TOWN OF CONCORD FLEET ELECTRIFICATION STUDY

MARCH 2022

PREPARED FOR:

Town of Concord, Massachusetts

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

ACRONYMNS

AC	Alternating Current
BEV	Battery Electric Vehicle (See also *EV* & *PEV*)
DC	Direct Current
DCFC	Direct Current Fast Charge (DC Fast Charge)
ePTO	Electric Power Take Off
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment (EV charger)
ICE	Internal Combustion Engine
kW	Kilowatt
kWh	Kilowatt hour
PEV	Plug-in Electric Vehicle (See also EV & BEV)
PHEV	Plug-in Hybrid Electric Vehicle
TBD	To Be Determined
TCO	Total Cost of Ownership
V	Volt
ZEV	Zero-Emissions Vehicle

EXECUTIVE SUMMARY

This report provides a systematic assessment of all current Town-operated vehicles with the primary goals of identifying vehicle electrification opportunities, establishing an Electrification Timeline based on vehicle replacements and determining the costs and emissions benefits of fleet electrification. The analysis assessed relevant vehicle data in the Towns records and ultimately compiled a fleet database. Available data included vehicle makes, models, ages, purchase date and price, fuel type, usage and costs, and miles travelled. Quantitative data was supplemented by interviews with appropriate Town of Concord staff to better understand how vehicles are used and the anticipated future mobility needs of each department.

The Town of Concord has 227 total vehicles on-road and off-road vehicles, including the Concord Public School's fleet. For the purposes of the electrification study, **177 vehicles were studied for electrification, which excluded** off-road assets and vehicles that are already electric**.** Of this subset, more than a third (34%) can be replaced with equivalent electric vehicles that are currently commercially available, predominantly sedans, SUVs and pickup trucks. Concord Public School's buses (22) are also primed for electrification and would normally fall under the "Best Fit" for Full Electrification category. Instead, they have been placed in their own separate category at the request of the Town to better understand and quantify the benefits of bus electrification as a subset. Outside of vehicles designated as "Best Fit" for electrification and buses, many of the remaining vehicles (36% of 177) have potential electric candidates for replacement but challenges, primarily related to cost-effectiveness or operational requirements. About 17% of the vehicles studied do not have a potential candidate for electrification currently available or announced in the market.

The key findings of the Fleet Assessment Report are summarized on the following page.

KEY FINDINGS

- One third (34%) of Concord's studied fleet (61 out 177 assessed) can be replaced with equivalent electric vehicles that are currently commercially available and likely to be cost-effective ("Best Fit" for Full Electrification). At current vehicle costs, excluding incentives, electrifying the subset of these vehicles coming due for replacement from 2022 to 2025 will **save approximately $200,00** over the lifespan of the vehicles. Conversion of the subset of these coming due for replacement from 2025 - 2030 is expected to **save approximately $180,000** during the lifetime of the vehicles excluding incentives. Finally, conversion of the subset of vehicles due for replacement from 2031 - 2035 is expected to **save approximately $140,000** over the lifetime of the vehicles. Expected reduction in vehicle prices over the next 10 years will reduce this marginal cost. Please note that these estimates do not include the cost of installing and maintaining EV chargers.

- The carbon emissions reductions corresponding with replacement of the Town's "Best Fit" vehicles is an estimated **49 mTCO2 (4%)** from 2019 levels by 2025, **205 mTCO2 (18%)** by 2030 and **223 mTCO2 (20%)** by 2035. The carbon emissions reductions corresponding with replacement of the Town's "Best Fit" vehicles in addition to the electrification of the 22 Buses is an estimated **119 mTCO2 (11%)** from 2019 levels by 2025, **391 mTCO2 (39%)** by 2030 and **4 mTCO2 (40%)** by 2035. If the Town expands its electrification efforts to include vehicles that are potentially electrifiable, it can achieve carbon emissions reductions of **224 mTCO2 (20%)** from 2019 levels by 2025, **635 mTCO2 (57%)** by 2030 and **728 mTCO2 (65%)** by 2035. Full decarbonization of electrified vehicles will require charging EVs with a fully decarbonized electricity source.

- Following current replacement schedules, and if Concord only electrified "Best Fit" vehicles, **25%** of its light-duty vehicles would be electric by 2025 and **60%** would be electric by 2030 ("Best Fit" Electrification Scenario). If Concord also transitioned "potentially electrifiable" vehicles, Concord can electrify **40%** of its light-duty vehicles by 2025 and **89%** by 2030 (Potential Electrification Scenario).

- Availability of medium- and heavy-duty electric vehicles is a significant challenge limiting Concord's ability to electrify its fleet. With the exclusion of the 22 buses, only a select few are potentially electrifiable with currently available electric vehicles all of which have cost-effectiveness or operational concerns. Considering "potentially electrifiable" vehicles, **16%** can be electrified by 2025 and **39%** by 2030. However, to achieve this level of electrification the Town will have to address operational and budget concerns during the purchasing process.

- Electric vehicle range is not a barrier to vehicle electrification for the Town of Concord. For **100%** of the vehicles assessed, **the recommended EV option could satisfy 100%** of the existing vehicle's historical driving behavior.

- Under the "Best Fit" Electrification scenario, vehicles in the Police Department represent the most cost-effective opportunity for carbon emissions reductions on a capital cost basis. The police departments vehicles, particularly patrol vehicles, are high utilization vehicles being used to drive a great distance annual making them ideal candidate for electrification. However, the unique operational needs of patrol and special unit vehicles require additional consideration.

INTRODUCTION

The purpose of this report is to document the analysis of each fleet asset studied, and include the following research elements:

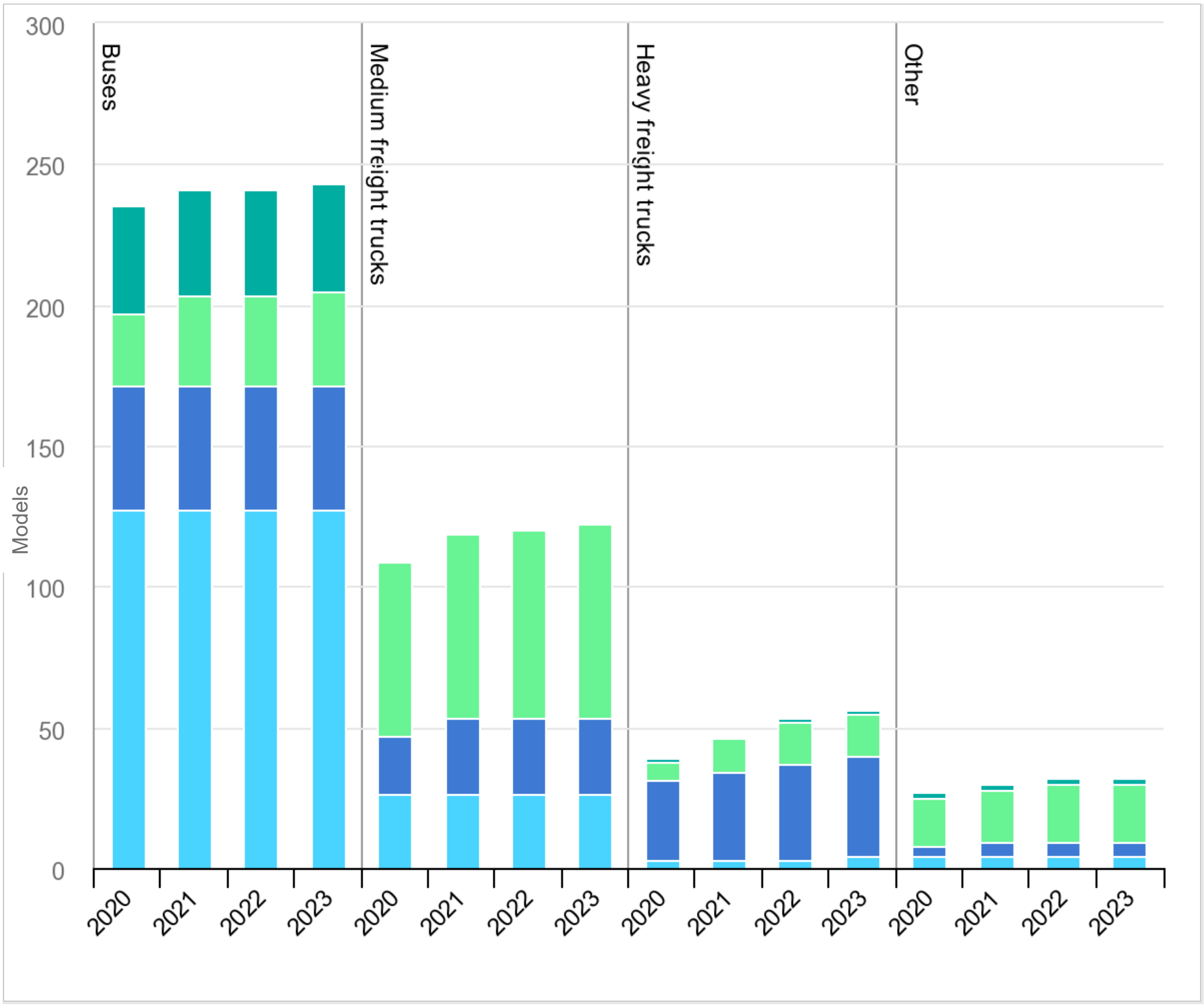
1. Fleet baseline summarizing vehicles studied, fleet composition and categorization of fleet by electrification potential
2. Explore appropriate vehicle needs of each department to guide fleet electrification, including a schedule and recommendation for electrification of each analyzed vehicle, or category of vehicle.
3. Analysis of Total Cost of Ownership and capital budget needs associated with fleet electrification
4. Analysis of potential carbon emissions reductions associated with fleet electrification

CHALLENGES OF VEHICLE ELECTRIFICATION PLANNING IN A DYNAMIC MARKET

The Town of Concord can only make fully informed electric vehicle purchase decisions regarding the information on currently available EV models. The Town can also make preliminary plans for purchasing vehicles based on product announcements by the automotive industry, but specific information on purchase prices and dates of availability remains speculative. Beyond 2022-2024, limited actionable information is available on product offerings, but the market dynamics indicate that the Town can safely assume that zero-emission vehicle offerings will be available for most vehicle categories by 2030 and prepare for that eventuality.

In the last year multiple electric models that are viable options for municipal fleets, beyond standard light-duty sedans, have become commercially available, including the Ford F-150 Lightning, Ford eTransit and Mustang Mach E, Chevy Silverado-EV and this trend is expected to continue and expand beyond the light-duty segment. According to the International Energy Agency's 2021 EV Outlook, 18 of the 20 largest Original Equipment Manufacturers (OEMs) have committed to increase their EV offerings.[1] Additionally, the availability of medium-duty and heavy-duty electric vehicles is expanding globally (see Figure 1), including in the U.S., although the total number of models available in China and Europe still outpaces the U.S..

[1] Global EV Outlook 2021, International Energy Agency



Source: International Energy Agency. Colors denote number of models by Country. Light blue denotes China, dark blue denotes Europe, light green denotes U.S., and turquoise denotes Rest of the World.

FIGURE 1. AVAILABILITY OF HEAVY-DUTY ELECTRIC VEHICLES (2020-2023)

As options expand, costs are continuing to fall, mostly related to continued decline in battery costs.[2] In light of the rapidly changing market, this analysis attempts to include at least one electric option, even if that option may not be cost-effective, to provide the Town with the most up to date view of potential electric options and ensure that the charging infrastructure needs modeling informed by this analysis is considering energy demands that reflect a completely electrified fleet.

[2] See here for more information on projected price decreases of PEVs: https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf

FLEET COMPOSITION

This section describes in further detail the data sources used in this report and summarizes the composition of Concord's fleet.

DATA SOURCES

As one of the first steps of this project, the Town of Concord's fleet data were gathered from various data sources and a comprehensive database was compiled for further analysis. The data sources used in this project include the following:

- A **Town Fleet database** was compiled by the Project Team during this project. The Town-wide equipment ID system was created to enable simple tracking of vehicles across departments once the data was aggregated into a central database. Working with Town staff, the Project Team assigned prefixes to existing vehicle numbers to create a set of equipment IDs that delineated vehicles from different departments while keeping the existing numbers intact. For example, vehicle 1 in the Police Department was assigned CPD1. Due to the limited amount of data that the Town collected historically, several data fields were completed or estimated by Longobart & Ross with Optony's support. Estimates were informed by industry best practices from the American Public Works Association (APWA), data from similar fleets and the expertise of the Longobart & Ross team. A list of data fields for which values were estimated or assigned based on best practices is as follows:
    - Life Expected Years, Life Expected Hours, Life Expected Miles, In-Service Year, Target Maintenance, Class Code, Status, Condition, Department Name, and Original Purchase Price.
- **National Highway Traffic Safety Administration (NHSTA) Vehicle Identification Number (VIN) Decoder**: To supplement vehicle information included in the Town Fleet Inventory, the NHSTA VIN Decoder, an online software tool that interprets VINs and provides an extensive list of characteristics corresponding to that VIN, was used to gather additional vehicle characteristics. Specifically, it was used to gather the Gross Vehicle Weight Rating (GVWR) and Body Type of each vehicle.

In addition to the above-mentioned data sources, qualitative data was collected through discussions with Town staff, such as vehicle duty cycles and emergency response requirements. In all, the data collection efforts described above led to the creation of a comprehensive fleet database, attached to this report as **Appendix A**, which served as the basis for all further analyses.

FLEET COMPOSITION AND CHARACTERISTICS

SUMMARY OF FLEET ASSETS

This section provides descriptive statistics to understand the current condition and composition of Concord's fleet. The final fleet database included a total of 227 units, including light-, medium-, heavy-duty vehicles and off-road assets. After accounting for the six existing electric vehicles in the Town's fleet, 177 of units were included in the electrification analysis. However, all 227 are included in the figures 2, 3, and 4. Table 1 only includes the studied fleet of 177 vehicles.

Figure 2 depicts the breakdown of the fleet by vehicle type. Over half of the fleet falls under two vehicle categories, Pickup, and Truck. The "Pickup" category includes light- and medium-duty vehicles ranging from smaller pickups such as the Ford Ranger to larger pickups such as the Ford F-350. The "Truck" category designates a vehicle body type for Medium- and heavy-duty vehicles such as the Ford F550, Ford F750 and International 7000.

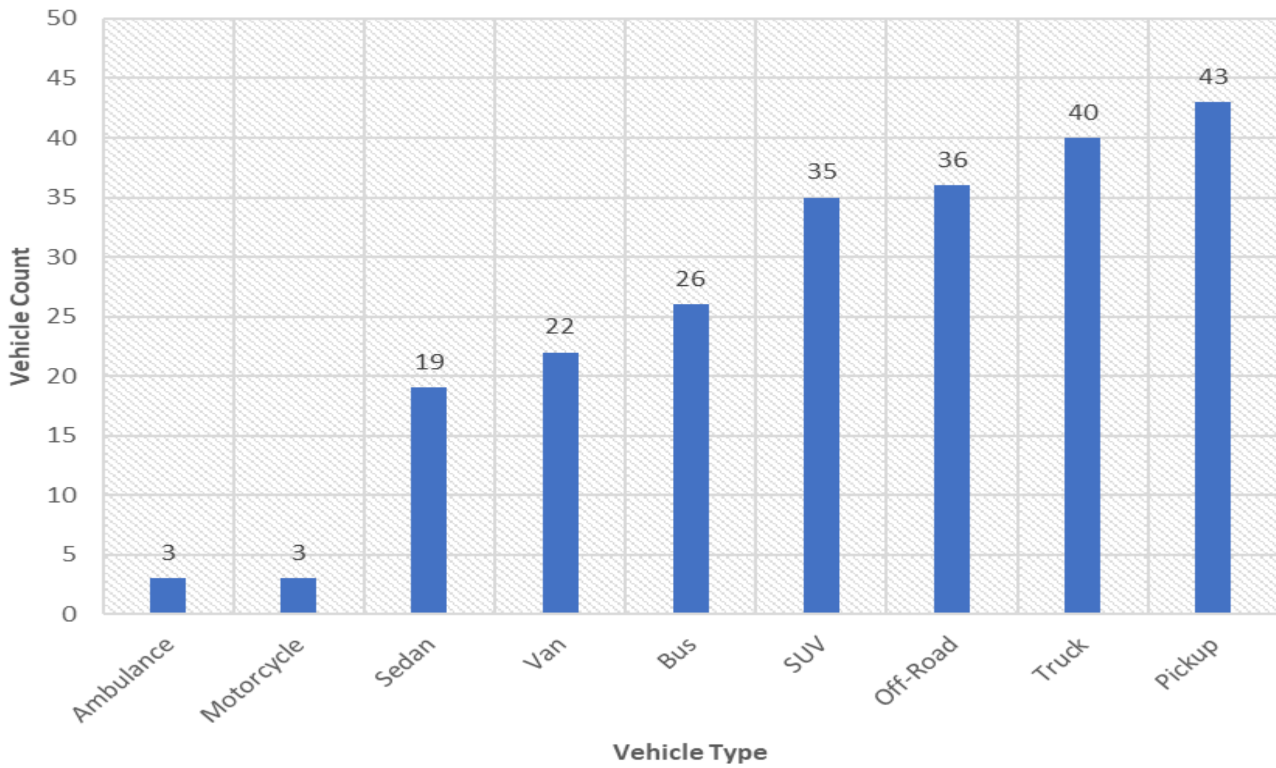


FIGURE 2. ENTIRE FLEET – COMPOSITION

Figure 3 shows a count of all vehicles by their model year. Oldest model years are shown first, followed by progressively new model years from left to right.

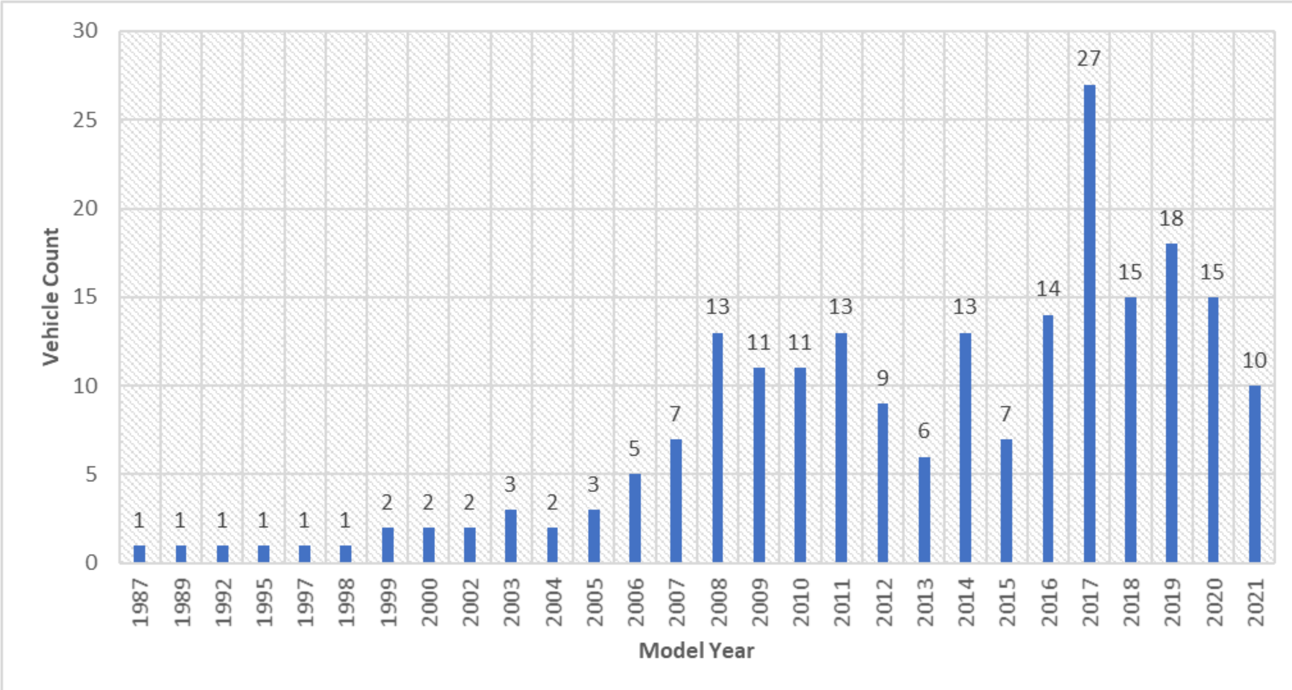


FIGURE 3. ENTIRE FLEET – AGE BY MODEL YEAR

In terms of the powertrain, the large majority (91%) of the fleet are internal combustion engines (ICE) followed by hybrids (5%) and battery electric vehicles (BEV) (3%) and Plug in Hybrids (1%). Split out by fuel type in **Figure 4**, the majority (54%) of the fleet use only unleaded gasoline, followed by diesel (43%), and electricity (3%).

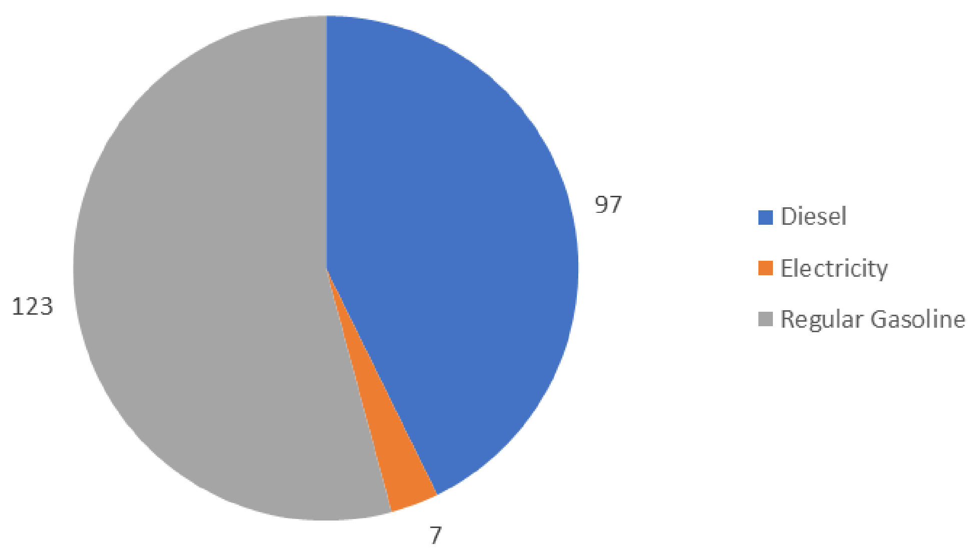


FIGURE 4: FLEET – VEHICLE COUNT BY FUEL TYPE

Table 1 summarizes the 177 vehicles of the studied portion of the Town's fleet and includes the number of vehicles considered in each department, total annual mileage and average annual vehicle mileage by department. Among the Town's various departments, Public Works has the largest fleet with 51 vehicles, followed by Schools (26) and Concord Municipal Light Plant (25). A detailed version of Table 1 has been provided in **Appendix C**.

TABLE 1: STUDIED FLEET SUMMARY BY DEPARTMENT AND ANNUAL MILEAGE DRIVEN[3]

DEPARTMENT	NUMBER OF VEHICLES	TOTAL ANNUAL MILES TRAVELED	ANNUAL MILES PER VEHICLE
BUILDING	3	21,511	7,170
FACILITIES	5	16,119	3,224
FIRE	16	71,769	4,486
HEALTH	2	3,062	1,531
HUMAN SERVICES	5	22,012	4,402
LIBRARY	1	1,486	1,486
MUNICIPAL LIGHT PLANT	25	94,629	3,785
NATURAL RESOURCES	2	10,206	5,103
POLICE	20	257,870	12,893
PUBLIC WORKS	51	277,876	5,449
SCHOOLS	47	383,766	8,165
TOTAL	**177**	**1,160,307**	**-**

VEHICLE CATEGORIZATION

As mentioned earlier, the fleet inventory curated for the Town of Concord consists of 227 units. Of the entire fleet 50 units were excluded leaving the studied fleet of 177.

STUDIED FLEET

[3] Total and average annual usage are calculated from 12-months of vehicle mileage recorded from January 1st 2019 to December 31st.

177 vehicles were studied in detail. However, not all of these vehicles can be fully electrified based on currently available technologies. Therefore, based on the vehicle body type (as will be discussed later), these fleet vehicles were further categorized into sub-categories:

- **"Best Fit" for Full Electrification:** 61 vehicles that can be fully replaced with an equivalent EV available on the market today. It is important to note that 36 of the vehicles in this category are in the Police or Fire Department and implementation will need to be phased to avoid compromising department operations. Specific considerations related to vehicle selection for these departments are included under **Electric Vehicle Selection**.

- **Just Buses:** The towns 22 **buses** would normally fall into the "Best Fit" for Full Electrification, but they have been moved into their own category as the Town is addressing their electrification separately.

- **Potentially Electrifiable:** 64 vehicles are potentially electrifiable using EVs available on the market today, but questions remain around cost-effectiveness, vehicle-specific operational and outfitting requirements and whether vehicle replacements that are not "like for like" are supported by internal stakeholders. Further analysis by Town staff is needed prior to a purchasing decision being made. This category is further summarized below:

    - There are 8 pickup trucks that do not have an exactly equivalent EV available at the time of writing, but can potentially be downsized to a smaller pickup (e.g., Ford F-250 to Ford F150 Lightning), or upsized to a larger medium-duty chassis option (e.g. Ford F-350 to Lightning eMotors F-550), depending on vehicle operational needs such as towing or storage capacity.

    - There are 43 vehicles that have potential "like for like" vehicle options but may be cost prohibitive. Examples include all electric fire engines (e.g., Pierce Volterra Pumper) and heavy-duty trucks (e.g., Peterbilt 579EV).

    - There are 13 vehicles that also have potential "like for like" vehicle options but due to their use may have operational concerns. An example would be the Fire Departments 4 SUVs and 1 pickup that have lights and sirens, which would have to be retrofitted onto an electric replacement.

- **No Electric Option:** 30 vehicles in Concord's fleet have no electric option currently available. This category includes vehicles like ambulances and heavy-duty dump trucks. For the vehicles under this category, other short-term emissions reduction options can be considered, such as switching to renewable diesel, and long-term electrification is likely to be possible as the market develops.

EXCLUSIONS

50 units were excluded from the detailed analysis. These exclusions were applied in cases where there was no need for further study because the asset was already electrified, the vehicles operation was classified as off-road or the vehicle had already been replaced immediately prior to the project and was still a part of the Towns fleet, but unused. More information on the electrification of off-road assets can be found on page 24.

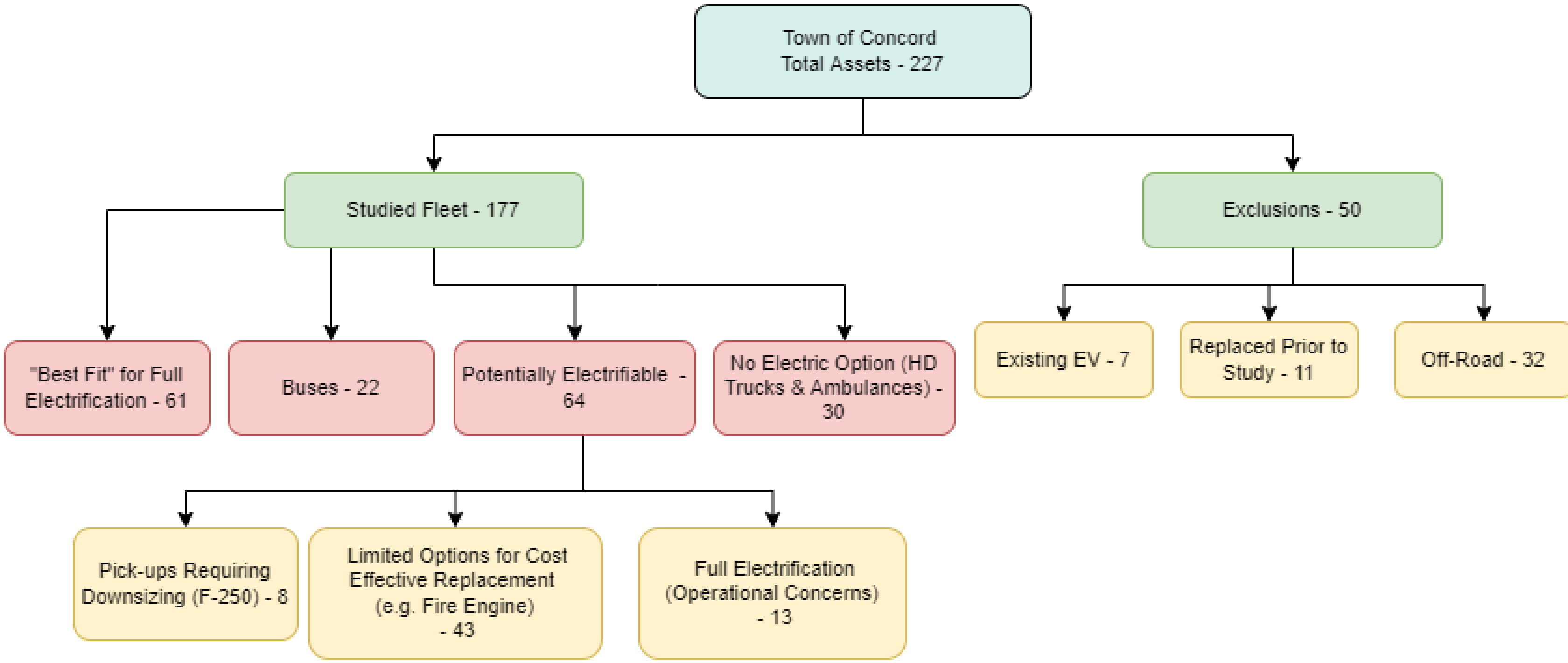


FIGURE 5: TOWN OF CONCORD FLEET COMPOSITION & ASSESSMENT APPROACH

VEHICLE ANALYSIS METHODOLOGY & RESULTS

After the initial assessment of the fleet and identification of the studied vehicles, the next was to analyze the data to identify specific electrification opportunities. The fleet electrification methodology consisted of the following major steps:

- **Step 1 - Electrification Timeline**: An electrification timeline was established based on expected replacement years for each vehicle provided by Town staff.
- **Step 2 - Electric Vehicle Selection**: Identification and selection of electrification options, either for complete replacement of vehicles based on the availability of equivalent EVs, or other electrification options such as partial electrification, powertrain replacement, or renewable diesel.
- **Step 3 – Range Suitability:** Analysis of miles driven by existing vehicle to determine whether each proposed EV has a sufficient battery range to meet existing driving needs.
- **Step 4 - Total Cost of Ownership Analysis for a Fully Electrified Fleet**: A calculation of the total cost of ownership (TCO) that compares the conventional ICE vehicle replacement with potential EV models, comparing a combination of capital costs (vehicle purchase price) and operating costs over the expected lifespan of the vehicle for each replacement option.

While the Fleet Electrification Methodology is presented as a linear process, in order to have the highest confidence in its procurement decisions and to adapt to an evolving market, it is recommended that Step 2 and Step 3 (above) are completed each year as the vehicles in the electrification timeline come up for replacement and the Town begins implementing fleet electrification.

ELECTRIFICATION TIMELINE

Figure 6 depicts the electrification timeline and the number of vehicles to be replaced and electrified each year over the next 20 years. Vehicles are split by the electrification potential categorization described under the **Vehicle Categorization** section**.** All vehicles analyzed in the studied fleet, except 2, are expected to be replaced by 2036 based on their historical usable life. Additionally, over the next five years an average of 21 vehicles are scheduled to be replaced each year.

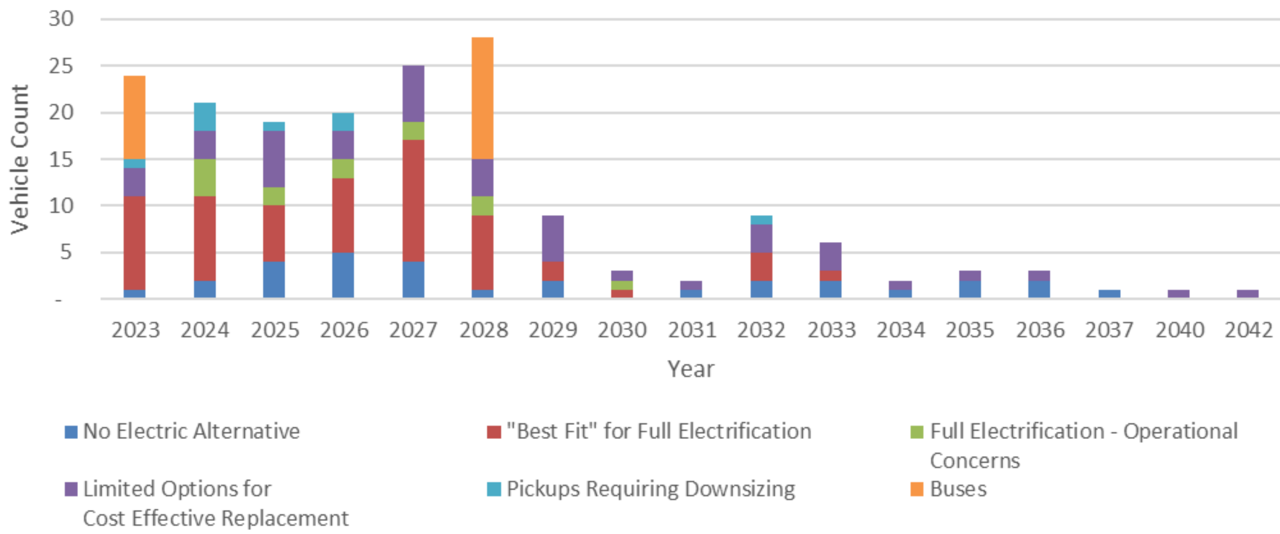


FIGURE 6: FLEET ELECTRIFICATION TIMELINE

As electrification options for medium- and heavy-duty vehicles become increasingly available, the number of vehicles eligible for full electrification will increase as operational concerns are addressed by newly offered models that may also be cost competitive. The potential impacts of this trend are demonstrated in **Figure 16** under the "Complete Electrification Scenario".

ELECTRIC VEHICLE SELECTION

To balance the diverse composition of the Town of Concord's fleet, the types of electric vehicles currently available and the Town's objectives of reducing costs and carbon emissions, this analysis attempted to assign at least one potential EV option to each existing vehicle in the Town's fleet, while clearly defining which vehicles had "Best Fit" options and which had more uncertainty surrounding the suitability of the available EV options. The following discussion provides additional information on the current and expected market availability of EV options for various vehicle sizes, giving context to the limitations of the analyses presented in this report and future opportunities that may enable the Town to determine a clearer path toward electrification of its medium- and heavy-duty vehicles. A summary of all vehicles, ICE and Electric, included in the analysis can be found in **Appendix B.**

LIGHT-DUTY VEHICLE SELECTION

Sedans, SUVs & Light Duty Vans

As of mid-2021, there are a range of battery-powered vehicles suitable for municipal fleets currently priced around $35,000 with a range greater than 100 miles. The most common choices are the Nissan Leaf or Chevrolet Bolt, both of which were considered as potential EVs for Concord's fleet. Other light-duty, electric vehicles available for immediate fleet purchase include the Chevrolet Bolt EUV, Ford Focus; Chrysler Pacific PHEV; Honda Clarity Electric; Hyundai Ioniq & Kona and Kia Niro. While there are more EV options available now than previous years, this list is still a tiny fraction of all light-duty vehicle models currently available to fleet buyers. The EV models selected for inclusion in this analysis prioritized models and OEMs with which the Town is familiar, which are easily purchased through existing procurement contracts and attempted to standardize across vehicle types in support of the Town's efforts to standardize its fleet at large around preferred OEMs.

Concord also operates 15 light-duty vans, ranging from smaller Chevrolet Astros to Ford E-350s. The 2022 Ford eTransit is currently available and would be an appropriate replacement vehicle for the majority of this group of existing vehicles. The estimated 126 miles of range is more than sufficient for the daily driving needs of the Town's vehicles. Ford is offering three different vehicle weights of the eTransit, as well as chassis cab and cutaway options, which make the eTransit an appropriate option to replace the larger light-duty vans in the Town's fleet.

CMLP light duty vehicles all have some form of emergency response requirement where they need to be active for long periods of time during an outage. For that reason, PHEVs were considered for some light duty vehicles that would otherwise have been recommended as all electric. Additionally, some of the light-duty vehicles required 4WD options (PLM6, PLM2, CMLP21, CMLP20, PLM3). For these, the VW ID4 was recommended as an all electric option. While these vehicles are slightly more expensive than the Nissan Leaf and Chevy Bolt, it better matches the operational requirements.

Pickup Trucks

Pickup trucks represent a significant challenge to electrification due to their prevalence in the Town's fleet and the lack of available electric options matching the range of ICE options. The Town fleet includes 41 pickup trucks, mostly Ford F-150, Ford F-250, and Ford F-350s. When considering electrification of the smaller pickup trucks (1/2-ton trucks such as the F-150), recent all electric options have come to market including the Ford F-150 Lightning and Lordstown Endurance. With 10,000 pounds of towing capacity, range of 230-300 miles and a price point of $42,000, the Ford F-150 is a good option for municipal fleets and was included as the primary option in this analysis.

Alternative US-made pickup trucks that could be appropriate for the fleet are the Cybertruck ($49,900 – 69,900), Endurance (expected MSRP $52,000), and the Silverado EV ($39,000 - $80,000) under development or beginning production by Tesla, Lordstown Motors and Chevy, respectively. Other pickup trucks are also in development or nearing production by companies like Bollinger, Rivian, and Nikola in 2021-2022, but those are aimed at the luxury market and have MSRPs ranging from $60,000 to $125,000.

For the 18 larger trucks in Concord's fleet, options remain extremely limited and there are no equivalent all electric options on the market. After discussion with Town staff, the option deemed to be the best fit was the SEA Electric F450, which is an electric F-450 EV built on a E4E-450 cab chassis platform with a GVWR range from 14,000lbs to 14,500lbs. Considering this option, as well as the potential to downsize larger pickups to a ½ ton option if deemed operationally feasible through discussions with drivers, there is no perfect path for electrification of these vehicles. A final option for these vehicles would be conversion to a plug-in hybrid using an aftermarket solution from XL Fleets. XL Fleets is an upfit solution that is installed onto an existing ICE vehicle where an electric motor is integrated into the drive system, offering improved performance with reduced emissions. Significant concerns exist related to the XL Fleets solutions, including the efficacy and maintenance;

significant concerns also exist related to a chassis conversion option like Lighting Motors, including upfront cost, warranty/repair issues and availability of parts in the future; and downsizing to a ½ ton option may not be possible due to operational requirements like utility bodies.

There are additional companies besides Lightning Motors that offer EV chassis conversions that can be fitted with a utility body, such as Motiv Power Systems. Motiv's E-450 and F-450 options are also larger than the F-250 and F-350s the Town commonly operates today. Any chassis conversion option can require long lead times for ordering and are often significantly more expensive to purchase.

Police Department

While administrative vehicles in the Police Department can be replaced with standard light-duty options, the unique operational needs of patrol and special unit vehicles require additional consideration.

Police departments throughout the country, such as Westport, Connecticut; Bargersville, Indiana; and Fremont, California have deployed electric patrol vehicles, all manufactured by Tesla. The Fremont Police Department reports that their initial vehicle, a Tesla Model S, has behaved favorably in the role of a patrol vehicle despite not yet being pursuit-rated, with considerably less downtime than the Ford Explorer Utility Interceptor models which comprise the majority of their patrol vehicle fleet. Following this success, they purchased and deployed (in September 2021) a Model Y. Moving forward, the Model Y is likely to be the most appealing option as it provides a balance between size and purchase price. The Town currently has a Mustang Mach-E that is currently being used as a admin car and has purchased a Model Y and reserved a Ford F150 Lightening that will be added to the fleet later this year.

However, as mentioned above, while the Tesla vehicles have the performance required in a police application, no models currently have an official pursuit rating from the Michigan State Police or L.A Sheriff's Department, the two entities in the Country in charge of testing vehicles for police use. Prior to deployment, Fremont PD had to receive approval from the City's Risk Management department since the Tesla vehicle did not have an official pursuit rated designated. In light of this, another potential model for the Police Department to consider is the Mustang Mach E GT Performance, which received an official pursuit designation in September 2021 from the Michigan State Police. Similar to the Model Y, the Mach E is a crossover vehicle that should provide sufficient interior capacity, battery range, and performance at comparable pricing to Ford vehicles currently purchased.

As it is advantageous for special unit vehicles, such as those used by detectives or in undercover operations, to be a range of models, the analysis included a range of light-duty electric options matching the body type of the existing vehicles. However, it is understood that these vehicles must blend in with surrounding traffic and concerns exist that electrifying these vehicles ahead of the general market may limit this ability. Additionally, the lack of sufficient public fast charging infrastructure may limit these vehicles' ability to perform during extended pursuits. As such, while a range of EV options could be suitable, piloting will be required by Concord's Police Department to determine comfort with specific models.

Finally, the Police fleet includes three motorcycles which have potential for electrification. There are promising products on the market, such as Zero Motorcycle (https://www.zeromotorcycles.com/) that were modeled. Zero Motorcycles have been deployed by police departments in California, including by the City of Burbank. Just as piloting is need for replacing any patrol vehicle, such piloting is likely necessary to ensure a replacement vehicle has enough range and storage capacity to meet the needs of the Towns police department.

MEDIUM- AND HEAVY-DUTY VEHICLES

Medium-duty and heavy-duty electric vehicle offerings are generally limited to OEM options approaching production but not yet available or semi-custom, electrified or hybrid versions of commercially available vehicle platforms such as the Ford and Izuzu chassis conversions Motiv, SEA and Lightning. Today's limited offerings will be augmented by increasingly numerous commercially available medium- and heavy-duty electrified vehicle platforms by manufacturers like Nikola, AVEAI, Mitsubishi, Daimler, and Tesla. In effect, numerous zero emission replacement options will be available for a significant percentage of diesel and gas-powered fleet components before 2030, though the timeline is difficult to accurately predict beyond manufacturers' announcements within the next two production years.

Fire Department

Fire trucks pose a particular challenge for fleet electrification. Stringent performance requirements mean that an EV option must be purpose built. Per the National Fire Protection Association (NFPA) classifications, electric options from fire truck Types 1-7 were evaluated. Two potential options for Type 1 fire trucks exist, the Rosenbauer Concept Fire Truck and the Pierce Volterra Pumper, neither of which are in full production as of writing but are expected by 2023. The Volterra Pumper is in service with the Town of Madison, Wisconsin[4] and in February 2020, the Los Angeles Fire Department ordered a Rosenbauer CFT, which is the first in operation in North America. Both vehicles cost on the order of $1.2-1.3 million which is more expensive than Concord's existing fire engines with similar capability.

Conversations with staff at a peer municipality that attended a demonstration of the Rosenbauer model indicated that the vehicle exhibited impressive acceleration, control, and proficiency in navigating tight spaces. There were concerns about its ability to completely replace existing fire engines, but staff were optimistic about the truck's potential role as a vehicle tasked with transporting essential supplies during fires.

No options were found for Types 2-7, although First Priority Group (https://www.1fpg.com/electrified), a large upfitter of emergency and command center vehicles primarily operating on the East Coast, offers various emergency response and command center vehicle options in collaboration with another chassis conversion company Roush Cleantech.

[4] https://www.wpr.org/madisons-fire-department-tests-out-fire-truck-runs-electricity

CMLP

One challenge relevant to CMLP that has not been discussed elsewhere is the lack of all electric options for aerial bucket trucks. Lion Electric, a Canada-based OEM of electric trucks, has announced a Class 8 all electric option, with delivery of the first units ordered by utilities and municipalities expected at the end of 2022. While pricing has not been announced, correspondence with Lion Electric employees indicated that the first models would be 2.5 – 3 times the price of a diesel option.

The needs of CMLP crews go beyond just the typical number of miles driven in a day. In emergency situations, CMLP crews will work straight through the first 24 hours of the event. Miles driven during these emergencies are not the metric to determine vehicle suitability. Vehicles will drive very short distances to sites but need to be powering equipment on site through a 24-hour period. The significance of this operational challenge cannot be ignored. The Town of Concord, as well as other municipalities and utilities, will need to pay attention to pilot deployments and begin planning an emergency response strategy as more options for electrified equipment that will be relied on in those situations comes the market.

Public Works

The Public Works department has 51 vehicles in the fleet that was studied (and 30 off road assets). Among the 51 vehicles, only 9 are included in the "Best Fit" for electrification category. Of the remaining 42 vehicles, 13 are light duty, 15 medium duty and 16 heavy duty vehicles, none of which have a clear option for cost effective or operationally sufficient electrification with current technology available in the market today. However, 7 pickup trucks have been identified by staff as vehicles that could be downsized to facilitate electrification. These pickup trucks are a mix of F250s, Silverado 2500 and one F350. Public Works' staff indicated that downsizing to an F-150 Lightning would be viable (e.g., CPWW80, CPWW85 and CPWW89) given that, in practice, these vehicles' towing and hauling demands do not require a ¾ ton or larger vehicle. The Town already plans to replace one of these vehicles, CPWW79, with a hybrid F-150. CPW replaced four additional vehicles with hybrid F-150s and in FY2023 plans to replace three more pick-up trucks with electric F-150 Lightning trucks. This initial round of replacement will provide the Town with data to inform purchasing decisions for further electrification of pick-up trucks.

Like CMLP, the Public Works department has operations where only considering daily mileage does not fully capture operations. For example, many of the departments medium and heavy duty vehicles, have axillary equipment (that are not currently available for EVs), are used to tow off road equipment such as mowers and other off road assets and are deployed on shifts that can be up to 14 hours long outside of emergency requirements. Emergency response of Public Works vehicles includes responding to oil spills or fires as well as needing to maintain roads and clear roads of snow during extreme winter weather events. In short, particularly for the heavy-duty vehicles, EVs would be hard pressed to meet all these operational demands cost effectively based on the technology currently available in the EV market. While waiting for the market to catch up to these vehicles, a viable strategy for beginning to decarbonize the current assets during their useful life could be to fuel them with renewable diesel.

Medium- and Heavy-Duty Trucks & Chassis Cabs

Excluding fire engines, ambulances, bucket trucks and school buses, the Town fleet has 42 vehicles (Class 3 or higher) that range from special-purpose vehicles like dump trucks to a variety of utility vehicles such as digger derricks, operating primarily in the Public Works, Municipal Light Plant and Schools departments. While this class of vehicles was largely included in the "No Electric Option" category, mostly due to the operational requirements discussed in the previous sections, there are limited number of all electric options are offered by OEMs and chassis conversion companies that could be considered for a pilot. Options offered by OEMs include the Peterbilt 220EV and 520EV and the Global Environmental Products M3 Electric Sweeper (the lone sweeper in Concord's fleet was classified as "off-road"). The purchase price of the EV options ($378,000, $407,000 and $501,000, respectively) and low mileage of the existing vehicle precludes the EV options from being cost-effective, but the Town could decide to purchase these vehicles to achieve emissions reductions in the future as the market progresses and options become more cost effective. Overall, for the Town's heavy-duty municipal fleet vehicle use cases, cost-effective EVs are likely five years away, even when accounting for incentives.

While these vehicles may be far away, there are a growing number of manufacturers who have indicated they will be bringing Class 8 trucks to market. It will be worthwhile for the Town to track their progress as well as the different types of vehicles that are based on the long-haul truck platforms. The list of electric semi-truck manufacturers to follow is briefly: Tesla, Mercedes, Freightliner, BYD, Volvo, Peterbilt, Lion Electric, Kenworth, Man, Workhorse, Cummins, Xos, and Navistar.

Bus Electrification

The market for electric buses has grown rapidly in recent years. In most cases electrifying a fleet of buses is a clear choice as they typically drive more than 10,000 miles in a year and only average between 6 to 10 miles per gallon of diesel as their use requires frequent stops and starts. There is a significant difference however between transit buses and school buses, who's national average miles traveled annually is 34,000 and 12,000 respectively. School buses tend to make less frequent stops than transit and are typically only on the road during months when school is in session. The options for school bus electrification are growing rapidly as there is a significant push to electrify this segment of vehicles. Optony recommends tracking and potentially engaging with WRI's Electric School Bus Initiative to identify deployment and funding strategies such as the EPA's distribution of the Clean School Bus Program consisting of $500 million per year. Electric bus manufacturers to keep an eye on include: Blue Bird, Lion Electric, Transtech, Collins, IC Bus, Thomas Built Buses and Starcraft. The electric bus model recommended for Concord's current fleet in this study is the Lion C 168 kWh buses (~125 miles of range) with the assumed price of $370,000 per bus. The Town already owns one electric bus manufactured by Lion and reported that School staff would be happy to purchase more Lion vehicles.

It's important to note that the market for electric school buses remains nascent, less than 1% of buses nationwide have been replaced with electric versions as of the end of 2021.[5] As manufacturers ramp up production economies of scale may be achieved, in the meantime considering the use of renewable diesel may be a viable short term alternative to electrification for decarbonizing this class of vehicles.

Electrification of Off-Road Assets

The Town has already deployed a few of electric off-road assets such as mowers and forklifts. Town staff indicated that they have enjoyed the experience, with these mowers producing less noise and fumes, but have had a couple operational challenges, particularly in dealing with wet grass conditions and mowing field grass to regulation length. The Town is participating in a trend of electrifying typically small engine assets that are responsible for significant emissions. The potential for electrification of lawn and gardening equipment is vast and already a national trend. According to The California Air Resources Board approximately 35% of the small-engine market is now electric and the trend is projected to continue.[6]

The Town has many other types of off-road assets which may have the potential for electrification as markets mature. These include stump and brush grinders, front loaders, backhoes, excavators, rollers, various tractors and snowplows. Tractors, excavators, and backhoes do have some options on the market to date. While little information is known about their performance, due to lack of deployments, it may be an ideal time to seek out demonstrations. There is a single electric Backhoe Loader on the market, the CASE 580 EV by Case Construction. Electric tractors are also beginning to pop up including Monarch Tractors, two electric Kubota Prototypes, and the Fendt E100 VARIO. The most notable set of backhoes and front loaders is the offerings by Volvo, they offer Front loaders and excavators for reservation in European markets currently. Finally, a Dutch company claims to have the first all-electric road roller called the BAM Infra. Each of these electric offerings may have limited applications to the Town's regular operations currently as their battery life and performance remains inferior to existing diesel-powered equipment. However, this market is worth keeping an eye on as the industry matures. Optony recommends the Town begins systematically monitoring the latest news on fleet developments from sources such as Greenfleetmagazine.com, chargedfleet.com, and automotive-fleet.com as well as consider engaging with industry groups such as the Electric Vehicle Association, Plug In America, World Electric Vehicle Association, and International Council on Clean Transportation. Additionally, google alerts can be set up to monitor news developments using a variety of key words.

ANALYSIS PROCESS

In order to assign EV alternatives to existing vehicles, each existing vehicle was assigned a label based on its GVWR and Body Type (e.g., MD Van). Up to five ICE replacement possibilities and five EV alternatives were assigned to each vehicle label for analysis and the selected replacements were

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[5] Electric School Buses and the Grid Unlocking the power of school Link
[6] 2020 Emissions Model for Small Off-Road Engines, California Air Resources Board, Link

applied to every vehicle with that label. Taking into account all of the vehicle type and department specific considerations above, individual vehicles were updated manually to ensure that only relevant models were included in the comparison and a single model was designated as the primary option and used to inform that TCO and capital budget need calculations completed later in the analysis.

RANGE SUITABILITY

For every EV option assigned to an existing vehicle during the Vehicle Selection process, Optony's Fleet Assessment Tool calculated the **"EV Range Viability,"** comparing the range and battery capabilities of the selected EV option to the driving patterns of the existing vehicle. **"EV Range Viability"** is determined by calculating the percent of trips performed by the existing vehicle that are within the range of the battery.

Accounting for Idling, Auxiliary Loads & Vehicle Weight Variations

Additional factors affecting the energy needs of an EV replacement were accounted for in the analysis in two ways. First, idling and auxiliary loads were considered when determining the energy needs of EV alternatives. While EVs do not idle in the same way as ICE vehicles, the equipment causing ICE vehicles to idle (e.g., air conditioning) will still create draw on the battery. A significant portion of Town's fleet is composed of police vehicles, most of which idle for a significant percentage of their daily operations. These vehicles are also outfitted with auxiliary equipment that consumes additional energy. To account for this, estimated daily amount of energy (in kWh) consumed by the auxiliary equipment, as well as during idle time (mostly from the air conditioning or heating system), was added to the annual energy usage of each unit. Estimates were based on data and estimates of auxiliary equipment operation collected from police fleets similar in size to Concord's. Additionally, the upfitting required on police patrol vehicles increases the vehicle weight when compared to a standard model. Additional weight reduces vehicle range. To ensure that EV recommendations identified and analyzed would have enough battery capacity to support vehicle "idle" time, auxiliary equipment power needs and added weight, the daily kWh energy usage was adjusted to reflect the higher energy needs and was applied directly as a reduction of the battery state-of-charge of the EV being analyzed.

Second, actual miles per gallon efficiency numbers from existing vehicles (which are inclusive of idling and actual operations) were used to inform the estimated annual fuel usage of the replacement ICE vehicles considered in the TCO analysis (discussed in the following section).

Finally, when assessing the range suitability of an EV option the analysis discounts the rated range by 20% to create an effective range that is then compared to the existing vehicle's estimated daily mileage. This is designed to account for fluctuations in vehicle range based on weather conditions or driving behavior.

TOTAL COST OF OWNERSHIP (TCO) ANALYSIS

TCO METHODOLOGY

Total cost of ownership (TCO) refers to a calculation of adding capital and operating costs of an asset to determine the total cost of that asset over its lifespan. As part of the analysis, the TCO for two different scenarios of vehicle replacement was calculated: (1) an existing vehicle is replaced with an equivalent ICE vehicle and (2) an existing vehicle is replaced with the equivalent, or nearly equivalent, EV. Given the age of some of the Town's vehicles, the changing availability of vehicle models in the market, and to simplify the analysis, a representative ICE vehicle replacement for each vehicle body type (e.g., Ford Escape for SUV) was used as the equivalent ICE replacement vehicle to create the scenarios in the TCO analysis. The "Representative ICE Replacement" was determined in collaboration with the Town's staff during interviews. For heavy-duty vehicles, the ICE replacement vehicle was deemed to be identical to the existing model. *It is important to note that the replacement ICE vehicle choice presented here is used to represent the approximate cost of replacing an existing vehicle with a new ICE vehicle and may not perfectly reflect the Town's actual procurement choice to replace an existing vehicle.*

For both scenarios, the TCO is the sum of the following cost components:

- **Total purchase price**: The sum of the Manufacturer Suggested Retail Price (MSRP) and any auxiliary equipment. The MSRPs of the vehicles were discussed with the Town of Concord to ensure that the actual price paid by the Town (incorporating fleet procurement discounts) of the proposed vehicles were factored into the analysis. Available incentives were not included in the base TCO analysis but the impacts of these incentives on the cost of electrification can be observed using the Fleet Electrification Pro-Forma provided to the Town. For heavy-duty vehicles, purchase price for the ICE replacement vehicle was calculated using the purchase price of the existing vehicle and adjusted for inflation.

- **Annual fuel cost**: This was calculated based on the estimated annual mileage of the studied vehicle. For this calculation, the gas and diesel prices were assumed to be $3.02 per gallon, calculated using five years of available historical data provided by Concord via fuel purchase reports. Annual fuel cost for EVs was calculated using the average price of electricity at each domicile facility of the ICE vehicle being replaced and was calculated using rates provided by the Town of Concord. For simplicity the average price of electricity among all locations was determined to be 0.14 $/kWh and does not include costs from any potential increase in demand charges.[7] The potential impacts of escalations in fuel costs (liquid fuel and electricity) can be observed in the Fleet Electrification Pro-Forma provided to Concord.

- **Annual Operations and Maintenance (O&M) cost**: Concord did not have access to life-to-date maintenance costs, so assumptions were made for maintenance cost of ICE vehicles based on recent studies by Argonne National Lab, data from peer organizations and discussions with staff. For the ICE vehicles, an average of $0.15 per mile was used. For EVs, the industry standard average cost of $0.06 per mile was used.

The TCO calculations did not include the cost of Electric Vehicle Supply Equipment (EVSE), as that is likely to be funded through a different Town budget pool and is being addressed in subsequent deliverables.

All components included in the TCO calculations were calculated over the expected lifespan of the existing vehicle, which ranges from 6 to 20 years depending on the vehicle type.

The TCO calculations do not account for the possibility that electric police patrol vehicles could last longer that than the 6-year lifespan expected of the Town's ICE police patrol vehicles. Initial indications from a police patrol pilot project run by the City of Fremont, who deployed a Tesla Model S as a pursuit vehicle, have indicated that the reduced maintenance needs of EVs will likely result in an expected lifespan of longer than 6 years. Despite these indications, this assumption is still being proven through real-world application. Thus, TCO calculations for this project assumed a simple case where both ICE vehicles and EVs in the Police Department are owned for the same amount of time.

Resale Value

The resale value of the vehicle at the end of its lifecycle was not considered in the TCO analysis and was set to zero for both ICE vehicles and EVs. Due to the relatively short amount of time that EVs have been on the market, there is not robust data on the resale value of an EV in use for 10 years. Currently, the Town does not return any revenue earned from sale of retired vehicles to the vehicle replacement fund, instead returning that revenue to the general fund. Thus, existing vehicles are not used to buy down the cost of new vehicle purchases, and resale value/depreciation does not factor into the TCO analysis. Estimated resale value of EVs is assumed to be 0 in the TCO analysis for reference (see Appendix B).

TCO BY DEPARTMENT & ELECTRIFICATION CATEGORY

To summarize the TCO calculations across the entire fleet a summary of TCO by department is included below. Given the large number of vehicles analyzed, detailed TCO calculations for each vehicle are presented in **Appendix B**.

The following figures summarize the TCO for all expected vehicle electrification purchases by Town departments over three time periods, from short-term (2023 – 2025), medium-term (2026 – 2030) and long-term (2031 – 2040). These figures only include Town departments that are projected to have vehicle replacements in the given period.

Under each period, there are figures representing three scenarios. The first figure provides a TCO comparison for only the vehicles included in the "Best Fit" for Full Electrification, the second for only the electrification of the school departments 22 Buses, and the third figure provides a TCO comparison for all vehicles with a Potential Electrification option, which includes all vehicles in the previous two scenarios. Since the second and third scenario includes EV options that may not be cost effective, the TCO of the EVs is generally higher than for the ICE vehicles.

The time periods segment vehicle purchases by purchase year, but the costs displayed include operating costs expected over the lifetime of the new vehicle stretching from the purchase date through the end of its lifespan. For example, an EV purchased in 2023 with a 10-year life span realizes annual savings for the Town through 2033, compared to the alternative scenario of purchasing an ICE vehicle. Those savings are aggregated in the figures below. Dollar amounts are provided in nominal dollars.

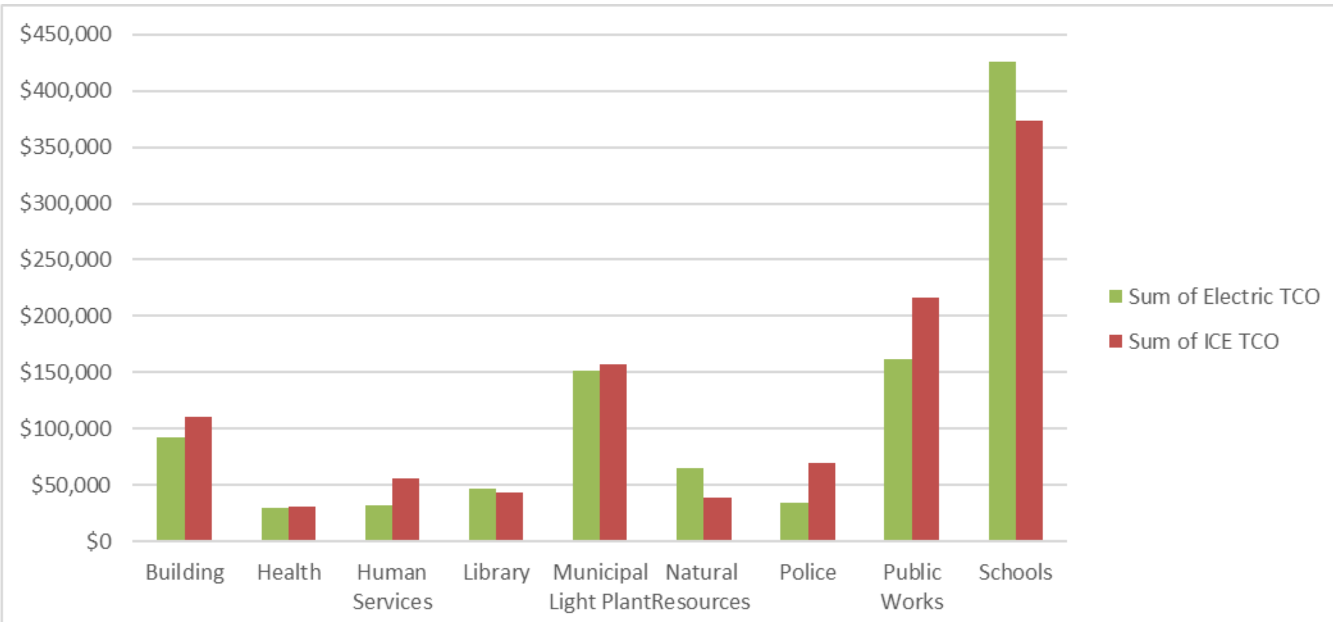

FIGURE 7: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – "BEST FIT" FOR ELECTRIFICATION

TABLE 2: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – "BEST FIT" FOR ELECTRIFICATION

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Building	2	91,791	109,998
Health	1	29,096	30,805
Human Services	1	31,817	55,357
Library	1	47,035	43,537
Municipal Light Plant	4	151,164	157,420
Natural Resources	1	65,183	39,327
Police	2	34,390	69,930
Public Works	4	162,077	216,003

Schools	9	425,597	373,817
Grand Total	**25**	**1,219,123**	**1,416,732**

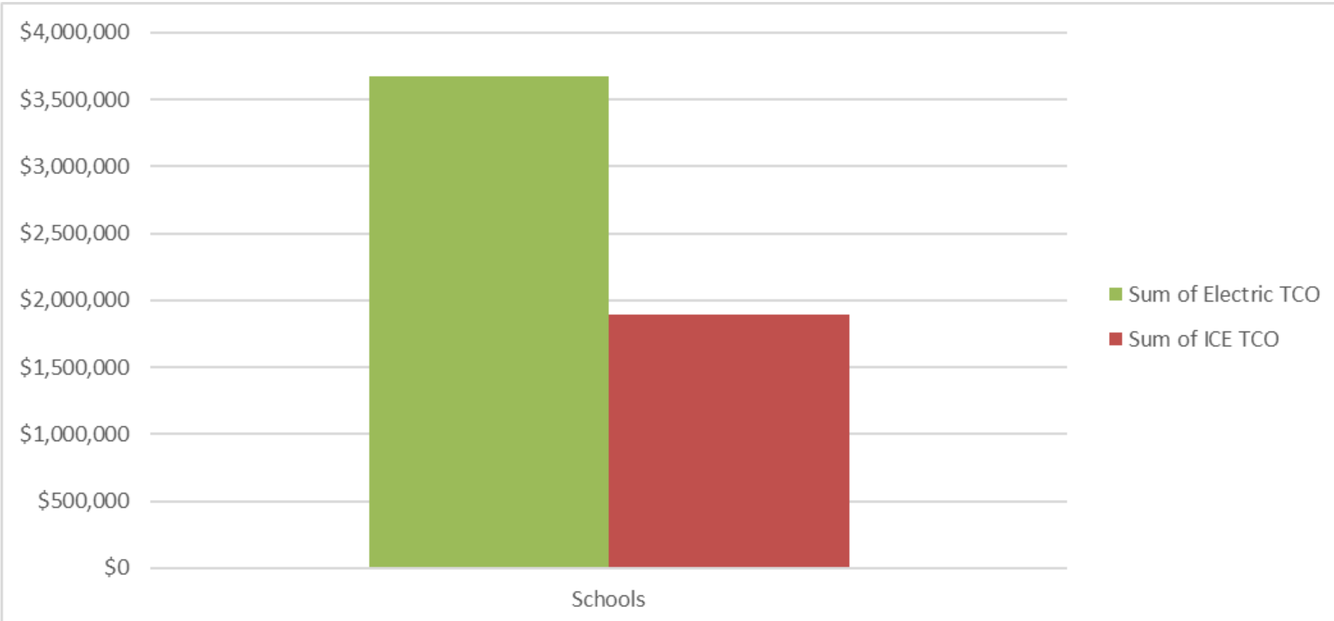

FIGURE 8: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – BUSES ONLY

TABLE 3: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – BUSES ONLY

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Schools	9	3,669,816	1,894,299
Grand Total	**9**	**3,669,816**	**1,894,299**

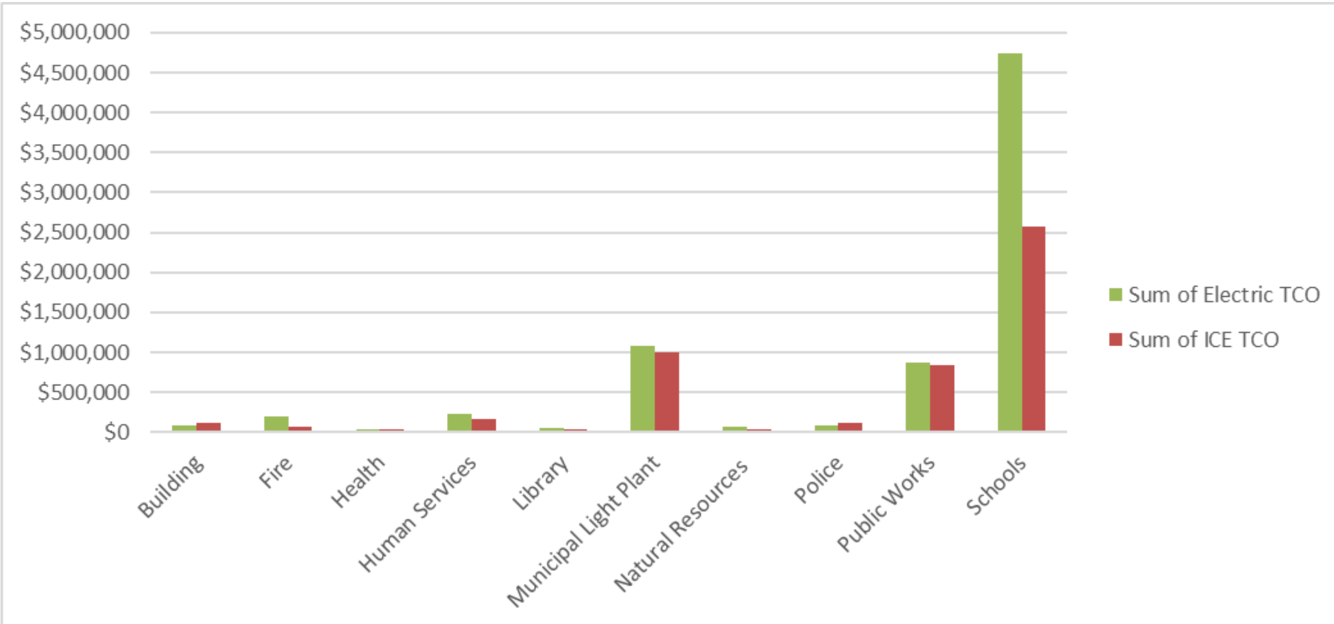

FIGURE 9: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – ALL POTENTIAL ELECTRIFICATION

TABLE 4: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – ALL POTENTIAL ELECTRIFICATION

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Building	2	91,791	109,998
Fire	1	190,177	63,402
Health	1	29,096	30,805
Human Services	2	233,682	165,640
Library	1	47,035	43,537
CLMP	12	1,074,358	1,005,929
Natural Resources	1	65,183	39,237
Police	3	81,213	119,466
Public Works	12	877,247	833,914
Schools	22	4,742,911	2,577,668
Grand Total	**57**	**7,432,693**	**4,989,597**

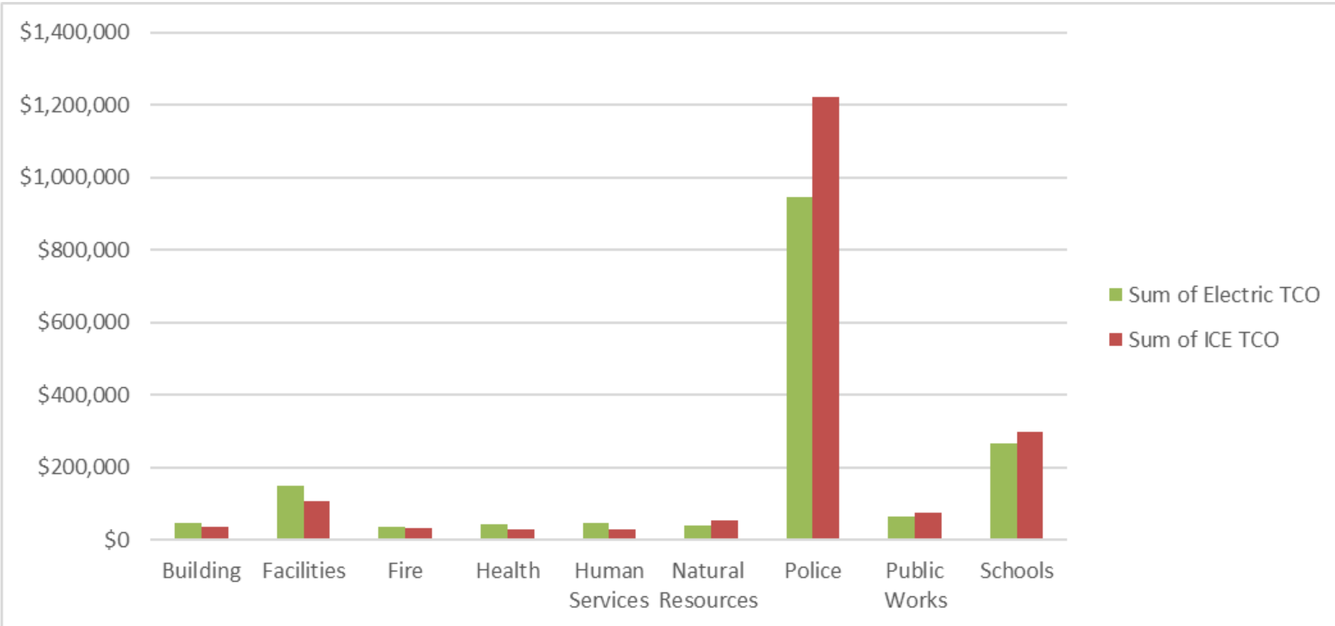

FIGURE 10: TCO OF MID-TERM VEHICLE PURCHASES (2026 – 2030) – "BEST FIT" FOR ELECTRIFICATION

TABLE 5: TCO OF MID-TERM VEHICLE PURCHASES (2026 – 2030) – "BEST FIT" FOR ELECTRIFICATION

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Building	1	47,018	36,819
Facilities	3	146,992	107,641
Fire	1	36,334	30,594
Health	1	41,479	27,091
Human Services	1	45,307	26,573
Natural Resources	1	40,551	54,344
Police	16	946,377	1,223,293
Public Works	1	65,081	75,217
Schools	7	266,652	296,329
Grand Total	**32**	**1,496,273**	**1,678,802**

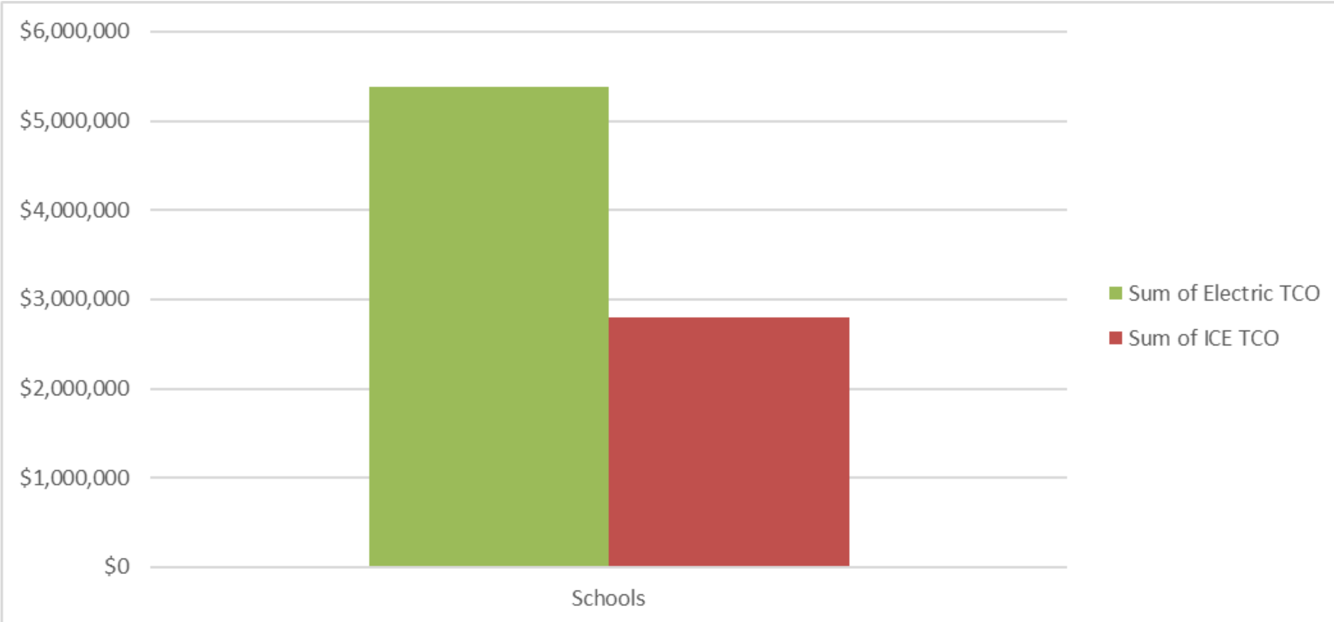

FIGURE 11: TCO OF MID-TERM VEHICLE PURCHASES (2026 – 2030) – BUSES ONLY

TABLE 6: TCO OF SHORT-TERM VEHICLE PURCHASES (2023 – 2025) – BUSES ONLY

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Schools	13	5,374,335	2,799,159
Grand Total	**13**	**5,374,335**	**2,799,159**

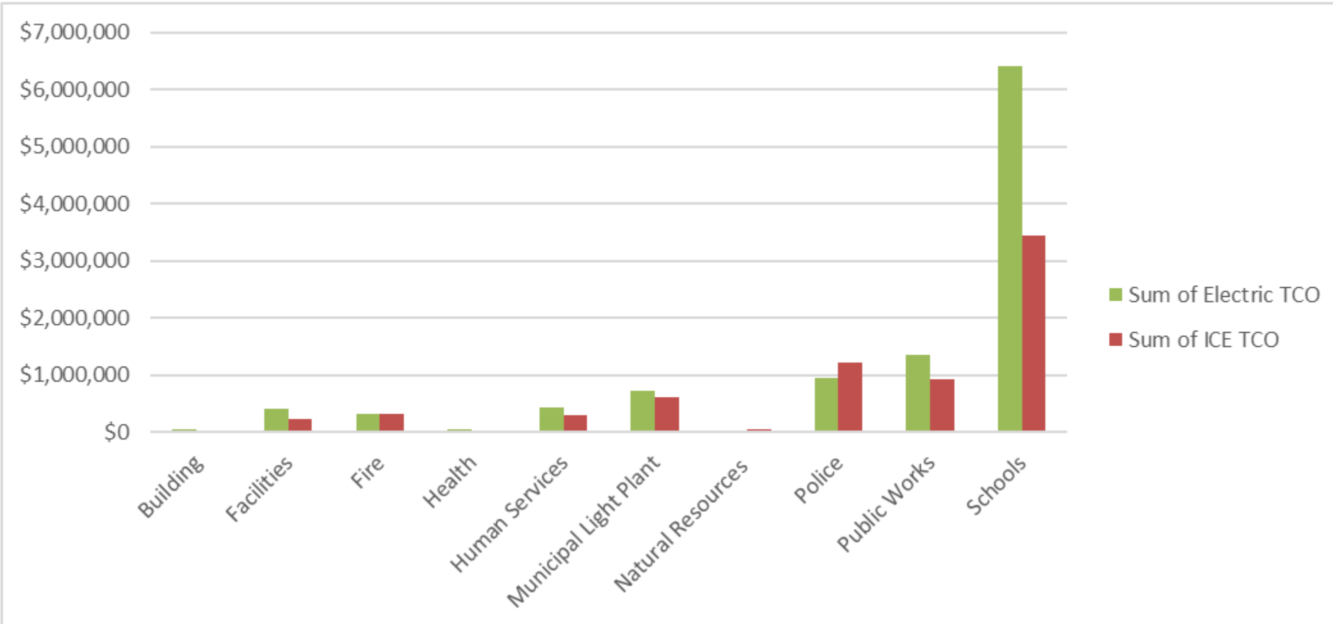

FIGURE 12: TCO OF MID-TERM VEHICLE PURCHASES (2026 – 2030) – POTENTIAL ELECTRIFICATION

TABLE 7: TCO OF MID-TERM VEHICLE PURCHASES (2026 – 2030) – ALL POTENTIAL ELECTRIFICATION

Department	Vehcicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Building	1	47,018	36,819
Facilities	5	409,116	221,333
Fire	7	327,535	331,221
Health	1	41,479	27,091
Human Services	3	444,240	305,800
Municipal Light Plant	3	728,351	622,626
Natural Resources	1	40,551	54,344
Police	16	946,377	1,223,293
Public Works	12	1,350,614	921,699
Grand Total	**73**	**10,752,427**	**7,185,405**

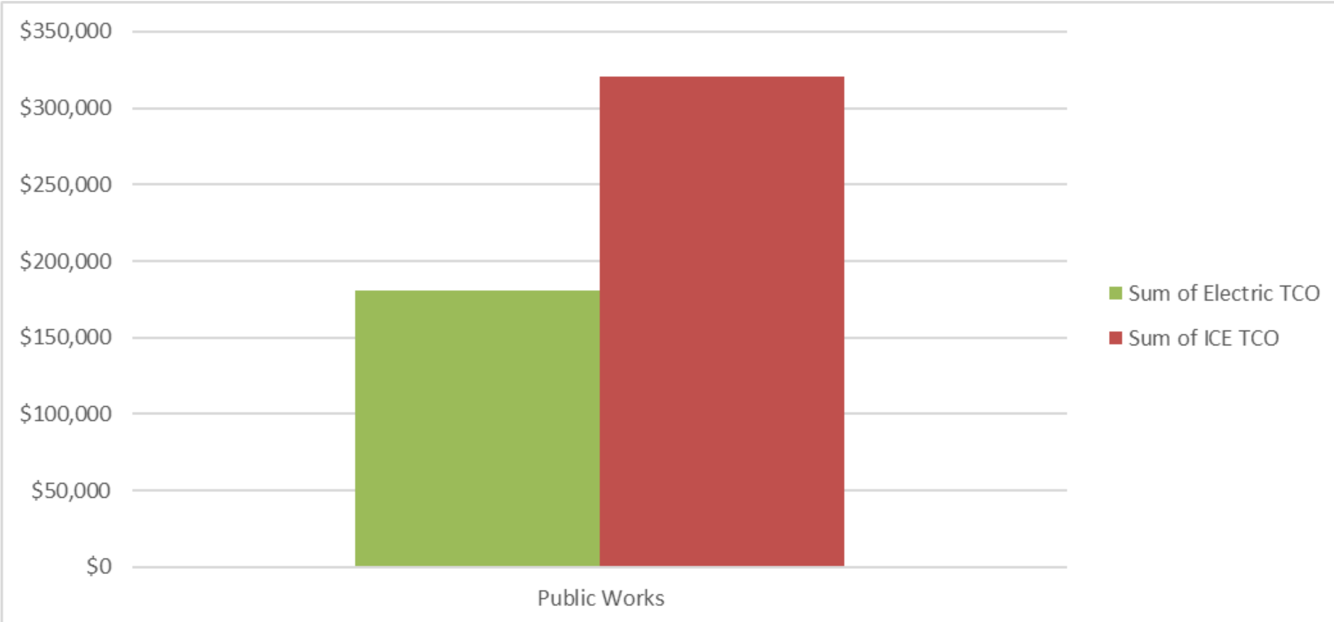

FIGURE 13: TCO OF LONG-TERM VEHICLE PURCHASES (2031 – 2035) – "BEST FIT" FOR ELECTRIFICATION

TABLE 8: TCO OF LONG-TERM VEHICLE PURCHASES (2031 – 2035) – "BEST FIT" FOR ELECTRIFICATION

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Public Works	4	180,974	320,628
Grand Total	**4**	**180,974**	**320,628**

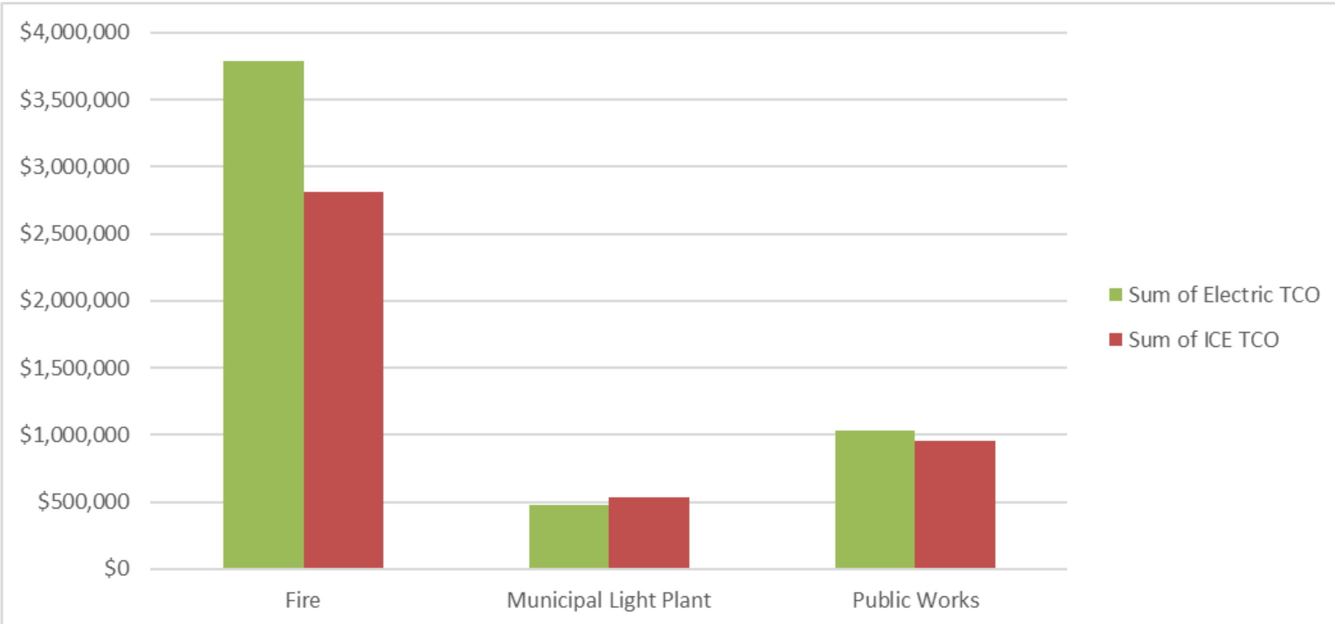

FIGURE 14: TCO OF LONG-TERM VEHICLE PURCHASES (2031 – 2035) –POTENTIAL ELECTRIFICATION

TABLE 9: TCO OF LONG-TERM VEHICLE PURCHASES (2031 – 2035) –POTENTIAL ELECTRIFICATION

Department	Vehicles Replaced	Total EV TCO ($)	Total ICE TCO ($)
Fire	3	3,785,029	2,816,516
CLMP	1	472,667	536,356
Planning	10	1,033,039	954,815
Grand Total	**14**	**5,290,735**	**4,307,688**

When only considering the "Best Fit" scenario, over the lifespan of the vehicles purchased, near-term electrification for all departments would save the Town nearly $200,000 over the lifespan of the vehicles purchased. Without incentives, mid-term electrification has the potential to save the town roughly $180,000, and long-term electrification is expected to save the Town just under $140,000. Under the "Potential Electrification" scenario, near-term electrification is estimated to cost the Town about $2,443,000 over the lifetime of the vehicles, mid-term electrification is expected to cost the Town more than $3.5 million and long-term electrification is estimated to cost the Town nearly $1 million over the lifespan of the vehicles purchased when compared to ICE equivalents. The "Potential Electrification" scenario is more expensive for the Town primarily due to the current cost differences between ICE and EV heavy-duty options, including fire engines and school buses. TCO calculations in the long-term do not include any assumptions for reduced purchase prices of EV models over the next 10 years, which are likely to change the financial outlook. There are a few uncertain factors that could impact these savings estimates, as described below:

- If purchased EVs last longer than current ICE vehicles, the estimated savings will **increase**
- If purchased EVs last less than current ICE vehicles, the estimated savings will **decrease**
- If it is determined that EV Police pursuit vehicles can consistently outlast the expected 6-year lifespan of ICE pursuit vehicles, savings in the Police Department could **increase** significantly

Overall, falling MSRPs of long-range EVs, lower fuel costs and lower maintenance costs combine to enable EVs to provide emissions reductions, to the Town's fleet. This is particularly true for vehicles with high mileage, such as the Police Department where high fuel and maintenance costs represent additional room for cost savings. In departments where vehicles have lower usage, such as Library and Human Services, and high EV replacement costs, such as Schools, EVs are unlikely to show TCO savings under current costs.

Finally, the **School Department's 22 buses** were included in the above TCO analysis, 9 buses are scheduled to be replaced in 2023 and 13 buses are scheduled for replacement in 2028. According to our calculations, electrifying the 2023 tranche of buses would cost the Town nearly $1.8 million and the 2028 tranche $2.5 million, over the lifetime of the purchased vehicles when compared to ICE equivalents.

DISCUSSION OF OWNERSHIP MODELS: OWNED VS LEASED

While the Town traditionally purchases fleet assets, and this ownership model was assumed throughout this analysis, leasing electric vehicles, particularly light-duty options, is an increasingly available ownership model with the potential to further reduce TCO for EVs. Leasing opportunities for municipal fleets are offered through Sourcewell and the Climate Mayors EV Collaborative.[8]

[8] https://driveevfleets.org/wp-content/uploads/2018/09/NCL_OneSheet_ClimateMayors.pdf

There are two common types of leasing: fleet leasing or lease financing. Fleet leasing refers to a contract the enables vehicle leasing, often a large number of vehicles, that encompasses maintenance costs, fuel costs and other services. It is appealing for fleets that do not have in-house maintenance operations and are interested in outsourcing a significant portion of fleet management. Discussions with Concord staff indicated that this form of leasing was not appealing to the Town because of the lack of control the Town has over the assets.

Lease financing refers to a contract that provides a vehicle without fleet management services and is similar to the structure of a lease for a personal vehicle. Within lease financing, there are two common types; closed- and open-ended leases. Closed-ended leases have a set term, after which the Town returns the vehicle. Closed-ended leases enable fleets to phase new vehicle models into their fleet quickly and monthly payments are often lower than other options, but the Town does not retain ownership of the asset at the end of the lease.[9] Open-ended leases are essentially a financing mechanism allowing the Town to pay down the cost of a vehicle over the term of the lease, often down to a 1 dollar buy out, enabling the Town to maintain ownership of the asset at the end of the lease term.

The primary benefits of leasing are the ability to defer capital costs into operating costs and utilize the 3rd-party providing the lease to monetize the federal tax incentive on behalf of the Town. The deferral of capital costs into operating budgets can help to align the cost of acquiring a new vehicle with the operational savings provided by that new EV and streamline the process of leveraging operational cost savings from EVs in the Town's budget. Using the lease provider (a private entity with a tax liability) to monetize the $7,500 federal tax credit for applicable EVs can further reduce the total cost of ownership of an EV because the 3rd-party leasing company can share the value of that tax credit with the Town reducing the total lease payments required. For example, The City of Des Moines, Iowa, was able to save $7,700 off the MSRP of five Nissan Leafs using a 36-month open-ended lease that included a buy-out option.[10] However, under current policies, vehicles become ineligible for that tax credit when 250,000 models are sold. As such, Tesla and General Motors (e.g., Chevy Bolt) vehicles are not eligible for this tax credit, limiting the applicability for Concord's fleet.

While leasing can offer a simple and cost-effective solution to procure vehicles, it requires that a specific model of EV be available for lease by a 3rd-party provider. This may limit the availability of models and prevent leasing from being the only procurement strategy used by Concord. In the near term, Concord could utilize both open and closed leasing opportunities to procure EVs and reduce the TCO when replacing low-mileage light-duty vehicles that are a good fit for EVs operationally but may not provide TCO savings when compared to their ICE counterparts due to low mileage and fuel usage.

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[9] Saving Money with Electric Vehicle Leasing: A Case Study of City Fleets, Electrification Coalition, November 2020
[10] Ibid.

CARBON REDUCTIONS FROM FLEET ELECTRIFICATION

Figure 15 summarizes total, annual carbon emissions from the Town's fleet by the percentage of contribution of each department. To account for the impacts of COVID-19 on vehicle use, fuel usage from 2019 was used to calculate baseline carbon emissions. The total annual carbon emissions associated with the Town's studied fleet, including the School Department's Buses, is 1,114.7 $mTCO_2$.[11]

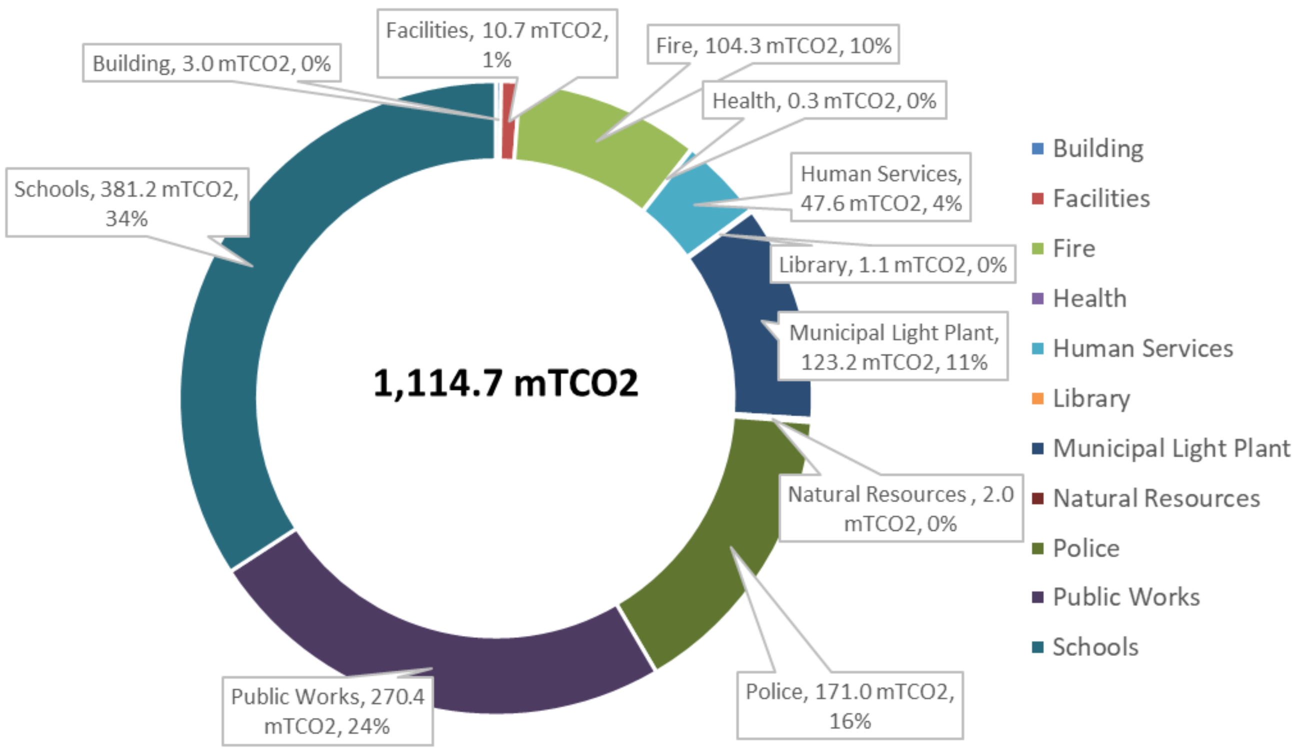

FIGURE 15: ANNUAL CARBON EMISSIONS OF VEHICLE FLEET BY DEPARTMENT- 2019

The expected carbon reductions from fleet electrification are presented below based on the Fleet Replacement and Electrification Timeline. **Figure 15** includes projected carbon reductions under three electrification scenarios matching those discussed previously in this report.

[11] 28 vehicles (CCRSDD6, CCRSDD7, CCRSDD8, CCRSDM11, CCRSDM12, CCRSDM4, CCRSDM8, CCRSDS2, CCRSDT-3, CFC4 CFS6, CPDMC1, CPDMC2, CPDMC3, CPSI1, CPSM1, CPSM10, CPSM5, CPST1, CPST2, CPST50, CPWG48, CPWH11, CPWH3, CPWW81A, CPWW89A, HS3, and HS5) did not have fuel usage provided and estimated annual GHG emissions were calculated based on vehicle mileage.

- **"Best Fit" for Full Electrification:** The first scenario considers the electrification of only vehicles that can be fully electrified based on current technology.

- **Electrified School Buses**: This scenario assumes the electrification of the 22 buses in addition to the vehicles in the "Best Fit" for Full Electrification scenario.

- **Potential Electrification:** This scenario considers the electrification of all "Best Fit" vehicles, the 22 Buses as well as the Potentially Electrifiable vehicles.

- **Complete Electrification**: The final scenario includes all vehicles in the previous scenarios as well as the full electrification of all vehicles identified as having no electric option currently available in the market, including full electrification of vehicles that are currently only candidates for partial electrification. *This is included as a representative scenario and does not specify vehicle models/technologies used to achieve electrification but assumes sufficient technology advancement to electrify every vehicle that comes up for replacement through 2035.*

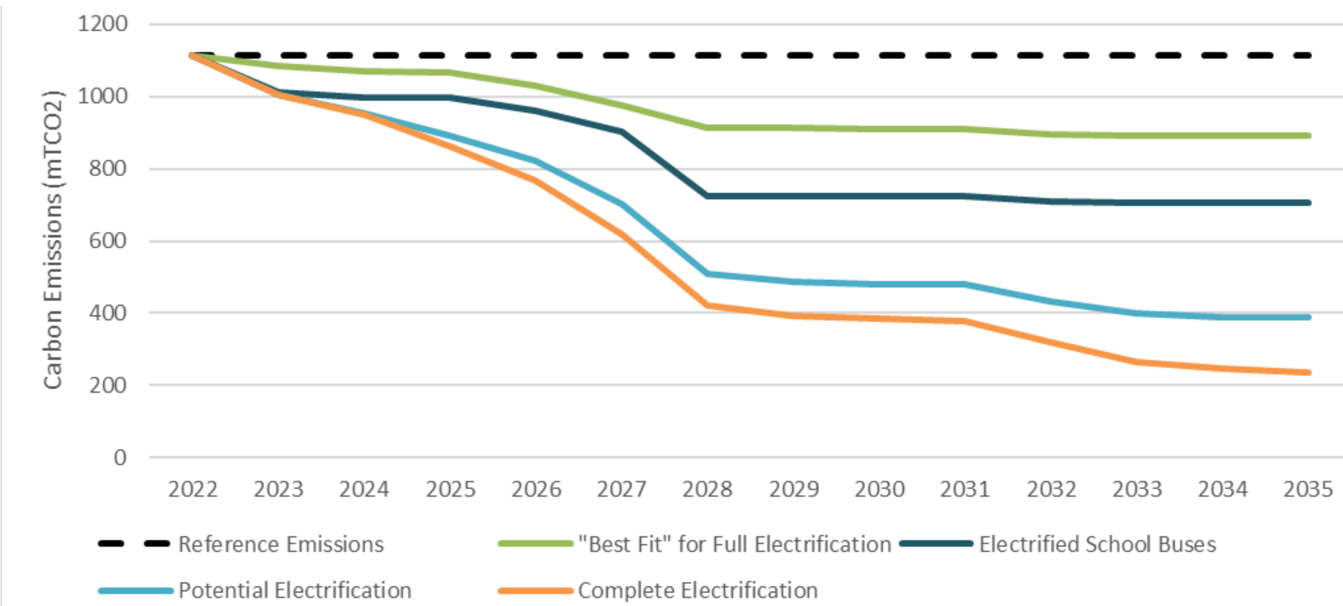

FIGURE 16: EMISSION REDUCTION SCENARIOS THROUGH 2035

By 2030, the **"Best Fit" for Full Electrification** scenario (green line), above, represents a 18% reduction in carbon emissions, the **Electrified School Buses** scenario (dark blue line) represents a 35% reduction in carbon emissions, the **Potential Electrification** scenario (green line) represents a 57% reduction in carbon emissions and the **Complete Electrification** scenario (green dashed line) represents a 65% reduction in carbon emissions. EVs are not carbon free if their electricity source has carbon emission associated with it. For this analysis, the regional carbon intensity of 0.255 MTCO2 per MWh was assumed. 100% emissions reductions from a fully electrified fleet can only be achieved by charging EVs with carbon free electricity.

INCREMENTAL COST OF CARBON REDUCTIONS

In order to provide guidance for the Town's budget towards the most cost-effective vehicles for emissions reductions, the following tables summarize the marginal cost, or savings, of vehicle electrification on a capital cost and total cost of ownership basis, the associated carbon reductions, and the cost of carbon abatement on a dollar per ton basis. The incremental cost of carbon reductions are calculated for 2022 – 2025, 2026 – 2030, and 2031-2035 under the "Best Fit" for Full Electrification, Electrified School Buses and Potential Electrification scenarios described above.

TABLE 10: INCRIMENTAL COST OF CARBON REDUCTION – "BEST FIT" SCENARIO

DEPARTMENT	# OF VEHICLES	CARBON REDUCTIONS ($MTCO_2$)	MARGINAL CAPITAL COSTS ($)	MARGINAL TOTAL COST OF OWNERSHIP ($)	COST OF ABATEMENT – CAPITAL COST ($/$MTCO_2$)	COST OF ABATEMENT – TCO ($/$MTCO_2$)
2023 – 2025 VEHICLE REPLACEMENTS						
BUILDING	2	0.02	$29,238	$18,207	$1,333,382	$830,320
HEALTH	1	0.17	$5,100	$1,709	$29,554	$9,903
HUMAN SERVICES	1	6.91	$5,100	$23,540	$738	$3,406
LIBRARY	1	0.91	$7,000	$(3,498)	$7,661	$(3,828)
MUNICIPAL LIGHT PLANT	4	3.63	$28,174	$6,257	$7,759	$1,723
NATURAL RESOURCES	1	1.98	$34,000	$(25,946)	$17,195	$(13,121)
POLICE	2	0.07	$(36,010)	$35,540	$(509,963)	$503,307
PUBLIC WORKS	4	4.72	$44,000	$53,926	$9,319	$11,422
SCHOOLS	9	30.26	$167,000	$(51,779)	$5,519	$(1,711)
2026 – 2030 VEHICLE REPLACEMENTS						
BUILDING	1	1.49	$18,238	$(10,199)	$12,265	$(6,859)
FACILITIES	3	5.84	$58,500	$(39,350)	$10,026	$(6,744)
FIRE	1	4.67	$11,000	$(5,741)	$2,356	$(1,230)
HEALTH	1	1.07	$18,338	$(14,388)	$17,138	$(13,446)
HUMAN SERVICES	1	2.49	$19,500	$(18,735)	$7,833	$(7,526)
NATURAL RESOURCES	1	6.28	$11,000	$13,793	$1,752	$2,196
POLICE	16	115.68	$112,995	$276,916	$977	$2,394

PUBLIC WORKS	1	5.99	$16,075	$10,136	$2,683	$1,692
SCHOOLS	7	20.62	$61,874	$29,677	$3,000	$1,439
2031 – 2035 VEHICLE REPLACEMENTS						
PUBLIC WORKS	4	17.24	$43,948	$139,654	$2,549	$8,100

TABLE 11: INCREMENTAL COST OF CARBON REDUCTION – ELECTRIFIED SCHOOL BUSES SCENARIO

DEPARTMENT	# OF VEHICLES	CARBON REDUCTIONS ($MTCO_2$)	MARGINAL CAPITAL COSTS ($)	MARGINAL TOTAL COST OF OWNERSHIP ($)	COST OF ABATEMENT – CAPITAL COST ($/$MTCO_2$)	COST OF ABATEMENT – TCO ($/$MTCO_2$)
2023 – 2025 VEHICLE REPLACEMENTS						
SCHOOLS	9	69.92	$2,014,788	$(1,775,517)	$28,815	$(25,393)
2026 – 2030 VEHICLE REPLACEMENTS						
SCHOOLS	13	116.12	$2,972,537	$(2,575,177)	$25,599	$(22,177)

TABLE 12: INCREMENTAL COST OF CARBON REDUCTION – POTENTIAL ELECTRIFICATION SCENARIO

DEPARTMENT	# OF VEHICLES	CARBON REDUCTIONS ($MTCO_2$)	MARGINAL CAPITAL COSTS ($)	MARGINAL TOTAL COST OF OWNERSHIP ($)	COST OF ABATEMENT – CAPITAL COST ($/$MTCO_2$)	COST OF ABATEMENT – TCO ($/$MTCO_2$)
2023 – 2025 VEHICLE REPLACEMENTS						
BUILDING	2	0.02	$29,238	$18,207	$1,333,382	$830,320
FIRE	1	0.06	$127,048	$(126,775)	$2,153,139	$(2,148,520)
HEALTH	1	0.17	$5,100	$1,709	$29,554	$9,903
HUMAN SERVICES	2	10.54	$114,566	$(68,042)	$10,870	$(6,456)
LIBRARY	1	0.91	$7,000	$(3,498)	$7,661	$(3,828)
MUNICIPAL LIGHT PLANT	12	39.77	$331,437	$(68,429)	$8,333	$(1,721)

NATURAL RESOURCES	1	1.98	$34,000	$(25,946)	$17,195	$(13,121)
POLICE	3	3.72	$(25,036)	$38,253	$(6,729)	$10,281
PUBLIC WORKS	12	51.59	$346,667	$(43,334)	$6,719	$(840)
SCHOOLS	22	115.00	$2,564,671	$(2,165,242)	$22,301	$(18,828)
2026 – 2030 VEHICLE REPLACEMENTS						
BUILDING	1	1.49	$18,238	$(10,199)	$12,265	$(6,859)
FACILITIES	5	8.90	$219,548	$(187,783)	$24,661	$(21,093)
FIRE	7	27.11	$93,196	$3,687	$3,438	$136
HEALTH	1	1.07	$18,338	$(14,388)	$17,138	$(13,446)
HUMAN SERVICES	3	33.06	$238,433	$(138,440)	$7,211	$(4,187)
MUNICIPAL LIGHT PLANT	3	17.94	$198,891	$(105,725)	$11,083	$(5,892)
NATURAL RESOURCES	1	6.28	$11,000	$13,793	$1,752	$2,196
POLICE	16	115.68	$112,995	$276,916	$977	$2,394
PUBLIC WORKS	12	48.06	$603,861	$(428,915)	$12,564	$(8,924)
SCHOOLS	24	158.98	$3,542,603	$(2,975,968)	$22,283	$(18,719)
2031 – 2040 VEHICLE REPLACEMENTS						
FIRE	4	35.29	$2,200,938	$(2,169,179)	$62,363	$(61,463)
MUNICIPAL LIGHT PLANT	2	23.07	$77,643	$34,548	$3,365	$1,497
PUBLIC WORKS	10	46.72	$419,957	$(78,224)	$8,989	$(1,674)

OTHER EMISSIONS REDUCTION OPTIONS

While the past few years have witnessed significant growth in the availability and adoption of consumer electric vehicles, the electromobility industry is in a period of rapid growth. While many additional models are expected to become available in the next few years, municipal fleets like the Town of Concord's are typically comprised of significant numbers of specialty vehicles including medium and heavy-duty vehicles for which few electric substitutes are currently available from mass-market suppliers. In cases where electric substitute vehicles will not be commercially available through standard procurement mechanisms in the near-term, several other options may be worth considering, including:

- **Partial electrification**: One way to reduce emissions on ICE vehicles for which cost-effective BEV substitutions are not available is the electrification of auxiliary loads with stored energy using mobile batteries. Several aerial bucket trucks in CMLP fleet have been identified as potential candidates. Under this option, traction power would still be provided by gas or diesel engines, but batteries could be used to reduce idle times, saving fuel and cutting emissions.

- **Renewable diesel**: While not an electrification option, this option can be used to significantly reduce emissions of heavy-duty vehicles in the near term. Renewable diesel is a liquid renewable fuel created from processing fat, oil and grease feedstocks. Its chemical composition is comparable to fossil fuel and it behaves exactly like conventional fossil diesel. This enables fleets to switch to cleaner fuel without making any additional investments or modifications to their fleet, but the Town should note the specific feedstock used has an impact on the carbon intensity of renewable diesel. Additionally, in older diesel engines (pre-2010) renewable diesel has the potential to reduce particulate matter and NO_x emissions. Finally, switching to premium-quality renewable diesel can help lower a fleet operator's service and maintenance costs.

NEXT STEPS

IMMEDIATE (2022-2024) ELECTRIFICATION OPTIONS & TCO

A summary of the identified EV alternatives and associated TCOs for immediate vehicle replacements (2023-2024) is included to guide immediate action by the Town of Concord. **Table 10** summarizes the total upfront investment and TCO for the ICE and the best fit EV alternative for all vehicles to be replaced for each year. This table also identifies the total number of vehicles to be electrified, which is consistent with the numbers presented in the Electrification Timeline. **This table only includes vehicles that were identified as a "Best Fit" for Full Electrification.** The number of vehicles to be electrified could be increased if the Town confirms feasible models for vehicles in the Potential Electrification category.

TABLE 13: UPFRONT COST & TCO SUMMARY FOR IMMEDIATE VEHICLE ELECTRIFICATION

REPLACE-MENT YEAR	# OF VEHICLES	ICE		RECOMMENDED EV ALTERNATIVE		
		MSRP	TCO	MSRP	TCO	Projected TCO Savings from Electrification
2023	10	$280,000	$431,981	$378,990	$413,086	$18,895
2024	9	$218,800	$393,843	$353,212	$399,289	$(5,445)
TOTAL	**19**	**$498,800**	**$825,824**	**$732,202**	**$812,375**	**$13,450**

OTHER NEAR-TERM VEHICLE REPLACEMENTS

About half of the vehicles studied in this analysis do not have a clear electric option currently available in 2022 or imminently available in 2023 and the Town will need to reassess the electrification potential of each of those vehicles as they come up for replacement. Depending on the vehicle, the Town can either pursue an alternative electrification or emissions reduction option or delay the vehicle replacement and wait for an equivalent EV to become available, even if it means extending a vehicle's service life beyond what is optimal.

In 2023 and 2024 there are 13 vehicles that will come up for replacement that are categorized in the Potential Electrification or No Electric Alternatives category. For these vehicles, the Town can consider the following options to determine the appropriate course of action.

- **Option 1 – Reassess the Market**: The Town can search for available equivalent options to identify any new models/technologies that have entered the market since the beginning of 2022.

- **Option 2 – Vehicle Downsizing:** For small to mid-size pickups, the Town can explore downsizing the vehicle to a BEV or PHEV option. To support this possibility, this analysis included the Ford F-150 Lightning as a replacement option for larger pickups. This aspect of the analysis was intended to provide Town fleet management and sustainability staff with the information needed to explore downsizing these individual vehicles. Through conversations with Town staff operating the pickup trucks, it can then be determined whether an individual vehicle can be downsized, or if specific operational requirements prevent that.

- **Option 3 – Delayed Replacement:** If no suitable EV option is identified and vehicle downsizing is not an option, the Town can consider keeping the vehicle in the fleet for a year or two more to wait for a viable EV option. The budget for replacing the existing vehicle could be earmarked for an appropriate EV replacement if it becomes available during the delay time.

- **Option 4 – Pilot Chassis Conversion Technology or Less Cost-effective OEM Offering:** In cases where there is a suitable electric option, but that option may be from an aftermarket vendor or is a new EV model that is significantly more expensive than its ICE counterpart, the Town may still want to purchase the EV option to meet environmental goals and pilot new technologies within the fleet.

APPENDIX A: VEHICLE INCENTIVES

APPENDIX A

AVAILABLE INCENTIVES

Financial incentives have played an important role in the expansion of the EV market and the deployment of EVs by municipal fleets. As incentives continue to expand in the medium- and heavy-duty sectors, they will likely continue to play an important role in accelerating Concord's fleet electrification. This section provides a summary of the most important incentive programs that the Town can take advantage of in order to procure EVs as well as provide charging for the electrified fleet. The following incentives are available on a first-come, first-served basis until all available funding is spent, which indicates the urgency to apply.

MassEVIP Fleets is a Massachusetts Department of Environmental Protection (MassDEP) rolling grant program that aids public entities in acquiring leased or purchased EVs for their fleets. It provides up to $7,500 per BEV purchase, $5,000 per BEV lease and PHEV purchase, $3,000 per PHEV lease, and $750 per ZEM purchase as long as the total sale price does not exceed $50,000 and funds for the vehicle are not combines with funds obtained through MOR-EV, MOR-EV Trucks, or Green Communities program. A maximum of 25 EVs can be funded for a single applicant, including any EVs previously funded through MassEVIP Fleets. The public entity must operate each EV and maintain valid registration through Massachusetts Registry of Motor Vehicles for at least 3 consecutive years beginning with the date of registration.

MOR-EV is an Executive Office of Energy and Environmental Affairs' Department of Energy Resources (DOER) funded program that issues rebates for purchasing or leasing a new EV after June 25, 2020. Entities are able to receive a $2,500 rebate for a new BEV or FCEV and a $1,500 rebate for a new PHEV as long as the purchase price is less than $50,000 and the application is submitted within 3 months of the purchase or lease date and after taking possession of the EV. The following EVs are eligible: Audi Q4 e-tron (50), BMW i3, BMW i3 Rex, BMW i3s, Chevrolet Bolt EUV, Chevrolet Bolt EV, Ford Mach E, Hyundai Ioniq Electric, Hyundai Kona Electric, Kia Niro EV, Kia Soul EV, MINI Cooper SE Hardtop 2 Door, Nissan Leaf, Tesla Model 3, Volkswagen e-Golf, Volkswagen ID.4, Honda Clarity Fuel Cell, Hyundai Nexo Fuel Cell, Toyota Mirai, Chrysler Pacifica, Ford Escape, Ford Fusion Energi, Honda Clarity PHEV, Hyundai Ioniq Plug-in Hybrid, Hyundai Santa Fe PHEV, Hyundai Sonata Plug-in Hybrid, Kia Niro Plug-in Hybrid, Kia Optima Plug-in Hybrid, Kia Sorrento PHEV, Toyota Prius Prime, and Toyota RAV4 Prime. Entities are eligible for 10 rebates per calendar year and no more than 20 over the program lifetime.

MOR-EV Trucks is a program design to reduce air pollution emissions by increasing the use of medium- and heavy-duty BEVs and FCEVs on the road. It offers rebates for public and private purchases or leases of qualified new vehicles made on or after February 16, 2021. The EVs must have a total sales price more than $50,000 and have a gross vehicle weight rating (GVWR) exceeding 8,500 lbs. The EVs need to be registered in the Commonwealth and maintained for at least 36 months. Increased funding is available if the EV is registered in or will operate more than 50% of the time within a designated environmental justice community census block. There is potential for an additional 10% increase to be added to the currently available incentive value. Incentives are issued by GVWR and follow a declining value as blocks are exhausted. Applicants many only reserve a maximum of 10% of an available block and vehicle eligibility will be determined on a case-by case basis. The incentive values decline by 15% following each full block and will remain static at Block 3 values until the DOER completes a program review. Due to this being a first-come, first-served program, MOR-EV updates its website every so often to reflect the remaining rebates and vouchers left in the current value block.

MassEVIP Workplace & Fleet Charging is a rolling grant program aimed at making EVs and EV charging stations more widely available. It provides incentives for employers and fleet operators to acquire and install Level I and Level II EV charging stations for applicants with 15 or more employees in non-residential places of business. MassDEP provides up to 60% of the funding, with a maximum of $50,000 per street address, for hardware and installation costs.

Concord Municipal Light Plant (CMLP) Commercial EV Charging Station is a rebate program aimed to assist with the costs of installing new Level II EV charging stations. The charging station must be commercial-grade Level II (208-240V), dual port or 2 single ports, 13 amp or greater per port, and network enabled. The installation of a new charging station must be on a separate meter and usage be billed at a new rate tariff. Entities are eligible to receive up to $3,000 in eligible hardware costs per charging station and up to $3,000 per dual port station in eligible installation costs. This program is designed to, when combined with MassEVIP rebates, fully cover the cost of installing a typical $30,000 dual port charging station. The customer is still responsible for non-covered costs such as software and warranty subscriptions, maintenance, permitting, bollards, etc.

APPENDIX B: DETAILED TCO ANALYSIS

APPENDIX B

The detailed results of the Total Cost of Ownership calculations have been provided to the Town separately from this document in an Excel spreadsheet. This database allows the Town to sort results by any category necessary including Department, Division and Replacement Year.

APPENDIX C: COMPHRENENSIVE FLEET DATABASE& VEHICLE MILEAGE TABLE

APPENDIX C: COMPHRENSIVE FLEET DATABASE (*EXCEL ATTACHMENT)*

The Town of Concord's Comprehensive Fleet Database has been provided as an Excel attachment. A detailed table of vehicle mileage by division is provided below.