicle interaction with the electrical grid and provides net benefits to ratepayers” [180]. These efforts are often led by electric utilities and strategies can include both indirect tools such as time-of-use (TOU) rates encouraging off-peak charging as well as utility-managed charging where the utility directly controls charging station energy use. EVs can also provide bi-directional power flow (V2G) where EVs act as distributed energy resources for grid operators [84].

VGI is not just beneficial to the electrical grid but also to EV drivers and fleets. Access to favorable electricity rates and managed charging incentives can lower fuel cost for fleet operators and encourage EV adoption. More than 20 states have rates that are favorable to EVs, including TOU rates [35]. Pacific Gas & Electric (PG&E) and Southern California Edison’s commercial and industrial EV rates offer fuel cost savings of up to 50 percent by tailoring rates to more accurately reflect the cost of service and therefore offering lower rates for charging at certain times [181]. PG&E went a step further by removing demand charges and replacing them with a subscription fee to allow for more predictable savings for fleet operators and to avoid the situation where fast charging stations with low utilization incur large demand charges due to their high power requirements [182]. PG&E and SCE’s transportation electrification programs have not just been beneficial to EV drivers and combined, these two utilities have already generated up to $806 million in revenue above costs between 2012 and 2019 through the implementation of their transportation electrification [84]. This additional reveprorevenue can help lower electricity rates or provide more investments into transportation.

In addition, fleet operators may be able to generate revenue for vehicles if they are allowed to sell power back to the grid by using V2G technologies [183]. For V2G, the use of vehicles that are parked for extended periods with large batteries, such as school buses, are particularly promising though this technology is not expected to go beyond demonstration projects in the near future [184].

The study team modeled a VGI policy via a decrease in electricity rates where the demand charge is mitigated. For electricity rates, the study team considered a flat commercial rate with no demand charge, a commercial rate with a demand charge and a commercial rate with smart charging to mitigate demand charges. The team modeled the commercia rate with a demand charge by doubling the flat commercial rate with no demand charge and the team modeled the commercial rate with smart charging by multiplying the flat commercial rate with no demand charge by 1.5. For the VGI policy, the rate was assumed to be less than the smart charging rate, at 1.2 times the flat commercial rate (see *Chapter 3*).

A VGI program has a small, positive effect on the electrification potential of all vehicle classes, increasing the share of vehicles that meet TCO thresholds by between one and five percent. For light-duty vehicles, a VGI program increases the number of vehicles that met the 10 percent threshold by 32 percent, reaching seven percent of all light-duty vehicles at a net cost of $366,101. At the 20 percent threshold, a VGI program increases the number of vehicles by a similar level (36 percent) reaching 19 percent of all light-duty vehicles at a net cost of $10.6 million.

For medium- and heavy-duty vehicles specifically, a VGI program has a similar effect on the TCO of EVs versus conventional vehicles. An additional 271 trucks and buses met the 10 percent threshold described in Table 28at a sizeable net savings of $55 million. In total, 11 percent of trucks and buses met the threshold for electrification. At the 20 percent threshold, the costs of electrification rose noticeably, reaching $100.8 million. At this level, 17 percent of the total truck and bus fleet can be electrified.

The overall effect of the VGI program modeled in this study was small, resulting in between 453 and 994 additional EVs that had a favorable TCO compared to conventional vehicles than would otherwise be deployed. However, California has demonstrated that these programs can generate significant revenue above costs even when they include costs for the charging installation. As a result, VGI programs may be combined with other policies, such as the *Utility Grants or Rebates* resulting in a much larger, positive effect on transportation electrification.

TABLE 28: SUMMARY OF RESULTS FOR VGI PROGRAM

Smart Charging with VGI Program	Vehicle Class	Electrification Threshold (% TCO of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	All	10%	2,314	8%	-$37,336,863
No	All	20%	4,126	14%	$95,826,624
Yes	All	10%	2,767	10%	-$54,663,060
Yes	All	20%	5,120	18%	$121,405,292
No	Light	10%	571	5%	$414,359
No	Light	20%	1,547	14%	$8,124,419
Yes	Light	10%	753	7%	$366,101
Yes	Light	20%	2,108	19%	$10,653,388
No	Medium/Heavy	10%	1,743	10%	-$37,755,456
No	Medium/Heavy	20%	2,579	14%	$87,697,605
Yes	Medium/Heavy	10%	2,014	11%	-$55,029,161
Yes	Medium/Heavy	20%	3,012	17%	$110,751,904

CLEAN FUEL STANDARDS AND CREDIT SYSTEMS

Clean fuel standards and cap-and-invest programs are beginning to take hold in different areas throughout the country. At the regional level, the Regional Greenhouse Gas Initiative (RGGI) is generating revenue for clean energy and transportation investments, including EV rebate programs [185]. The program has already saved customers in member states more than $1 billion on energy bills and it has helped finance state rebate programs like New York's Drive Clean EV program which is funded at more than $55 million [186]. Many of the states in RGGI are also considering a regional cap-and-invest program through the Transportation and Climate Initiative that could finance clean transportation. The group received significant public support for this type of approach based on the responses to a public comment period that closed in December 2019 [187].

California and Oregon are the only two states to have established market-based credit systems offering credits to entities that reduce the carbon intensity of transportation fuels [46]. California's credit-based program is called the Low Carbon Fuel Standard (LCFS) program and Oregon's is called the Clean Fuels program. The LCFS program in California has generated more than $100 million in credits for utilities, drivers, charging station hosts, and other entities each year since 2017 [188]. Legislation in California requires the utilities to use credits to benefit "current and future EV customers" in the state, instituting a positive cycle of reinvestment in transportation electrification. Funds from the LCFS program have also helped advance truck electrification of private fleets [189]. Oregon's Clean Fuels Program has generated an estimated $7 million from the credit system and is expected to amass another $5.5 million in 2020 [190]. Washington is also considering adopting a clean fuel standard program [191].

The study team used the social cost of carbon as determined by Washington in WAC 194-40-100 to assess the impact a carbon pricing program could have on the value proposition of EV adoption in Washington. The social cost of carbon can be used to approximate the monetary value of benefits that are not accrued specifically to fleet owners but are accrued to society. The social cost of carbon, while not directly incurred by one specific person or entity, is meant to reflect real monetary values and is calculated based on scientists' and economists' projections regarding costs such as health costs and natural disaster damages. The United States Interagency Working Group on the Social Cost of Greenhouse Gases in 2016 described the social cost of carbon as "the monetized damages associated with an incremental increase in carbon emissions in a given year" and explained that these damages include things like "changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change ." Even in the absence of a carbon pricing policy, there are carbon-related costs and benefits associated with varying degrees of transportation electrification that a social cost of carbon analysis can help approximate [192].

The social of carbon in Washington is $74 per ton which could be used to inform a carbon price for vehicle emissions being considered in Washington House Bill 1110, a bill to implement a clean fuels standard [193, 194]. This threshold is significantly lower than the current average carbon price of $200 per ton on the California market established through the LCFS program [188].

A price on carbon, as implemented via a clean fuel standard or credit-based system would have a significantly positive effect on the electrification potential of all vehicle classes. For light-duty vehicles, a price of $74 per ton nearly triples the number of vehicles that met the 10 percent threshold, reaching 14 percent (1,520) of all light-duty vehicles at a net savings of $145,208. At the 20 percent threshold, a carbon price increases the number of vehicles by nearly 160 percent reaching 36 percent (3,904) of all light-duty vehicles at a net cost of $16 million.

For medium- and heavy-duty vehicles, the price on carbon is less pronounced than for light-duty vehicles but is still significant due to the considerable cost savings at the 10 percent threshold. A carbon price results in a 40 percent increase in the number of trucks and buses at the 10 percent threshold at a sizeable net savings of $121 million; with the carbon price, 14 percent (2,519) of trucks and buses met the threshold for electrification. Raising the threshold to 20 percent results in a considerable cost increase, reaching $96.4 million with a carbon price. At this level, 22 percent (4,006) of the total truck and bus fleet can be electrified.

In sum, a carbon price can result in the electrification of between 1,725 and 3,774 additional vehicles in the present day beyond what would be done otherwise. Considering the promising results from *Chapter 5* for the TCO of many EVs, it is likely a carbon price would bring in the timeline for widescale fleet electrification using only funding from the pricing of greenhouse gas pollution. A summary of the carbon price analysis results is in Table 29.

TABLE 29: SUMMARY OF RESULTS FOR CARBON PRICE

Carbon Price	Vehicle Class	Electrification Threshold (% TCO of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	Light	10%	571	5%	$414,359
No	Light	20%	1,547	14%	$8,124,419
Yes	Light	10%	1,520	14%	-$145,208
Yes	Light	20%	3,904	36%	$16,305,419
No	Medium/Heavy	10%	1,743	10%	-$37,751,222
No	Medium/Heavy	20%	2,579	14%	$87,702,206
Yes	Medium/Heavy	10%	2,519	14%	-$121,223,957
Yes	Medium/Heavy	20%	4,006	22%	$96,478,545

UTILITY GRANTS OR REBATES

Utility grants and rebates are made by investor-owned, publicly owned, or cooperative electric utilities and are a valuable way to monetize some of the public benefits of EVs. These programs typically provide funding to qualifying entities to install charging infrastructure or purchase EVs. As of October 2020, programs at least partially targeted at public or private fleets exist in at least 27 states valued at more than $1 billion. Washington utilities including Puget Sound Energy, Pacific Power, and Avista Utilities account for $4.3 million of this total, although all programs are directed towards private fleets. Puget Sound Energy's program is the largest at $2.8 million for 150 charging stations [41].

Among approved fleet programs for investor-owned companies, 23 utilities in 13 states have EV charging programs that provide rebates for customer charging infrastructure installation, utility ownership of charging infrastructure, and utility investment in make ready infrastructure, which covers all components of installation up to the charging station itself as well as any necessary local upgrades to the electrical grid [41].

Xcel Energy in Minnesota operates a notable fleet program and was approved in April 2019 to invest more than $25 million, part of which is going towards their Fleet EV Service program for government fleets. For this program, the utility is working with fleet operators to identify opportunities to save money and partner with the utility on vehicle electrification. The pilot program will invest $14.4 million for at least 200 charging stations to be used by the state government to support fleet electrification targets. The program also includes the installation of charging infrastructure for electric transit buses [195].

At the municipal level in Washington, Seattle City Light ("City Light") worked with Rocky Mountain Institute to develop the utility's transportation electrification plan. The plan, which was approved by the city council in October 2020, focuses on fleet electrification and providing make-ready investments to scale up charging infrastructure [196, 197]. Focus on fleet electrification has allowed the city to electrify 20 percent of light-duty city vehicles and the newly approved plan will accelerate the focus on electrifying high mileage vehicles including transit buses. The city has already deployed 300 fleet charging stations in partnership with the municipal utility to support more than 200 fleet EVs since the initiative launched in 2017 [198].

For this report, the study team assessed the effects of charging infrastructure grants on the total cost of ownership of EVs. The remainder of this section assesses the results of a program that covers 100 percent of the equipment and installation costs for Level 2 equipment and 50 percent of costs for DCFC.

Funding these programs would require additional action by investor-owned electric utilities, publicly owned utilities, and public utility districts. As discussed above, Washington utilities statewide have active programs to support transportation electrification. In some cases, these programs have already been found to provide a net benefit to ratepayers, meaning the revenue generated from the additional electricity costs outweigh the program costs. Between 2012 and 2019, increasing EV adoption has generated $801 million in revenue above costs for California's two largest utilities [199]. These promising findings are a major opportunity to reduce a notable cost component of the TCO for EVs of all classes.

LEVEL 2 GRANT PROGRAM

The study team modeled Level 2 charging grant programs based on existing programs offered by utilities in Washington. In particular, customers of Pacific Power in Washington were able to request up to 100 percent of the cost of charging installations in a $900,000 program approved in October 2018. Modeling utility grants covering up to the full cost of charging infrastructure equipment and installation also came out of talks with staff members at the Department of Commerce.

For all vehicle classes that relied on Level 2 charging, 1,623 out of 25,999 vehicles had an EV alternative that was 10 percent or less above the TCO of the conventional vehicle on average and 3,520 vehicles had an EV alternative that was 20 percent or less expensive. Reaching 10 percent electrification for these vehicles would save the state $15.2 million, even without a charging infrastructure grant while getting to 20 percent would cost more than $2.6 million.

The addition of the grant would allow the state to electrify considerably more vehicles at both the 10 percent and 20 percent thresholds. More than 3,400 vehicles met the 10 percent threshold and 7,574 met the 20 percent threshold (29 percent of all vehicles that would charge at Level 2). The 10 percent threshold would save the state about the same as without the grant program ($16.3 million) but would electrify an additional 1,828 vehicles. At the 20 percent threshold, the state would need to invest $11.8

million. While this figure is $9.2 million higher than without the grants, it would result in the electrification of more than 4,054 additional vehicles.

Looking at light-duty vehicles reveals the challenges and opportunities of a grant program for Level 2 charging stations. For these vehicles, the upfront cost of the charging infrastructure is a much larger share of the total cost than for other vehicle classes. Without the grant program, seven percent of vehicles met the 10 percent threshold and 23 percent of vehicles met the 20 percent threshold. With the grant program, 24 percent of vehicles met the 10 percent threshold, and nearly 60 percent of vehicles met the 20 percent threshold. The cost to electrify these vehicles with the grant program is between $1.5 million and $22.5 million, however, depending on the threshold used.

The grant program has little impact on the cost effectiveness of medium-duty or heavy-duty vehicles. Without the grant, six percent of vehicles met the 10 percent threshold and seven percent of vehicles met the 20 percent threshold. Even at the 20 percent threshold, the state can still save $9.7 million because the savings for some vehicles outweighs the additional costs for other vehicles. The grant has a minimal effect on this finding; at a 20 percent threshold, the state can electrify eight percent of these vehicles at cumulative savings of $10.7 million.

It is evident from the data that many light-duty vehicles are on the margin of being within 20 percent of the total cost of their conventional counterpart. The cumulative cost of a Level 2 grant program to achieve this threshold would be expensive at first ($22.5 million) but could be combined with other policies mentioned in this chapter to achieve greater electrification levels at a lower total cost. See Table for a summary of results from the Level 2 grant program.

TABLE 30: SUMMARY OF RESULTS FOR LEVEL 2 GRANT PROGRAM

Grant Program	Vehicle Class	Electrification Threshold (% Cost of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	All	10%	1,623	6%	-$15,210,276
No	All	20%	3,520	14%	$2,608,825
Yes	All	10%	3,451	13%	-$16,325,128
Yes	All	20%	7,574	29%	$11,837,109
No	Light	10%	786	7%	$389,261
No	Light	20%	2,471	23%	$12,313,767
Yes	Light	10%	2,579	24%	$1,525,769
Yes	Light	20%	6,436	59%	$22,531,977
No	Medium/Heavy	10%	837	6%	-$15,599,537
No	Medium/Heavy	20%	1,049	7%	-$9,704,942
Yes	Medium/Heavy	10%	872	6%	-$17,850,897
Yes	Medium/Heavy	20%	1,138	8%	-$10,694,868

DCFC GRANT PROGRAM

The study team modeled DC fast charging grant programs for light-, medium-, and heavy-duty vehicles based on existing programs offered by utilities in other states. Based on input from the Department of Commerce and examples from around the country, the study team decided to model utility grant programs covering up to 50 percent of the DC fast charging stations.

For all vehicle classes that relied on DC fast charging, 2,314 out of 28,913 had a TCO that was 10 percent or less above the conventional vehicle on average. If the threshold was increased to 20 percent, 4,126 vehicles could be electrified. Electrifying at a 10 percent threshold would save the state $37.3 million, even without grants for charging infrastructure, while electrifying vehicles at a 20 percent threshold would cost the state nearly $95.8 million since more vehicles would be electrified at a higher net cost per vehicle.

With the grant program in place, 2,888 vehicles met the criteria where TCO is less than 10 percent higher than that of conventional vehicles and 5,773 would qualify with a 20 percent threshold. The grant increases the savings to the state when following the 10 percent threshold from $40 million to $58.7 million. The grant program also increases the costs to fleet managers when applying the 20 percent threshold from $108 million to $122 million since more vehicles would be electrified.

The grant program has the most impact on light-duty vehicles' TCO because of the high share of costs from charging infrastructure. The grant program marginally increases the number of light-duty vehicles that could be electrified at the 10 percent threshold going from four to eight percent. The effects of the grant program when following the 20 percent threshold are more stark, increasing from 10 percent to 25 percent. The vehicles to deploy increases by 160 percent while the costs increase by 137 percent.

The effects of adding grants for medium- and heavy-duty vehicles had a larger financial effect than on the number of vehicles that could be electrified. At the 10 or 20 percent threshold, adding grants only increased the proportion of the fleet that could be electrified by two percent in both cases. However, the savings associated with electrifying vehicles under the 10 percent threshold increased under the grant program by 46 percent from $40.5 million to $59.1 million; under the 20 percent threshold, the grant program increased the costs from $102.3 million to $108.3 million since more vehicles would be electrified at a higher net cost per vehicle.

TABLE 31: SUMMARY OF RESULTS FOR DCFC GRANT PROGRAM

Grant Program	Vehicle Class	Electrification Threshold (% Cost of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	All	10%	2,075	7%	-$40,036,276
No	All	20%	3,687	13%	$108,057,543
Yes	All	10%	2,888	10%	-$58,743,851
Yes	All	20%	5,773	20%	$122,004,864
No	Light	10%	418	4%	$469,565
No	Light	20%	1,048	10%	$5,749,682

Grant Program	Vehicle Class	Electrification Threshold (% Cost of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
Yes	Light	10%	833	8%	$415,621
Yes	Light	20%	2,734	25%	$13,617,519
No	Medium/Heavy	10%	1,657	9%	-$40,505,842
No	Medium/Heavy	20%	2,639	15%	$102,307,861
Yes	Medium/Heavy	10%	2,055	11%	-$59,159,472
Yes	Medium/Heavy	20%	3,039	17%	$108,387,345

STATE GRANT PROGRAMS

State grant programs can alleviate some of the upfront costs of acquiring EVs through rebates directly to fleet managers for vehicle and charging equipment. Grant funding is a core component of Washington's strategy under the Clean Energy Fund mentioned above. Additionally, the Washington Department of Transportation administers the Green Transportation Capital Grant program which provides funding to public agencies for medium- and heavy-duty vehicle electrification. The 2019 to 2021 funding cycle allocated $12 million for electric transit buses and supporting infrastructure across eight transit agencies [200].

California's Clean Vehicle Rebate Project offers up to $2,000 per vehicle on the purchase or lease of up to 30 all-electric vehicles annually and public fleets located in disadvantaged communities with high air pollution are eligible for higher rebates. This program has issued more than $875 million in rebates for more than 381,000 fleet and personal vehicles since the program started in 2010. The large majority of this has gone to personal vehicles with government fleets receiving only 2,000 rebates worth $5 million [201].

Massachusetts is taking advantage of multiple programs to finance fleet electrification, drawing on funding available through the VW Settlement. The Massachusetts Electric Vehicle Incentive Program draws on VW Settlement for several categories of electrification, although the fleet component does not rely on settlement funding. To date, the state has provided 83 entities with nearly $2.3 million in grant funds for 267 electric vehicles and 92 charging stations [202].

State grant programs have been particularly vital for advancing electric medium- and heavy-duty vehicles, which can cost up to three times as much as conventional models [53]. In California, municipal fleets are eligible to receive funds through the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). The program has provided more than $324 million in vouchers for zero emission vehicles and is oversubscribed for the 2020 budget year [26]. Table 32 outlines the voucher amounts for different vehicle types through the HVIP [57]. New York has implemented a similar program with the New York Truck Voucher Incentive Program (NYT-VIP). The program draws from several funding sources including the VW Settlement and currently has more than $35 million available [203].

TABLE 32: HVIP INCENTIVE AMOUNTS BY VEHICLE TYPE

Vehicle Type	Voucher Amount
School Bus (Higher Incentive for Larger Buses)	$120,000-$220,000
Coach Bus (Higher Incentive for Larger Buses)	$80,000-$150,000
Transit Bus (Higher Incentive for Larger Buses)	$90,000-$175,000
Shuttle Bus (Higher Incentive for Larger Buses)	$80,000-$90,000
Delivery Van	$50,000-$80,000
Medium-duty Delivery Truck	$80,000-$95,000
Heavy-duty Delivery/Freight Truck	$150,000
Refuse Truck	$45,000-$150,000

LIGHT-DUTY VEHICLE INCENTIVE PROGRAM

The study modeled the Washington's existing light-duty EV incentive for all scenarios. This incentive is a sales tax exemption applies to all new passenger vehicles that are priced below $45,000. Only the first $20,000 is exempt from the tax as of August 1, 2021. As no modeling was completed without this policy, the analysis does not allow for a comparison of the impacts of the program on the TCO of passenger vehicles.

In order to review the effects of an additional light-duty vehicle incentive, see *Bundled Procurements and Cooperative Purchasing* where the full federal EV tax credit is considered.

TRUCK AND BUS GRANT PROGRAM

Instituting a truck and bus program similar to California's HVIP program as outlined in Table 32 makes all publicly-owned trucks and buses cost effective to electrify in the present day. The grant program complements the findings from Chapter 4 and Chapter 5, essentially bringing the timeline in for cost reductions for vehicles to the present day. As these EVs are less expensive to operate than their conventional counterparts and tend to have high mileage requirements, the savings are considerable.

As outlined in Table 33, the state could save hundreds of millions over the life of their truck and bus fleet with electrification with truck and bus program in place. Although only 77 percent of vehicles met the 10 percent threshold, electrifying all vehicles still yields a net savings of more than $300 million because the net savings from some vehicles far outweigh the net costs from other vehicles.

Of course, a truck and grant bus program would likely be financed through public funds in some form though these funds could come from sources that value the environmental benefits of EVs. For example, in California, the HVIP program is funded from the state's cap-and-trade program revenue, so funds do not come from the budgets of public or private fleets directly. Washington could expand existing programs, such as the Green Transportation Capital Grant Program to provide regular funding opportunities for fleets to acquire medium- and heavy-duty EVs. This program could be combined with programs that support infrastructure, like those discussed in *Vehicle Leasing*, to make accelerate an EV transition.

TABLE 33: SUMMARY OF RESULTS FOR TRUCK AND BUS GRANT PROGRAM

Grant Program	Vehicle Class	Electrification Threshold (% Cost of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	All	10%	1,743	10%	-$37,751,222
No	All	20%	2,579	14%	$87,702,206
Yes	All	10%	13,808	77%	-$547,905,199
Yes	All	20%	15,393	86%	-$420,034,582
No	Heavy	10%	1,033	9%	-$28,039,405
No	Heavy	20%	1,742	15%	$94,810,102
Yes	Heavy	10%	10,799	92%	-$432,043,892
Yes	Heavy	20%	11,615	99%	-$317,231,635
No	Medium	10%	710	11%	-$9,711,817
No	Medium	20%	837	13%	-$7,107,897
Yes	Medium	10%	3,009	48%	-$115,861,307
Yes	Medium	20%	3,778	60%	-$102,802,948

BUNDLED PROCUREMENTS AND COOPERATIVE PURCHASING

Government fleets can use mechanisms that improve the efficiency of procurement and reduce costs, including cooperative purchasing, where multiple jurisdictions acquire products from the same contract, or bundled procurements, where a single vendor provides multiple products or services. In some cases, vehicles and infrastructure can be bundled or infrastructure contracts can include fuel costs as a part of the agreement to ensure that fleet operators have access to operating cost savings [145].

Washington is already planning to bundle the procurement of DC fast charging stations being deployed along highway corridors to reduce the administrative costs associated with vendor selection and contracting [204]. The state has taken a slightly different approach to transit bus electrification and has developed a cooperative purchasing agreement to provide buses and supporting infrastructure to multiple contract participants including agencies from other states [205].

A cooperative purchasing agreements is a “method of procurement conducted by, or on behalf of, one or more governmental units for use by other governmental units” [206]. A notable example of this approach is the Climate Mayors Electric Vehicle Purchasing Collaborative that seeks to leverage the buying power of participating members to accelerate public fleet electrification by securing competitive procurement prices. The collaborative is committed to purchasing 2,100 EVs by the end of 2020 [207]. Thirteen Washington cities are already a part of the Climate Mayors Electric Vehicle Purchasing Collaborative, though these cities are concentrated in the Puget Sound region.

The City of Columbus Ohio also completed a cooperative purchase by creating a contract from which several jurisdictions in Ohio could purchase EVs. The procurement, part of the Smart Columbus initiative, included a provision that captured a portion of the federal EV tax credit for the public agencies purchasing from the contract [208]. The city negotiated with the auto dealer on the contract to pass a portion of the value of the credit to city via a discount on the purchase price of the vehicle. The dealer then claimed the value of the credit on their federal taxes. Alameda County in California was also successful in negotiating this through a bulk purchase of EVs in 2017 where the dealership winning the bid was the one that passed the tax credit on to the fleet through lower purchase prices [209].

MEDIUM- AND HEAVY-DUTY VEHICLES

The study did not complete any modeling on the benefits of bundled procurements or cooperative purchasing for medium- and heavy-duty vehicles. The effects of these mechanisms could be similar to those described in *Utility Grants or Rebates* and *Truck and Bus Grant Program*.

CAPTURING THE FULL FEDERAL EV TAX CREDIT

Washington has experience with negotiations with dealers around the federal tax credit and according to DES, the state has been able to secure 50 percent of the tax credit for public fleet purchases in the state. This experience led the study team to use 50 percent as the default value of the federal tax credit for eligible vehicles.

One of the key opportunities of a cooperative purchase agreement is to capture the full federal EV tax credit for public agencies. The study team considered a scenario where the entire tax credit, worth up to $7,500 was captured in a procurement.

With capturing 50 percent of the tax credit, five percent of light-duty vehicles (571) met the five percent threshold at a cost of $414,359. Increasing the threshold to 20 percent increased the share of the fleet to electrify to 14 percent (1,547 vehicles) and increased the cost substantially to more than $8.1 million. Increasing the share of the tax credit captured to 100 percent increases the share of the vehicles to electrify by nearly 200 percent for the 10 and 20 percent thresholds. At a threshold of 10 percent, 16 percent of the fleet can be electrified at a net savings of $257,061. At a 20 percent threshold, 44 percent of the light-duty fleet could be electrified at a cost of more than $15.8 million.

Overall, the benefits of full federal EV tax credit can make it possible to electrify an additional 1,149 vehicles using 10 percent threshold above what would be electrified when capturing only 50 percent of the tax credit; importantly, this would be done at a net savings to the government. This mechanism has the effect of bringing in the timeline of future cost reductions in EVs and accelerating a transition to an electric fleet.

TABLE 34: SUMMARY OF RESULTS FOR CAPTURING THE FULL FEDERAL EV TAX CREDIT

Full Federal EV Tax Credit	Vehicle Class	Electrification Threshold (% Cost of EV Over Conventional Vehicle)	Number of Vehicles to Electrify	Percent of Total Fleet	Cumulative Cost to Electrify
No	Light	10%	571	5%	$414,359
No	Light	20%	1,547	14%	$8,124,419
Yes	Light	10%	1,720	16%	-$257,061
Yes	Light	20%	4,752	44%	$15,809,699

CONCLUSION AND RECOMMENDATIONS

The primary goals of this study were to establish a baseline for the current size and electrification status of the public fleet in Washington and estimate the benefits and costs of achieving substantial levels of electrification. To do so, the study team compiled an inventory of over 56,000 public vehicles across Washington state and used the data from that inventory to perform an individualized total cost of ownership analysis for more than 28,000 vehicles both today and in the future. The analysis resulted in over 4.2 million unique scenarios, covering a broad range of potential vehicle procurements including various electricity rates, EV models, charging configurations, and public policies.

The results of this analysis demonstrate that electrifying the entire public fleet in Washington is an achievable goal and one that becomes more financially viable with each passing year. By 2035, it will be considerably more expensive to operate a fully internal combustion fleet than one that is substantially electrified. Even in today's EV market with relatively few options across all vehicle types owned by Washington, more than 1,600 vehicles in total could be electrified cost-effectively, achieving a cumulative savings of more than $72 million. Optimizing EV procurements by focusing on low-cost EVs, electricity rates, and charging infrastructure could substantially increase both the number of vehicles that could be electrified cost effectively and the savings they could generate, increasing to nearly 6,200 vehicles and more than $173 million in cumulative savings under the best-case scenario.

However, significant gaps remain in the current EV market which present hurdles for electrifying certain public vehicles in the near term. Aside from medium-duty transit buses, which had positive results in the analysis, many medium-duty electric vehicles were several times more expensive than their internal combustion counterparts. As a result, very few met the five percent TCO threshold for electrification in the present day. Additionally, nearly all school buses fell below the threshold for electrification due to the high price of EV alternatives and low annual mileage. For these vehicles, the proliferation of first-party offerings that can take advantage of economies of scale and technological advancements which reduce the cost to manufacture EVs will be critical before large numbers of vehicles can be electrified cost-effectively.

A primary advantage of electrification which is lost in the discussion of cost savings are the human health and environmental benefits of EVs. Achieving substantial electrification of the fleet would nearly eliminate all greenhouse gas and criteria pollutant emissions from the state fleet due to Washington's low-carbon grid and commitment to fully decarbonize by 2030. Even just focusing on electrification of heavy-duty vehicles could substantially reduce pollutants and improve air quality particularly in dense urban areas. Monetizing the health and other societal benefits from reduced air pollution, such as the carbon pricing policy assessed in this study, could substantially tilt the economics in favor of EVs.

To accelerate the transition to EVs and more quickly realize the financial, human health, and environmental benefits of an electrified fleet, Washington state has several of policy options it can explore. These ranged from relatively expensive grant programs which would cover the incremental cost for electric vehicles, thus dramatically improving the electrification potential of a large portion of the fleet, to options which relied simply on prioritizing existing funding sources, such as the Volkswagen Settlement at no additional cost to the state.

After review of the analysis results for the present day, future, and policy scenarios, the study team recommends the following for accelerating the pace of fleet electrification in Washington:

- To enable regular assessments of the electrification potential of vehicles in Washington, it is recommended that the state implement standardized tracking of fleet data across public agencies. Doing so would not only allow for easier tracking of electrification across the state, but also a more targeted electrification approach that focuses on vehicles that offer the greatest savings from electrification based on vehicle characteristics like location or annual mileage.
- Medium- and heavy- duty transit buses should be the primary focus of electrification efforts in the state; these vehicles offered both the highest proportion of vehicles that qualified for electrification and the greatest savings from electrification.
- Light-duty vehicles should be the focus of state agencies; these vehicles offered the potential for large scale electrification as well though at lower cost savings.
- Outside of transit vehicles, high rates of electrification for medium- and heavy-duty vehicles should not be targeted until at least 2030 by which time research and development successes could have markedly increased the electrification potential of these vehicles.
- Based on the results of this analysis, the state should consider targeting 100 percent electrification of the entire public fleet by 2035. The results of the analysis show that even under the worst case assumptions for technological advancement used in this study, a completely electrified fleet represents a substantial cost savings compared to an internal combustion fleet and represents an incremental cost of just eight percent over 50 percent electrification.
- Right-sizing or selecting the least expensive EV alternative that meets the operational need of a given vehicle should be actively pursued by all public entities in Washington to substantially increase both the number of vehicles that can be electrified cost-effectively and the savings they can generate. This strategy alone could more than double the share of the fleet that can be electrified by the criteria from WAC 194-28.
- When selecting vehicles for electrification, the state should target vehicles with high annual mileages to maximize the likelihood that an EV will generate substantial cost savings over its lifetime.
- Wherever possible, the state should avoid unmanaged charging that would result in high electricity rates via smart charging systems or other means. Unmanaged charging nearly halved the number of vehicles that could be electrified cost-effectively.
- When planning for charging infrastructure, the state should prioritize low-cost level 2 charging solutions when feasible to substantially increase the number of light-duty vehicles that can be electrified cost effectively.
- When considering policy options, the state should first focus on policies which can markedly improve the electrification potential of vehicles at no additional cost to the state. These include bundled procurements that take advantage of the full value of the federal incentive for light-duty vehicles, right-to-charge legislation, the expansion of revolving loan funds, and proper fleet management. These policies could result in the cost-effective electrification of thousands of additional vehicles with no additional funding.
- To accelerate the electrification of medium- and heavy-duty vehicles other than transit buses in the near term, the state should consider expanding upon existing grant funding programs which subsidize the upfront cost for these vehicles. Doing so could result in substantial increases in the number of vehicles that can be electrified in the present day.
- The state should work with utilities throughout Washington to expand charging infrastructure grant programs. These programs can result in the electrification of thousands of additional vehicles and have been shown to pay for themselves via the increased revenue from vehicle charging resulting in a net benefit to rate payers.

While the results of this study provide a positive outlook for the economic viability of EVs in the public fleet, it should be noted that this analysis did not consider vehicle- or route-specific driving requirements or the distribution of daily vehicles miles necessary to accommodate deep levels of electrification. Based on the data available, EV alternatives were selected based on average, or typical, daily range requirements. Right sizing electric range for agency-specific applications could likely require larger or smaller vehicle battery packs than considered in this analysis (along with corresponding charging infrastructure), ultimately impacting the study findings.

Nevertheless, the results of the total cost of ownership analysis discussed in this study paint an encouraging picture for transportation electrification in Washington state. Although average figures for electrification in the present day are low, optimizing an electrification strategy via the recommendations above can result in the cost-effective electrification of large portions of the public fleet in the immediate future. Over time, the case for large-scale electrification of the public fleet improves markedly with the potential to reach nearly full, cost-effective electrification within just ten years.

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APPENDIX A: ANALYSIS ASSUMPTIONS

OVERALL ASSUMPTIONS

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Market	U.S.				
Zip Code	98501 - only used to determine power grid, data is the same across all WA zip codes				
Gasoline Price ($/Gallon)	Average 2015-2019 State fuel contract price for E-10 gasoline and EIA average for commercial fueling with regional fuel price differences determined by variations in price by region on the state fuel contract; mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Transit agencies assumed to fuel exclusively at stated-owned fuel sites.	Average State fuel contract price for E-10 gasoline and EIA average for commercial gasoline and diesel fueling with regional fuel price differences determined by variations in price by region on the state fuel contract; mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Transit agencies assumed to fuel exclusively at stated-	Average State fuel contract price for E-10 gasoline and EIA average for commercial fueling with regional fuel price differences determine by AAA gas price data (this is the source for DES commercial fuel price data); mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Projections of future gasoline prices are	Average 2015-19 State fuel contract price for E-10 gasoline. Projections of future gasoline prices are based on projections from AEO	Average 2015-19 State fuel contract price for E-10 gasoline and propane; listed as fuel of choice by interviewed transit agencies including King County Metro. Projections of future gasoline prices are based on projections from AEO

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
	Projections of future gasoline prices are based on projections from AEO	owned fuel sites. Projections of future gasoline prices are based on projections from AEO	based on projections from AEO		
Diesel Price ($/Gallon)	Average 2015-2019 State fuel contract price for B10 and B20 biodiesel, the diesel fuel used by WSDOT at their fueling stations, and B5 biodiesel for transit agencies and EIA average for commercial fueling with regional fuel price differences determined by variations in price by region on the state fuel contract; mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Transit agencies assumed to fuel exclusively at stated-owned fuel sites. Projections of future	Average 2015-2019 State fuel contract price for B10 and B20 (diesel fuel used by WSDOT at their fueling stations) gasoline and EIA average for commercial fueling with regional fuel price differences determined by variations in price by region on the state fuel contract; mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Transit agencies assumed to fuel exclusively at stated-owned fuel sites. Projections of future gasoline prices are	Average 2019 State fuel contract price for B10 and B20 (diesel fuel used by WSDOT at their fueling stations) gasoline and EIA average for commercial fueling with regional fuel price differences determined by variations in price by region on the state fuel contract; mix between state-owned and commercial fueling determined by self-reported estimates from state agencies. Transit agencies assumed to fuel exclusively at stated-owned fuel sites. Projections of future gasoline prices are	Average 2015-19 State fuel contract price for B5 biodiesel. Projections of future diesel prices are based on projections from AEO	Average 2015-19 State fuel contract price for B5 biodiesel; listed as fuel of choice by interviewed transit agencies including King County Metro. Projections of future diesel prices are based on projections from AEO

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
	gasoline prices are based on projections from AEO	based on projections from AEO	based on projections from AEO		
Electricity Cost ($/kWh)	Determined by utility. If several utilities present in a given area, the utility with the largest customer base was chosen. Assumed presence of demand charges across all utilities. 2x multiplier was used for commercial rates to approximate demand charges. A 1.5x multiplier was used to model the use of a smart charging system. A 1.2x multiplier was used to model the presence of a rate that includes VGI benefits. Projections of future electricity prices are based on projections from AEO.				
Public Charging Price ($/kWh)	N/A				
On-Route Charging Price ($/kWh)	N/A				
Inflation Rate (Excluding Fuel) (%/Year)	2% - Federal Reserve's medium-term target				
Cost of Downtime from Public Charging ($/Hour)	N/A				
Include Cost of Carbon?	No carbon price was included for the baseline analysis. To model potential clean fuel standards or credit systems the state could implement, the study team chose the social cost of carbon as determined by Washington in WAC 194-40-100				
Cost of Carbon ($/Ton)	$0.00; $74.00 depending on whether the social cost of carbon was being modeled				

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Vehicle Drivetrain Type	Make/Model Dependent				
Vehicle Class					
Vehicle Year					
Vehicle Make					
Vehicle Model					
Fuel Economy Gasoline/Diesel/Gas City (MPG)	Model Dependent; data from Fueleconomy.gov	Model Dependent; average fuel economy was determined from DES fuel economy records. DES data was checked against fuel economy figures reported by users on fuelly.com for consistency	Model Dependent; average fuel economy was determined from DES fuel economy records. DES data was checked against fuel economy figures reported by users on fuelly.com for consistency. In the case of Refuse trucks, no fuel economy data was available and the average fuel economy for refuse trucks reported by the Alternative Fuels Data Center was used	Model Dependent; data from Altoona Bus Research and Testing Center testing of models	
Fuel Economy Gasoline/Diesel/Gas Highway (MPG)					
Fuel Economy	Model Dependent; data from	Model Dependent; as no real-world fuel	Model Dependent; as no real-world fuel	Model Dependent; as no real-world fuel	Model Dependent; data from Altoona Bus

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Electric City (MPGe) Fuel Economy Electric Hwy (MPGe)	Fueleconomy.gov. In the case of vehicles not yet rated by the EPA, fuel economy was calculated based on estimated usable battery capacity and range based on observed data in similar vehicles	economy data was available, the study team used simulated fuel economy data from Argonne National Laboratory's Autonomie vehicle simulation tool	economy data was available, the study team used simulated fuel economy data from Argonne National Laboratory's Autonomie vehicle simulation tool	economy data was available, the study team used simulated fuel economy data from Argonne National Laboratory's Autonomie vehicle simulation tool along with actual data from data from Altoona Bus Research and Testing Center where available	Research and Testing Center testing of models
Expected Years of Use/Ownership (Years)	Vehicle dependent based upon actual data from WA fleet inventory. Vehicle useful life capped at 25 years as a result of financial model limitations				
Annual Vehicle Mileage (VMT/Year)	Vehicle dependent based upon actual data from WA fleet inventory; for vehicles with missing data, the average annual mileage for that use case was assumed				
% of Annual Miles on Gasoline/Diesel	Model dependent	N/A			
% of Annual Miles City Driving	Assumed EPA figures of 55%-45% city to highway ratio	EPA assumption for Vocational - Multipurpose (2b - 8)	EPA assumption for vocational - urban of 90%-10% city to highway for refuse vehicles; EPA	EPA assumption for Vocational - Urban (2b - 7) of 92%-8% city to highway ratio	EPA assumption for Vocational - Urban (8) of 90%-10% city to highway ratio for Class 8 Transit vehicles. EPA

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
		of 54%-46% city to highway ratio	assumption for Day cabs/heavy-haul tractors of 19%-81% city to highway ratio for Short Haul tractors		assumption for Vocational - Urban (2b - 7) of 92%-8% city to highway ratio for passenger vans.
Cost to Insure ($/Year)	Quoted rate for collision insurance from state insurer of $0.007498 per dollar of replacement value	Quoted rate for collision insurance from state insurer of $0.007498 per dollar of replacement value	Quoted rate for collision insurance from state insurer of $0.007498 per dollar of replacement value	Quoted rate for collision insurance from state insurer of $0.007498 per dollar of replacement value	Assumed Washington State Transit Insurance Pool rates for collision insurance
Use Drivetrain Default Maintenance and Repair Costs?	No				
Maintenance and Repair Cost - Years 1 - 5 ($/Mile) Maintenance and Repair Cost - Years 5+ ($/Mile)	DES Maintenance data. In cases where no maintenance data exists for EVs, the methodology from Argonne National Lab's AFLEET tool was applied in which the maintenance cost differential between electric and conventional sedans was applied to the	DES Maintenance data. In cases where no maintenance data existed for conventional vehicles, averaged maintenance cost data from analyses by California Air Resources Board and NREL were used. In cases where no maintenance data exists for EVs, the	Figures from Argonne's AFLEET tool were used except in the case of maintenance costs for Refuse vehicles, in which case the source was CARB data. Refuse maintenance costs from AFLEET were extremely high compared to two publicly available datasets and Argonne	Averaged maintenance cost data weighted by total mileage from the following studies from NREL: Eudy, L. et al., "Foothill Transit Battery Electric Bus Demonstration Results", 2016 Federal Transit Administration, "Zero-Emission Transit Bus	Averaged maintenance cost data weighted by total mileage from the following studies from NREL: Eudy, L. et al., "Foothill Transit Battery Electric Bus Demonstration Results", 2016 Federal Transit Administration, "Zero-Emission Transit Bus

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
	average maintenance costs for other vehicle types.	methodology from AFLEET was applied in which the maintenance cost differential between electric and conventional sedans was applied to the average maintenance costs for other vehicle types.	was unable to share details of the discrepancy because their data is from a third party.	Evaluations: King County Metro” Chandler, K. & Walkowicz, K. “King County Metro Transit Hybrid Articulated Buses: Final Evaluation Results”, 2006 Eudy, L. & Jeffers, M. “Long Beach Transit Battery Electric Bus Progress Report”, 2019	Evaluations: King County Metro” Chandler, K. & Walkowicz, K. “King County Metro Transit Hybrid Articulated Buses: Final Evaluation Results”, 2006 Eudy, L. & Jeffers, M. “Long Beach Transit Battery Electric Bus Progress Report”, 2019
Recurring Taxes and Fees ($/Year)	0				
Discount Rate for NPV Calculations (%)	1.36% - average over 10 years of short term bond rate for equipment purchases in Washington				
Number of Vehicles to Procure (#)	1 - scenarios are run on a vehicle by vehicle basis				
Pricing Approach (select one)	MSRP less discounts				

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
MSRP ($/Vehicle)	List price on WA state vehicle contract. When vehicles were not available on the state contract, an average discount was applied based on the average discount off MSRP for vehicles on the state vehicle contract of the same model year. Pricing for eligible EVs is inclusive of WA state sales tax exemption.	Average replacement value listed by state agencies; data verified against average list price of vehicles on commercialtrucktrader.com. Prices for EVs taken from state vehicle contracts in California and manufacturer quotes provided to Atlas.	Pricing for internal combustion vehicles taken from average list price of vehicles on commercialtrucktrader.com. Prices for EVs taken from state vehicle contracts in California and manufacturer quotes provided to Atlas.	Pricing data taken from WA state school bus master contract. Pricing for EVs taken from WA state school bus master contract, New York state vehicle contract and manufacturer quotes provided to Atlas.	Pricing data taken from WA state transit bus master contract and manufacturer quotes provided to Atlas.
Value of Negotiated Discounts off MSRP ($/Vehicle)	N/A				
Value of Federal Tax Incentives ($/Vehicle)	Model dependent - states are able to capture the value of federal tax incentives via appropriate procurement practices. This incentive was included for eligible vehicles.	N/A			

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Value of State Tax Incentives ($/Vehicle)	N/A				
State Tax Incentive Cap ($)	N/A				
Value of Non-tax Incentives ($/Vehicle)	$0; When modeling potential State Grant Programs, incentive amounts of between $60 - $150,000 were applied to EVs depending on the vehicle.				
Initial Tax, Title, and Registration Cost ($/Vehicle)	$50 - data from DES				
Initial Fee as Percent of Vehicle Base Price (%)	N/A				
Ownership Structure	Cash Purchase				
Tax Credits Can Be Monetized? (Y/N)	Y				

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Down Payment ($/Vehicle)	N/A				
Lease Term (Years)	N/A				
Lease Interest Rate (APR - %)	N/A				
Money Factor (#)	N/A				
Acquisition Fee ($/Vehicle)	N/A				
Disposition Charge ($/Vehicle)	N/A				
Negotiated Residual Value ($/Vehicle)	N/A				
Mileage Included (Closed-End Only)	N/A				

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Excess Mileage Cost ($/Mile)	N/A				
% Depot/Home Charging	100%				
% Public Charging	0%				
% On-Route Charging	0%				
Charging Level	Level 2; DCFC				
Maximum Power for Public Charging Only (kW)	N/A				
Procurement Includes EV Charging?	Yes (only for electric and plug-in hybrid vehicles)				
Number of EV Charging Stations Needed (#)	1; for scenarios where a charging station supports more than one vehicle, the cost of the charging station is split equally across all vehicles				
Charging Equipment	See Charging Table Below				

Category	Light-duty Vehicle Analysis Inputs and Assumptions	Medium-duty Truck and Van Assumptions	Heavy-duty Truck Assumptions	School Bus Assumptions	Transit Bus Analysis
Cost ($/Station)					
Construction & Equipment Installation Cost ($/Station)					
Electric Utility Upgrades and Grid Interconnection Cost ($/Site)					
Maintenance Cost ($/Station/Year)	3% of equipment cost				
Ownership Structure	Cash Purchase				

CHARGING ASSUMPTIONS

Vehicle Class	Charging Equipment	Charger Power (Kilowatts)	Vehicle to Charger Ratio	Charging Equipment Cost ($ Per Vehicle)	Construction, Equipment Installation, & Utility Upgrade Costs ($ Per Vehicle)
Light-Duty Vehicles	Level 2 Residential	7.6	1 to 1	$550	$1286
	Level 2 Private Depot	11.5	1 to 1	$834	$2,180
	Level 2 Private Depot	11.5	2 to 1	$417	$1,090
	DC Private Depot	50	10 to 1	$3,800	$2,000
	Level 2 Public Depot	7.6	1 to 1	$3,500	$2,500
	Replace Level 2 at Private Depot	11.5	2 to 1	$417	$0
Medium-Duty Trucks and Vans	Level 2 Private Depot	15.4	1 to 1	$1,010	$2,180
	DC Private Depot	50	5 to 1	$7,600	$4,000
	DC Private Depot	50	2 to 1	$19,000	$10,000
	Replace Level 2 at Private Depot	15.4	1 to 1	$1,010	$0
Heavy-Duty Trucks	DC Private Depot	150	5 to 1	$17,560	$12,000
	DC Private Depot	50	2 to 1	$19,000	$10,000
	DC Private Depot	50	1 to 1	$38,000	$20,000
	Replace DC	50	2 to 1	$19,000	$0
School Buses	Level 2 Depot	15.4	1 to 1	$1,010	$2,180
	DC Private Depot	50	5 to 1	$7,600	$4,000
	Replace Level 2 at Private Depot	15.4	1 to 1	$1,010	$0
Transit Buses	DC Private Depot	150	3 to 1	$29,267	$20,000

Vehicle Class	Charging Equipment	Charger Power (Kilowatts)	Vehicle to Charger Ratio	Charging Equipment Cost ($ Per Vehicle)	Construction, Equipment Installation, & Utility Upgrade Costs ($ Per Vehicle)
	DC Private Depot	50	1 to 1	$38,000	$20,000
	DC Private Depot	50	2 to 1	$19,000	$10,000
	On-Route	N/A	10 to 1	$49,564	$20,281
	Replace DC at Private Depot	50	1 to 1	$38,000	$0
DCFC Grant Program	DC Private Depot	150	5 to 1	$14,633	$10,000
	DC Private Depot	150	3 to 1	$8,780	$6,000
	DC Private Depot	50	10 to 1	$1,900	$1,000
	DC Private Depot	50	5 to 1	$3,800	$2,000
	DC Private Depot	50	2 to 1	$9,500	$5,000
	DC Private Depot	50	1 to 1	$19,000	$10,000
Level 2 Grant Program	Level 2 Depot	11.5; 15.4; 76	1 to 1; 2 to 1	$0	$0

APPENDIX B: VEHICLE MAPPING

LIGHT-DUTY VEHICLES

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
BMW R 1200 RT	2020 BMW R1250 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
BMW R 1250 RT	2020 BMW R1250 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
CHEVROLET 1500 SILVERADO	2019 Chevrolet Silverado K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET ASTRO	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET Blazer	2019 Chevrolet Blazer AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
CHEVROLET Blazer	2019 Chevrolet Blazer FWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
CHEVROLET C/K Pickup	2019 Chevrolet Silverado 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET C1500	2019 Chevrolet Silverado 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET Caprice Police Vehicle	2020 Chevrolet Impala ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
CHEVROLET Captiva Sport	2019 Chevrolet Traverse FWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
CHEVROLET Cargo Van	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
CHEVROLET City Express	2019 Nissan NV200 Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
CHEVROLET Colorado	2019 Chevrolet Colorado 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET Colorado	2019 Chevrolet Colorado 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Colorado	2019 Chevrolet Colorado 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Corvair	2019 Ford Mustang ICE	2019 Tesla Model 3 Long Range AWD Performance BEV	2019 Chevrolet Bolt EV BEV	N/A
CHEVROLET Equinox	2019 Chevrolet Equinox AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
CHEVROLET EXPRESS VAN	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
CHEVROLET EXPRESS VAN	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET G30	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
CHEVROLET GMT-400	2019 Chevrolet Colorado 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET GMT-400	2019 Chevrolet Colorado 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET GMT-400	2019 Chevrolet Silverado 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
CHEVROLET Impala	2020 Chevrolet Impala ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
CHEVROLET Impala Limited	2020 Chevrolet Impala ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
CHEVROLET K1500	2019 Chevrolet Silverado K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Malibu	2019 Chevrolet Malibu ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
CHEVROLET P - Series	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
CHEVROLET S-10 Pickup	2019 Chevrolet Colorado 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET S-10 Pickup	2019 Chevrolet Colorado 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Silverado	2019 Chevrolet Silverado 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET Silverado	2019 Chevrolet Silverado K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Silverado	2019 Chevrolet Silverado K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Silverado HD	2019 Chevrolet Silverado 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
CHEVROLET Silverado LD	2019 Chevrolet Silverado K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
CHEVROLET Suburban	2019 Chevrolet Suburban 2WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
CHEVROLET Suburban	2019 Chevrolet Suburban K1500 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
CHEVROLET Tahoe	2019 Chevrolet Tahoe C1500 2WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
CHEVROLET Tahoe	2019 Chevrolet Tahoe K1500 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
CHEVROLET Trailblazer	2019 Chevrolet Traverse AWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET Trailblazer	2019 Chevrolet Traverse FWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET Traverse	2019 Chevrolet Traverse AWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET TRLBLZR	2019 Chevrolet Traverse AWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET TRLBLZR	2019 Chevrolet Traverse FWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET Uplander	2019 Chevrolet Traverse FWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
CHEVROLET VAN	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
CHEVROLET Volt	2019 Chevrolet Volt PHEV	2019 Chevrolet Bolt EV BEV	N/A	N/A
CHRYSLER 300	2019 Chrysler 300 ICE	2019 Tesla Model 3 Long Range BEV	2019 Chevrolet Bolt EV BEV	N/A
CHRYSLER Pacifica	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A	N/A
CHRYSLER Town and Country	2019 Chrysler Pacifica ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
CLASSIC WELDING Classic Welding	2019 Dodge Grand Caravan ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
DODGE Avenger	2019 Chrysler 300 AWD ICE	2019 Tesla Model 3 Long Range BEV	2019 Chevrolet Bolt EV BEV	N/A
DODGE Avenger	2019 Chrysler 300 ICE	2019 Tesla Model 3 Long Range BEV	2019 Chevrolet Bolt EV BEV	N/A
DODGE Caravan	2019 Dodge Grand Caravan ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
DODGE Caravan/Grand Caravan	2019 Dodge Grand Caravan ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
DODGE Charger	2019 Dodge Charger AWD ICE	2019 Tesla Model 3 Long Range AWD Performance BEV	2019 Tesla Model 3 Long Range AWD BEV	2019 Chevrolet Bolt EV BEV
DODGE Charger	2019 Dodge Charger ICE	2019 Tesla Model 3 Long Range AWD Performance BEV	2019 Tesla Model 3 Long Range BEV	2019 Chevrolet Bolt EV BEV
DODGE D-Series	2019 Ram 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
DODGE Durango	2019 Dodge Durango AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
DODGE Grand Caravan	2019 Dodge Grand Caravan ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
DODGE Journey	2019 Dodge Journey ICE	2020 Tesla Model Y - Basic BEV	2019 Hyundai Kona Electric BEV	N/A
DODGE Ram	2019 Ram 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
DODGE Ram	2019 Ram 1500 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
DODGE Ram	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
DODGE Ram Chassis Cab	2019 Ram 1500 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
DODGE Ram Van	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
DODGE Ram Wagon	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
DODGE Sprinter	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
DODGE Stratus	2019 Chrysler 300 ICE	2019 Tesla Model 3 Long Range BEV	2019 Chevrolet Bolt EV BEV	N/A
DODGE, CHRYSLER, VOLKSWAGEN, JEEP, FIAT, RAM, LANCIA 0	2019 Dodge Grand Caravan ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
FORD 150XL	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD Bronco	2019 Ford Expedition 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
FORD CLUBWAGON	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
FORD C-max	2019 Ford Escape FWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
FORD C-max	2020 Ford Escape FWD HEV ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
FORD Crown Victoria	2019 Ford Taurus AWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD ECONLN	2019 Ford Transit Connect Cargo Van 2WD ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
FORD Escape	2020 Ford Escape AWD HEV ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Ford Escape FWD PHEV
FORD Escape	2020 Ford Escape FWD HEV ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Ford Escape FWD PHEV
FORD Excursion	2019 Ford Expedition MAX 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
FORD Expedition	2019 Ford Expedition 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
FORD Expedition	2019 Ford Expedition MAX 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
FORD Expedition EL	2019 Ford Expedition MAX 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A
FORD Expedition MAX	2019 Ford Expedition MAX 4WD ICE	2020 Rivian Rivian R1S 105 kWh BEV	N/A	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
FORD Explorer	2019 Ford Explorer AWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
FORD Explorer	2019 Ford Explorer FWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
FORD F150	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD F-150	2019 Ford F150 Pickup 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
FORD F-150	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD F150 CREW CAB	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD F-150 Heritage	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD F150H	2019 Ford F150 Pickup 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD Focus	2019 Ford Fusion AWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD Freestar	2019 Ford Transit Connect Cargo Van 2WD ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
FORD Fusion	2019 Ford Fusion AWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD Fusion	2019 Ford Fusion Energi Plug-in Hybrid PHEV	2019 Chevrolet Bolt EV BEV	N/A	N/A
FORD Fusion	2019 Ford Fusion FWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
FORD Mustang	2019 Ford Mustang ICE	2019 Tesla Model 3 Long Range AWD Performance BEV	2019 Chevrolet Bolt EV BEV	N/A
FORD Ranger	2019 Ford Ranger 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
FORD Ranger	2019 Ford Ranger 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
FORD Ranger	2019 Ford Ranger 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD Ranger	2019 Ford Ranger 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
FORD Taurus	2019 Ford Taurus AWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD Taurus	2019 Ford Taurus FWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD Taurus X	2019 Ford Taurus FWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
FORD Transit	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
FORD TRANSIT VAN	2019 Ford Transit Connect Cargo Van 2WD ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
FORD Windstar	2019 Ford Taurus FWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
GMC 0	2019 GMC Sierra C10 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
GMC Safari	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
GMC Sierra	2019 GMC Sierra C10 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
GMC Sierra	2019 GMC Sierra K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
GMC Sonoma	2019 GMC Sierra C10 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
GMC Sonoma	2019 GMC Sierra K10 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
HONDA Accord	2019 Honda Accord Hybrid ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA Accord	2019 Honda Accord ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA Civic	2019 Honda Civic 4Dr ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA Civic	2019 Honda Insight ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA CIVIC HYBRID	2019 Honda Insight ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA CLARITY	2019 Honda Clarity Plug-in Hybrid PHEV	2019 Honda Clarity EV BEV	N/A	N/A
HONDA Insight	2019 Honda Insight ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HONDA NC700X	2019 Yamaha TW200 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
HONDA Pilot	2019 Honda Pilot AWD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
HONDA ST1300PA	2019 Yamaha TW200 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
HYUNDAI Elantra	2019 Hyundai Elantra ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HYUNDAI Santa Fe	2019 Hyundai Santa Fe AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
HYUNDAI Santa Fe Sport	2019 Hyundai Santa Fe AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
HYUNDAI Sonata	2019 Hyundai Sonata Hybrid ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HYUNDAI Sonata	2019 Hyundai Sonata ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
HYUNDAI, GENESIS 0	2019 Hyundai Sonata Hybrid ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
JEEP 0	2019 Jeep Cherokee FWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
JEEP Cherokee	2019 Jeep Cherokee 4WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
JEEP Cherokee	2019 Jeep Cherokee FWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
JEEP Commander	2019 Jeep Grand Cherokee 2WD ICE	2020 Tesla Model Y - Basic BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
JEEP Commander	2019 Jeep Grand Cherokee 4WD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
JEEP Compass	2019 Jeep Compass 4WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
JEEP Compass	2019 Jeep Compass FWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
JEEP Grand Cherokee	2019 Jeep Grand Cherokee 2WD ICE	2020 Tesla Model Y - Basic BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
JEEP Grand Cherokee	2019 Jeep Grand Cherokee 4WD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
JEEP Liberty	2019 Jeep Compass 4WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
JEEP Patriot	2019 Jeep Compass 4WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
JEEP Wrangler	2019 Jeep Wrangler 4WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
KAWASAKI KLR650	2020 BMW R1250 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
KAWASAKI Police 1000	2020 BMW R1250 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
MAZDA 323	2019 Mazda 3 4-Door 2WD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
MAZDA CX-7	2019 Mazda CX-5 2WD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	N/A
MITSUBISHI 0	2019 Mitsubishi Outlander PHEV PHEV	2019 Hyundai Kona Electric BEV	N/A	N/A
MITSUBISHI Diamante	2019 Toyota Camry ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
MITSUBISHI Eclipse	2019 Mitsubishi Eclipse Cross ES 2WD ICE	2019 Mitsubishi Outlander PHEV PHEV	2019 Hyundai Kona Electric BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
MITSUBISHI Endeavor	2019 Mitsubishi Outlander 4WD ICE	2019 Mitsubishi Outlander PHEV PHEV	2019 Hyundai Kona Electric BEV	N/A
MITSUBISHI Outlander - PHEV	2019 Mitsubishi Outlander PHEV PHEV	2019 Hyundai Kona Electric BEV	N/A	N/A
NISSAN 0	2019 Nissan NV200 Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
NISSAN Frontier	2019 Nissan Frontier 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
NISSAN Frontier	2019 Nissan Frontier 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
NISSAN Murano	2019 Nissan Murano AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
NISSAN Pathfinder	2019 Nissan Pathfinder 4WD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	2019 Chrysler Pacifica Hybrid PHEV
NISSAN Pickup	2019 Nissan Frontier 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
NISSAN Quest	2019 Nissan Pathfinder 2WD ICE	2020 Tesla Model Y - Basic with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
NISSAN Rogue	2019 Nissan Rogue AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
NISSAN Rogue	2019 Nissan Rogue Hybrid AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
NISSAN Titan	2019 Nissan Titan 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
NISSAN Xterra	2019 Nissan Rogue AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
NISSAN, INFINITI 0	2019 Nissan Frontier 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
NISSAN, INFINITI 0	2019 Nissan Frontier 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
RAM 1500	2019 Ram 1500 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
RAM 1500	2019 Ram 1500 4WD - Diesel ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
RAM 1500	2019 Ram 1500 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
RAM Cargo Van	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
RAM Promaster 1500	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
RAM Promaster City	2019 Ram Promaster City ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV	N/A
SUBARU Forester	2019 Subaru Forester AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV
SUBARU Impreza	2019 Subaru Impreza Sport 4-Door ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	2019 Tesla Model 3 Long Range AWD BEV
SUBARU Legacy	2019 Subaru Legacy AWD ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	2019 Tesla Model 3 Long Range AWD BEV
SUBARU Outback	2019 Subaru Outback AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2020 Tesla Model Y - AWD BEV

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
TOYOTA 0	2019 Toyota Tacoma 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
TOYOTA 4-Runner	2019 Toyota 4Runner 4WD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
TOYOTA Camry	2019 Toyota Camry Hybrid LE ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
TOYOTA Camry	2019 Toyota Camry ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
TOYOTA Highlander	2019 Toyota Highlander AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
TOYOTA Highlander	2019 Toyota Highlander Hybrid AWD ICE	2020 Tesla Model Y - AWD BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
TOYOTA Pick-Up	2019 Toyota Tacoma 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
TOYOTA Pick-Up	2019 Toyota Tacoma 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
TOYOTA Previa	2019 Toyota Sienna 2WD ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
TOYOTA PRIUS	2019 Toyota Prius ICE	2019 Chevrolet Bolt EV BEV	2019 Toyota Prius Prime PHEV	N/A
TOYOTA PRIUS	2019 Toyota Prius ICE	2019 Chevrolet Bolt EV BEV	2019 Toyota Prius Prime PHEV	N/A
TOYOTA Prius C	2019 Toyota Prius c ICE	2019 Chevrolet Bolt EV BEV	2019 Toyota Prius Prime PHEV	N/A
TOYOTA Prius Prime	2019 Toyota Prius Prime PHEV	2019 Chevrolet Bolt EV BEV	N/A	N/A
TOYOTA Prius V	2019 Toyota Prius c ICE	2019 Chevrolet Bolt EV BEV	2019 Toyota Prius Prime PHEV	N/A
TOYOTA RAV 4	2019 Toyota RAV4 Hybrid AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2021 Toyota RAV4 Prime 4WD PHEV

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
TOYOTA RAV4	2019 Toyota RAV4 AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2021 Toyota RAV4 Prime 4WD PHEV
TOYOTA RAV4	2019 Toyota RAV4 Hybrid AWD ICE	2019 Hyundai Kona Electric BEV	2019 Kia Niro Electric BEV	2021 Toyota RAV4 Prime 4WD PHEV
TOYOTA Sienna	2019 Toyota Sienna 2WD ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
TOYOTA Sienna	2019 Toyota Sienna AWD ICE	2019 Chrysler Pacifica Hybrid PHEV	2020 Tesla Model Y - Basic with 7 seats BEV	N/A
TOYOTA Tacoma	2019 Toyota Tacoma 2WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2021 Tesla Cybertruck single-motor BEV	N/A
TOYOTA Tacoma	2019 Toyota Tacoma 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
TOYOTA Tundra	2019 Toyota Tundra 4WD ICE	2020 Rivian Rivian R1T 105 kWh BEV	2022 Tesla Cybertruck dual-motor BEV	N/A
VOLKSWAGEN 0	2019 Volkswagen Golf SportWagen ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
VOLKSWAGEN Jetta	2019 Volkswagen Jetta ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
VOLKSWAGEN Passat	2019 Volkswagen Passat ICE	2019 Chevrolet Bolt EV BEV	2019 Nissan Leaf (62 kW-hr battery pack) BEV	N/A
YAMAHA TW200	2019 Yamaha TW200 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
YAMAHA YW50 Zuma	2019 Yamaha Zuma 125 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A
YAMAHA YW50/ZUMA	2019 Yamaha Zuma 125 ICE	2019 Zero DSRP 14.4+ BEV	2019 Zero DSRP 14.4 BEV	N/A

Vehicle Identified in Fleet	Analyzed Conventional Vehicle	EV Alternative 1	EV Alternative 2	EV Alternative 3
DODGE Avenger	2019 Dodge Charger Police ICE	2019 Tesla Model 3 Long Range BEV	2019 Ford Fusion Special Service Vehicle PHEV PHEV	N/A
DODGE Charger	2019 Dodge Charger Police AWD ICE	2019 Tesla Model 3 Long Range AWD BEV	2019 Ford Fusion Special Service Vehicle PHEV PHEV	N/A
DODGE Charger	2019 Dodge Charger Police ICE	2019 Tesla Model 3 Long Range BEV	2019 Ford Fusion Special Service Vehicle PHEV PHEV	N/A
FORD Explorer	2019 Ford Explorer Interceptor Utility ICE	2020 Tesla Model Y - AWD with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
FORD Explorer	2019 Ford Explorer Interceptor Utility ICE	2020 Tesla Model Y - AWD with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A
FORD Explorer	2019 Ford Explorer Interceptor Utility ICE	2020 Tesla Model Y - AWD with 7 seats BEV	2020 Rivian Rivian R1S 105 kWh BEV	N/A

MEDIUM- AND HEAVY-DUTY VEHICLES

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET W4	2019 ISUZU NPR/NPR-HD ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
FORD F-550	2019 ISUZU NQR/NRR ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
FREIGHTLINER FL 70	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
GMC T-Series	2019 ISUZU NQR/NRR ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MA025	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
INTERNATIONAL MH025	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MH035	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MV607	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
ISUZU NPR/NPR-HD	2019 ISUZU NPR/NPR-HD ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
ISUZU NQR/NRR	2019 ISUZU NQR/NRR ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
ISUZU T6F	2019 ISUZU NPR/NPR-HD ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
KENWORTH K270/K370	2019 KENWORTH K370 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
PETERBILT 220	2019 PETERBILT 220 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
CHEVROLET Express	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
CHEVROLET P - Series	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
CHEVROLET P Truck Forward	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
DODGE Ram Van	2019 RAM Promaster Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
DODGE Sprinter	2019 MERCEDES-BENZ Sprinter 2500 Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
FORD E-250	2019 FORD Transit Full Size Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
FORD E-350	2019 MERCEDES-BENZ Sprinter 3500 Cargo ICE	2019 Phoenix Motorcars Z400 - Class 4 Cargo Van BEV	N/A
FORD E-450	2019 MERCEDES-BENZ Sprinter 3500 Cargo ICE	2019 Phoenix Motorcars Z400 - Class 4 Cargo Van BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FORD Transit	2019 FORD Transit Full Size Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
GMC P Truck Forward	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
GMC Vandura	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
GMC G3500	2019 Chevrolet Express 2500 2WD Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
MERCEDES BENZ SPRINTER VAN	2019 MERCEDES-BENZ Sprinter 2500 Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
MERCEDES-BENZ Sprinter	2019 MERCEDES-BENZ Sprinter 2500 Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
NISSAN NV3500	2019 NISSAN NV3500 ICE	2019 Phoenix Motorcars Z400 - Class 4 Cargo Van BEV	N/A
NISSAN NV	2019 NISSAN NV3500 ICE	2019 Phoenix Motorcars Z400 - Class 4 Cargo Van BEV	N/A
RAM Promaster 1500	2019 RAM Promaster Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
RAM Promaster 2500	2019 RAM Promaster Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
RAM Promaster 3500	2019 RAM Promaster Cargo Van ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
SPRINTER (DODGE OR FREIGHTLINER) Sprinter	2019 MERCEDES-BENZ Sprinter 2500 Cargo ICE	2019 Lightning Systems Transit 350HD Cargo Van 86 kWh BEV	2019 Lightning Systems Transit 350HD Cargo Van 43kWh BEV
WORKHORSE P42	2019 FREIGHTLINER MT 45 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
CHEVROLET GMT-400	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
CHEVROLET Silverado	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
CHEVROLET V Conventional	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET C3500	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
DODGE D-Series	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
DODGE Ram Chassis Cab	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
DODGE RAM 3500	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F-250	2019 FORD F-350 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F-350	2019 FORD F-350 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F-450	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F-550	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F-Super Duty	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F S D	2019 FORD F-350 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F350	2019 FORD F-350 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F450	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
FORD F550	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
GMC Sierra	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
GMC C3500	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
GMC K3500	2019 CHEVROLET Silverado 3500 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
INTERNATIONAL MA025	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MH025	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MH035	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL 4700	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL S1900	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL 4700 Low Profile	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
INTERNATIONAL MA035	2019 INTERNATIONAL DURASTAR 4300 ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
RAM 4500	2019 FORD F-450 Flatbed ICE	2019 Phoenix Motorcars Z400 - Flatbed Truck BEV	N/A
CHEVROLET Express	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET GMT-400	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET G-Series	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
DODGE Sprinter	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD E-250	2019 FORD Transit Full Size Passenger Van ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FORD E-350	2019 FORD Transit Full Size Passenger Van ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Transit	2019 FORD Transit Full Size Passenger Van ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
GMC P Truck Forward	2019 Chevrolet Express 2500 2WD Passenger ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET GMT-400	2019 CHEVROLET Silverado 3500 Service Truck ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
CHEVROLET Silverado	2019 CHEVROLET Silverado 3500 Service Truck ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
CHEVROLET V Conventional	2019 CHEVROLET Silverado 3500 Service Truck ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
DODGE Ram	2019 CHEVROLET Silverado 3500 Service Truck ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
DODGE Ram Chassis Cab	2019 FORD F-250 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F-250	2019 FORD F-250 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F-350	2019 FORD F-350 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F-450	2019 FORD F-450 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F-550	2019 FORD F-450 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F350	2019 FORD F-350 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
FORD F350 CREW CAB	2019 FORD F-350 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
RAM 4500	2019 FORD F-450 Service Body ICE	2019 Phoenix Motorcars Z400 - Work Truck BEV	N/A
CHEVROLET C3500	2019 Eldorado Aerolite/Aerotech 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD E-450	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD F-550	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD F450	2019 Eldorado Ford E450 16 Seat ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD F550	2019 Eldorado Ford E450 16 Seat ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
INTERNATIONAL 4700	2019 Eldorado Ford E450 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	N/A
INTERNATIONAL 4300	2019 Eldorado Ford E450 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	N/A
FREIGHTLINER M2	2019 FREIGHTLINER M2 106 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
FREIGHTLINER MT 45 Chassis	2019 FREIGHTLINER MT 45 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
FREIGHTLINER MT 45G Front Gasoline Engine Walk in Van Chassis	2019 FREIGHTLINER MT 45G ICE	2019 Lightning Systems F59 Step Van BEV	N/A
FREIGHTLINER MT 55 Chassis	2019 FREIGHTLINER MT 45 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
ISUZU NPR/ NPR-HD/ NPR-XD	2019 ISUZU NPR/NPR-HD ICE	2019 Lightning Systems 6500XD LCF - Box Truck BEV	N/A
WORKHORSE P42	2019 FREIGHTLINER MT 45 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
WORKHORSE W42	2019 FREIGHTLINER MT 45 ICE	2019 Lightning Systems F59 Step Van BEV	N/A
INTERNATIONAL G2504	2019 Peterbilt 567 ICE	2019 Lion Lion8 Tractor BEV	2021 Tesla Heavy Duty BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
PETERBILT 386	2019 Peterbilt 567 ICE	2019 Lion Lion8 Tractor BEV	2021 Tesla Heavy Duty BEV
PETERBILT 579	2019 Peterbilt 567 ICE	2019 Lion Lion8 Tractor BEV	2021 Tesla Heavy Duty BEV
FORD F-550	2019 Peterbilt 520 - Garbage Truck ICE	2019 Lion Lion8 Refuse BEV	N/A
GMC C4	2019 Peterbilt 520 - Garbage Truck ICE	2019 Lion Lion8 Refuse BEV	N/A
ALL AMERICAN Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
AMTRAN Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
B2VC1611 Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
BLEBIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
BLUE Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUE Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUE B Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE BIRD Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
BLUE BIRD Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
BLUE BIRD Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
BLUE BIRD Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
BLUE BIRD Type B	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
BLUE BIRD Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUE BIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUE BIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUE BIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUE BIRD Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type C - Conventional	2019 Thomas 311TS Diesel ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUE BIRD Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE BIRD Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUE BIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
BLUE BIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUE IRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUE VIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEB Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEBIRD Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
BLUEBIRD Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUEBIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUEBIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUEBIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUEBIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUEBIRD Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
BLUEBIRD Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUEBIRD Type C - Conventional	2019 Thomas 311TS Diesel ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUEBIRD Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLUEBIRD Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
BLUEBIRD Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
BLUEBIRD Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEBIRD Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUEBIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEBIRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
BLUEBIRD Type D - Transit Style	2019 Thomas 141YS ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEBRD Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
BLUEDBIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLURBIRD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BLURBIRD Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BUE BIRD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
BUEBIRD Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CARP Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
CE Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
CE SB Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
CHEV Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
CHEV Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
CHEV Type B	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
CHEVGMC Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROELT Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROLET Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROLET Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROLET Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
CHEVROLET Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROLET Type B	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
CHEVROLET Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
CHEVY Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
CHEVY Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
CHEVY Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
CHEVY/GIRARDIN Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
Collins Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
Collins Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
Collins Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
CROWN Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CUMMINS Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
FEEIGHTLINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FORD Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
FORD Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
FORD Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
FORD Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
FORD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FORD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
FORD Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
FORD Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHT Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHT Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
FREIGHT Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHT LINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINE Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FREIGHTLINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
FREIGHTLINER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
FREIGHTLINER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
FREIGHTLINER Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINER Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLINER Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
FREIGHTLINER Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
FREIGHTLINER Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
FREIGHTLINGER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FREIGHTLNER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FRGHT Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
FRGHT Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
GIRARDEN Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
GIRARDIN Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
GIRARDIN Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
GM Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
GM Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
GM Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
GM Type B	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
GM Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
GM Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
GMC Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
GMC Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
GMC Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
GMC Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
GMC Type B	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
GMC Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
GMC Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
GREIGHTLINER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
IC Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
IC Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
IC Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
IC Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
IC Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
IC Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
IC Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
IC Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
IC/RE Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
IHC Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INLT Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INT Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTER Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
INTER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
INTER Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTER Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTER Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTER Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTERN Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
INTERN Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTERN Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTERN Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTERN Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTERNATIONAL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTERNATIONAL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
INTERNATIONAL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTERNATIONAL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTERNATIONAL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
INTERNATIONAL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTERNATIONAL Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTERNATIONAL Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTERNATIONAL Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
INTL Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
INTL Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTL Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
INTL Type C - Conventional	2019 IC Corporation PB105 60 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
INTL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
INTL Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTL Type C - Conventional	2019 Thomas 311TS Diesel ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTL Type C - Conventional	2019 Thomas 311TS Diesel ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTL Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
INTL Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
INTL Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTL Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
INTL Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
INTL Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
INTL. Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
MID BUS Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
MID BUS Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
MINOTOUR Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
NAVI Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
NAVISTAR Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
NTL Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
OSHKOSH Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
SAFE-T-LINER Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
SAF-T-LINER Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOM Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOMA Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOMAS Type A	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
THOMAS Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
THOMAS Type A	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	2020 Lion Electric LionA 160 kWh BEV
THOMAS Type A	2019 Thomas 051MS ICE	2019 Blue Bird Microbird BEV	N/A
THOMAS Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
THOMAS Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
THOMAS Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
THOMAS Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
THOMAS Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 220 kWh BEV
THOMAS Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	2020 Lion Electric LionC 88 kWh BEV
THOMAS Type C - Conventional	2019 Thomas 251TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
THOMAS Type C - Conventional	2019 Thomas 311TS Propane ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
THOMAS Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOMAS Type D - Transit Style	2019 Thomas 0918S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
THOMAS Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOMAS Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
THOMAS Type D - Transit Style	2019 Thomas 141YS ICE	2019 Blue Bird All American RE Electric BEV	N/A
THOMS Type C - Conventional	2019 IC Corporation PB105 77 Passenger ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
THOMS Type D - Transit Style	2019 Thomas 1408S ICE	2019 Blue Bird All American RE Electric BEV	2020 Lion Electric LionD 220 kWh BEV
WORK Type B	2019 Starcraft Quest - Chevrolet ICE	2019 Blue Bird Microbird BEV	N/A
WORK Type B	2019 Starcraft Quest - Ford ICE	2019 Blue Bird Microbird BEV	N/A
Type C - Conventional	2019 Thomas 221TS ICE	2019 Blue Bird Vision Electric 3301 BEV	N/A
AM GENERAL MV-1	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET Arboc 0	2019 ARBOC Spirit of Mobility 10 Seat, 2 W/C ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Astro Van	2019 Eldorado Aerolite/Aerotech 7 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET C4	2019 Goshen Impulse 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Goshen C4	2019 Goshen G Force 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
CHEVROLET ELDORADO C5	2019 Eldorado Navistar TC 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
CHEVROLET Express	2019 Eldorado Aerolite/Aerotech 10 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Express	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Express	2019 Eldorado Aerolite/Aerotech 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET Express	2019 Eldorado Aerolite/Aerotech 7 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Express	2019 Eldorado Aerolite/Aerotech 8 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Express	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET Arboc Express	2019 ARBOC Spirit of Liberty 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
CHEVROLET Arboc Express	2019 ARBOC Spirit of Mobility 10 Seat, 2 W/C ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Arboc Express	2019 ARBOC Spirit of Mobility 12 Seat, 2 W/C ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Arboc Express	2019 ARBOC Spirit of Mobility 16 Seat, 2 W/C ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET Champion Express	2019 Champion Crusader Challenger 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Champion Express	2019 Champion Crusader Challenger 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET ELDORADO Express	2019 Eldorado Aerolite/Aerotech 10 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET ELDORADO Express	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET ELDORADO Express	2019 Eldorado Aerolite/Aerotech 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET ELDORADO Express	2019 Eldorado Aerolite/Aerotech 8 Seat, 1 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET ELDORADO Express	2019 Eldorado Aerolite/Aerotech 8 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET Glaval Express	2019 Glaval Titan II 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Glaval Express	2019 Glaval Titan II 12 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET Glaval Express	2019 Glaval Titan II 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET Goshen Express	2019 Goshen G Force 20 Seat ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
CHEVROLET Goshen Express	2019 Goshen G Force 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
CHEVROLET Goshen Express	2019 Goshen Impulse 10 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Goshen Express	2019 Goshen Impulse 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET Goshen Express	2019 Goshen Pacer II 8 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET StarTrans Express	2019 Startrans Senator II 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
CHEVROLET StarTrans Express	2019 Startrans Senator SII 10 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET StarTrans Express	2019 Startrans Senator SII 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET StarTrans Express	2019 Startrans Senator SII 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
CHEVROLET StarTrans Express	2019 Startrans Senator SII 8 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
CHEVROLET ELDORADO Venture	2019 Eldorado Aerolite/Aerotech 8 Seat, 1 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD E-350	2019 Startrans Candidate CII 10 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD E-350	2019 Startrans Candidate CII 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD E-350	2019 Startrans Candidate CII 8 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Diamond E-350	2019 Diamond Diamond Coach 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Goshen E-350	2019 Goshen Impulse 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Goshen E-350	2019 Goshen Impulse 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD StarTrans E-350	2019 Startrans Senator SII 10 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans E-350	2019 Startrans Senator SII 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD E-450	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FORD Champion E-450	2019 Champion LF Transport 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Diamond E-450	2019 Diamond Diamond Coach 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD Diamond E-450	2019 Diamond Diamond Coach 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FORD ELDORADO E-450	2019 Eldorado Aerolite/Aerotech 10 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD ELDORADO E-450	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD ELDORADO E-450	2019 Eldorado Aerolite/Aerotech 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD ELDORADO E-450	2019 Eldorado Ford E450 16 Seat ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD ELDORADO E-450	2019 Eldorado Ford E450 20 Seat ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD ELDORADO E-450	2019 Eldorado Ford E450 20 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FORD Goshen E-450	2019 Goshen Impulse 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD Goshen E-450	2019 Goshen Impulse 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD Starcraft E-450	2019 Starcraft Starlite 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FORD StarTrans E-450	2019 Startrans Candidate CII 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans E-450	2019 Startrans Candidate CII 8 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans E-450	2019 Startrans Senator SII 10 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans E-450	2019 Startrans Senator SII 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans E-450	2019 Startrans Senator SII 16 Seat, 2 W/C-Ford ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
FORD F-550	2019 Eldorado Advantage 8 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD F-550	2019 Eldorado Ford F550 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FORD ELDORADO F-550	2019 Eldorado Ford F550 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FORD Glaval F-650	2019 Glaval Apollo 28 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FORD Transit	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FORD StarTrans Transit	2019 Startrans Candidate CII 12 Seat, 2 W/C-Ford ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
FORD Transit Connect	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
FREIGHTLINER Glaval S2C 106 Conventional Cab & Chassis	2019 Glaval Legacy 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
FREIGHTLINER Arboc XBA Arboc Rail Rear Engine Commercial Bus Chassis	2019 ARBOC Spirit of Liberty 24 Seat ICE	2020 GreenPower Motor Company EV Star Plus 24 Seat BEV	2020 GreenPower Motor Company EV Star Plus ADA 24 Seat, 2 W/C BEV
GMC Savana	2019 Ford Transit Connect Passenger Van 2WD ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
INTERNATIONAL ELDORADO	2019 Eldorado Aerolite/Aerotech 16 Seat, 2 W/C-Chevy ICE	2020 GreenPower Motor Company EV Star 19 Seat BEV	N/A
WORKHORSE ELDORADO P32	2019 Eldorado Aerolite/Aerotech 12 Seat, 2 W/C-Chevy ICE	2019 Lightning Systems Transit 350HD 15 Passenger Van 86 kWh BEV	2019 Lightning Systems Transit 350HD 15 Passenger Van 43 kWh BEV
GILLIG 40' Bus	2019 Gillig 40' Low Floor BAE Hybrid ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
GILLIG 35' City Suburban Bus	2019 Gillig 35' Low Floor Diesel ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
GILLIG 40' City Suburban Bus	2019 Gillig 40' Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
GILLIG 30' City Transit Bus	2019 Gillig 30' Low Floor Diesel ICE	2019 BYD K7M 30' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV300 all-electric Transit Bus BEV
GILLIG 35' City Transit Bus	2019 Gillig 35' Low Floor Diesel ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
GILLIG 40' City Transit Bus	2019 Gillig 40' Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
GILLIG 28' Low Floor Bus	2019 Gillig Low Floor 29' ICE	2019 BYD K7M 30' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV300 all-electric Transit Bus BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
GILLIG 35' Low Floor Bus	2019 Gillig 35' Low Floor BAE Hybrid ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
GILLIG 35' Low Floor Bus	2019 Gillig 35' Low Floor Diesel ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
GILLIG 40' Low Floor Bus	2019 Gillig 40' Low Floor BAE Hybrid ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
GILLIG 40' Low Floor Bus	2019 Gillig 40' Low Floor CNG ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
GILLIG 40' Low Floor Bus	2019 Gillig 40' Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
INTERNATIONAL 35' #N/A	2019 Gillig 35' Low Floor Diesel ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 Proterra Proterra 35' Catalyst XR BEV
NEW FLYER 40' Invero	2019 New Flyer 40' Xcelsior Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
NEW FLYER 30' Low Floor	2019 New Flyer 35' Xcelsior Low Floor CNG ICE	2019 BYD K7M 30' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV300 all-electric Transit Bus BEV
NEW FLYER 40' Low Floor	2019 New Flyer 40' Xcelsior Low Floor CNG ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
NEW FLYER 60' Low Floor	2019 New Flyer 60' Xcelsior Low Floor Diesel ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV
NEW FLYER 60' Low Floor Re-styled	2019 New Flyer 60' Xcelsior Low Floor Diesel ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV
NEW FLYER 30' Transit Bus	2019 New Flyer 35' Xcelsior Low Floor CNG ICE	2019 BYD K7M 30' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV300 all-electric Transit Bus BEV
NEW FLYER 40' Transit Bus	2019 New Flyer 40' Xcelsior Low Floor CNG ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
NEW FLYER 40' Transit Bus	2019 New Flyer 40' Xcelsior Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
NEW FLYER 60' Transit Bus	2019 New Flyer 60' Xcelsior Low Floor BAE Hybrid ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV
NEW FLYER 60' Transit Bus	2019 New Flyer 60' Xcelsior Low Floor Diesel ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV

VIN Decoded Make and Model	2019/2020 Model Year Equivalent	2019/2020 EV Alternative 1	2019/2020 EV Alternative 2
NEW FLYER 35' Xcelsior	2019 New Flyer 35' Xcelsior Low Floor Allison Hybrid ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
NEW FLYER 35' Xcelsior	2019 New Flyer 35' Xcelsior Low Floor Diesel ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 Proterra Proterra 35' Catalyst XR BEV
NEW FLYER 40' Xcelsior	2019 New Flyer 40' Xcelsior Low Floor Diesel ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
NEW FLYER 60' Xcelsior	2019 New Flyer 60' Xcelsior Low Floor BAE Hybrid ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV
NEW FLYER 60' Xcelsior	2019 New Flyer 60' Xcelsior Low Floor Diesel ICE	2019 BYD K11M 60' Articulated All-Electric Transit Bus BEV	2019 New Flyer Xcelsior CHARGE 60' - 466 kWh BEV
ORION BUS 35' Model 05 (Orion V - 102" Wide)	2019 Gillig 35' Low Floor BAE Hybrid ICE	2019 BYD K9S 35' All-Electric Transit Bus BEV	2019 GreenPower Motor Company EV250 all-electric Transit Bus BEV
ORION BUS 40' Model 05 (Orion V - 102" Wide)	2019 Gillig 40' Low Floor BAE Hybrid ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV
ORION BUS 40' Orion VII	2019 Gillig 40' Low Floor BAE Hybrid ICE	2019 Proterra 40' Catalyst E2 BEV	2019 BYD K9M 40' All-Electric Transit Bus BEV

APPENDIX C USE CASES

Vehicle Fleet	Vehicle Class	Use Case
State Agency Fleet	Heavy	Refuse Truck
State Agency Fleet	Heavy	Short Haul
State Agency Fleet	Light	Motorcycle
State Agency Fleet	Light	Pickup
State Agency Fleet	Light	Police Pursuit
State Agency Fleet	Light	Sedan
State Agency Fleet	Light	SUV
State Agency Fleet	Light	Van
State Agency Fleet	Medium	Box Truck
State Agency Fleet	Medium	Cargo Van
State Agency Fleet	Medium	Flatbed Truck
State Agency Fleet	Medium	Passenger Van 7 - 15 Passenger
State Agency Fleet	Medium	Service Body/Work Truck
State Agency Fleet	Medium	Shuttle Bus, 15+ Passenger
State Agency Fleet	Medium	Step Van
School Buses	Heavy	Type C - Conventional
School Buses	Heavy	Type D - Transit Style
School Buses	Medium	Type A
School Buses	Medium	Type B
Public Transit	Heavy	Coach Bus

Vehicle Fleet	Vehicle Class	Use Case
Public Transit	Heavy	Transit Bus, 30'
Public Transit	Heavy	Transit Bus, 35'
Public Transit	Heavy	Transit Bus, 40'
Public Transit	Heavy	Transit Bus, 60'
Public Transit	Light	Pickup
Public Transit	Light	Sedan
Public Transit	Light	SUV
Public Transit	Light	Van
Public Transit	Medium	Cargo Van
Public Transit	Medium	Passenger Van, <15 Passenger
Public Transit	Medium	Shuttle Bus, 12-16 Passenger
Public Transit	Medium	Shuttle Bus, 16-20 Passenger
Public Transit	Medium	Shuttle Bus, 20-24 Passenger
Public Transit	Medium	Shuttle Bus, 24+ Passenger
Public Transit	Medium	Shuttle Bus, 8-12 Passenger

This table shows the full set of vehicle use cases included in the analysis. Use cases are broken down by fleet category and vehicle weight class.

APPENDIX D: FUTURE PROJECTIONS OF TECHNOLOGIES

FIGURE 100: PROJECTED PERCENTAGE CHANGES IN MSRP FOR MEDIUM- AND HEAVY-DUTY CONVENTIONAL VEHICLES IN BUSINESS-AS-USUAL TECHNOLOGY AND R&D SUCCESS SCENARIOS

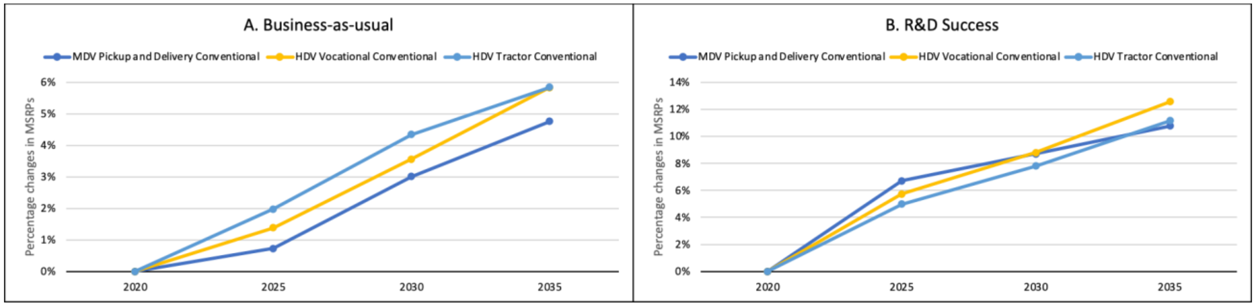
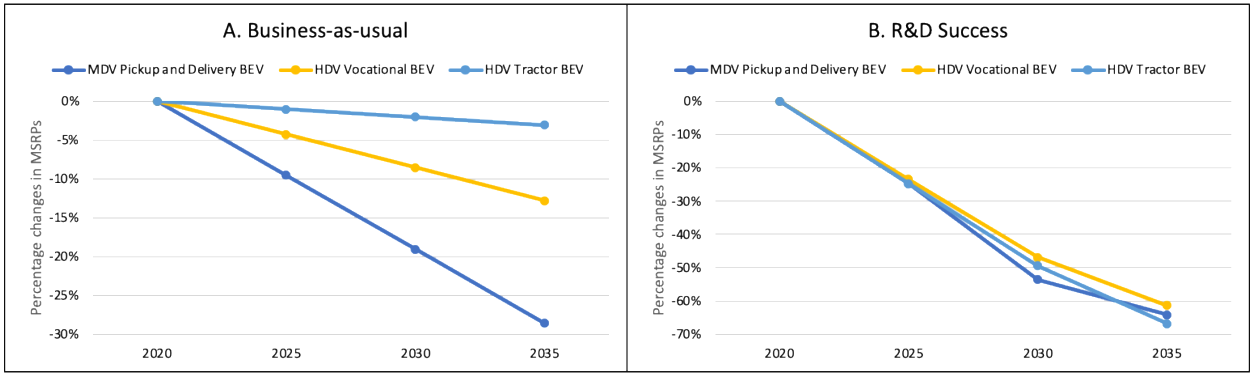


FIGURE 101: PROJECTED PERCENTAGE CHANGES IN MSRP FOR MEDIUM- AND HEAVY-DUTY CONVENTIONAL VEHICLES IN BUSINESS-AS-USUAL TECHNOLOGY AND R&D SUCCESS SCENARIOS



APPENDIX E: HIGH-POWER LEVEL 2 CHARGER COSTS

TABLE 35: COST PER CHARGING STATION FOR LEVEL 2 CHARGING STATIONS

Source	Power per charging port (kW)	Cost per charging station ($)
Clipper Creek[6]	15.4	$969
	11.5	$899
	9.6	$635
	7.7	$565
	5.8	$565
PGE 2019	8	$773
	15	$1,133
EPRI 2013, AFDC 2015[7]	1	$459
Bosch[8]	3.3	$476
	7.6	$559
	9.6	$695

[6] ClipperCreek. 2020. "Level 2 Electric Vehicle Charging Stations: 12-80 Amp | ClipperCreek." 2020. https://store.clippercreek.com/level2 .
[7] Estimated from multiple costs
[8] Bosch. 2020. "Charging Stations | Bosch EV Solutions." 2020. https://www.boschevsolutions.com/charging-stations.

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