CITY OF TEMISKAMING SHORES
PROJECT NUMBER: CA0051181.8757

GREEN MUNICIPAL FLEET STUDY

DELIVERABLE 2 – FINAL REPORT

NOVEMBER 07, 2025

REVISION HISTORY

THIRD ISSUE

07 Nov 2025	Revision C			
Prepared By	Reviewed By	Approved By		
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SECOND ISSUE

16 Oct 2025	Revision B			
Prepared By	Reviewed By	Approved By		
Jack O 'Donnell	Shervin Bakhtiari	Shervin Bakhtiari		

FIRST ISSUE

17 Sep 2025	Revision A			
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This project was carried out with assistance from the Green Municipal Fund, a Fund financed by the Government of Canada and administered by the Federation of Canadian Municipalities. Notwithstanding this support, the views expressed are the personal views of the authors, and the Federation of Canadian Municipalities and the Government of Canada accept no responsibility for them.

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ABBREVIATIONS LIST

Abbreviation	Definition
AC	Alternating Current
BAU	Business as Usual
BEV	Battery Electric Vehicle
CAD	Canadian Dollars
CAPEX	Capital Expenses
CCS	Combined Charging System
CO_2e	Carbon Dioxide Equivalent
DC	Direct Current
DCFC	Direct-Current Fast Charger
DOE	Department of Energy
EIA	U.S. Energy Information Administration
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
GHG	Greenhouse Gas
H2DF	Hydrogen-Diesel Dual Fuel
ICE	Internal Combustion Engine
kg	Kilogram
km	Kilometres
kW	Kilowatt
kWh	Kilowatt hour
MSRP	Manufacturer Suggested Retail Price
NRCan	Natural Resources Canada
OEM	Original Equipment Manufacturer
OPEX	Operational Expenses
PHEV	Plug-in Hybrid Electric Vehicle
RD	Renewable Diesel
SAE	Society of Automotive Engineers
SUV	Sport Utility Vehicle
tCO_2e	Tonnes of carbon dioxide equivalent
VKT	Vehicle Kilometers Travelled
ZEV	Zero Emission Vehicle

1 CONTEXT

1.1 BACKGROUND

The City of Temiskaming Shores was created by the amalgamation of the town of New Liskeard, the town of Haileybury, and the township of Dymond in 2004. Its northern climate and unique geographical configuration create interesting considerations to implement when planning a fleet transition—particularly in terms of cold-weather vehicle performance, charging infrastructure for electric vehicles, and the logistical challenges of servicing a dispersed municipal area.

Temiskaming Shores has demonstrated a firm commitment to environmental sustainability through its participation in the Partners for Climate Protection (PCP) program. In 2018, the City joined the PCP and has since developed a comprehensive Corporate Greenhouse Gas (GHG) Reduction Plan. This plan sets ambitious targets, including a 40% reduction in municipal GHG emissions by 2033 and achieving net-zero emissions by 2050[1]. The City is prioritizing reductions in emissions from municipal operations, such as transitioning to electric vehicles and improving building energy efficiency. Public engagement has also played a key role, with the formation of a Climate Change Committee in 2020 to guide and support these initiatives. Temiskaming Shores continues to evolve as a forward-thinking community, integrating sustainability into its long-term planning and operations.

In order to achieve these net-zero targets within its corporate operations, the City set out to investigate strategies to support the reduction of GHG emissions of its registered (licenced) fleet. WSP has been retained by the City of Temiskaming Shores to carry out a Green Municipal Fleet Study to transition their corporate fleet vehicles and equipment to low- or zero-emission alternatives and propose opportunities for the reduction of carbon emissions and optimization strategies. This Green Municipal Fleet Study will provide the City of Temiskaming Shores with a roadmap to reduce the City's fleet emissions to neutrality by 2050. As such, the scope of this study is limited to the City's registered fleet and equipment assets, which include light-, medium- and heavy-duty vehicles and some on-road equipment. The City's vehicles and equipment are used to support a wide range of municipal services, including public safety, facility maintenance, parks maintenance, public works, and more.

1.2 STUDY OBJECTIVES

The City of Temiskaming Shores has a target to achieve carbon neutrality by 2050, with the interim objectives of 40% below 2019 levels by 2033. The purpose of this Green Municipal Fleet Study is to propose different strategies and optimization measures to reduce the emissions from the fleet, and investigate how to transition to low and zero-carbon technologies with accurate costs and a deployment plan for the next two decades.

As low-emission and zero-emission alternatives are increasingly available for municipal vehicles and equipment, the City needs to understand the opportunities and challenges related to both vehicle fleet transition and required infrastructure upgrades. The current strategy will combine existing fleet information with ZEV options to produce a phased transition roadmap, propose solutions to infrastructure challenges and identify barriers limiting the City's plan to transition its assets to low or zero emission alternatives. For example, EV adoption requires deliberate planning for infrastructure upgrades

[1] Climate Change & Energy | City of Temiskaming Shores

and power grid supply management, while vehicles powered through alternative fuels might require additional consideration to be addressed, such as generation, distribution and safety.

This strategy will evaluate the achievements to date on fleet transition and propose new ideas and technologies which align with the City's direction for reducing fleet emissions while ensuring fiscal responsibility. As part of this strategy, the following considerations will be assessed:

- Capital and operating costs
- Technology maturity
- Impacts to current operations (i.e. Downtime, range limitations, power requirements)
- GHG reduction potential (Scope 1 emissions)
- Building-level requirements to support charging infrastructure.

While the primary focus on this study is to assess how the City could reduce its corporate GHG emissions, transitioning to low-emission technologies also presents other environmental and social benefits. These include criteria air pollutant[2] reduction, particulate matter reduction, noise reduction, and more. While these benefits are very important, they will not be quantified as part of this study.

1.3 LIMITATIONS

The findings presented in this study are based on the information and data available at the time of writing. The analysis is based on the asset data provided in May of 2025 by the City of Temiskaming Shores. It is assumed that the information provided by the City represents an accurate portrayal of the City's fleet and services.

The analysis was conducted on the assumption that the City of Temiskaming Shores assumes responsibility for the accuracy and quality of all data provided. Historical fleet data was used to help establish a baseline on current fleet operations in order to make comparisons against low carbon vehicle alternatives. Fleet statistics such as fuel economy and fleet maintenance costs are referenced from historical data to help develop lifecycle cost assessments of vehicles and equipment. Utilization information provided was in the form of vehicle kilometers travelled (VKT) and hours of utilization.

Analyses on low carbon vehicle technologies are subject to change due to the nature of continuing innovations in alternative propulsion technologies and evolving policies regarding environmental sustainability. The availability of market data on alternative vehicles is based on present conditions, providing a current snapshot of prices and specifications, and may change over time. It is recommended that the City review its fleet vehicles and technologies at least every five years or sooner (2-3 years) and update its strategy as necessary.

[2] Criteria air pollutants encompass the six most common air pollutants, including carbon monoxide, lead, ground-level ozone, particulate matter, nitrogen dioxide, and sulfur dioxide. Exposure to these pollutants has been associated with negative health effects.

2 CURRENT STATE OF THE FLEET

The fundamental objective behind investigating the current conditions is to derive estimates of the total cost and greenhouse gas (GHG) emissions associated with the existing corporate fleet used by the City of Temiskaming Shores. The following sections will provide a clear explanation of the detailed data collection, grouping, and analysis procedures completed to establish the baseline for this study.

2.1 ASSET INVENTORY

The assessment of the fleet began with a comprehensive analysis of its general characteristics and patterns of utilization. This involved gathering detailed information about the types of vehicles and equipment in the City's fleet asset list. Data on the fuel type and fuel usage of each vehicle category were visualized to understand the overall composition of the fleet.

Additionally, the patterns of vehicle usage were assessed, such as the average distance travelled, hours of utilization and the age of vehicles. Understanding how the fleet is utilized is crucial for formulating effective strategies to transition to an financial and environmentally sustainable fleet.

2.1.1 COUNT

The City of Temiskaming Shores operates and maintains over 196 assets. As the objective of this project is to create a strategy focusing on implementable actions regarding the City's corporate fleet, **only the on-road assets were considered**. For this study, it is understood that the City operates **52 on-road assets**, distributed across five (5) departments. These assets encompass various types of light duty, medium duty and heavy duty vehicles owned by the City, as well as leased with an external fleet management company (Enterprise Fleet Management). These assets have been grouped into different categories. Refer to Appendix A for the complete asset list and their respective designated classification.

Figure 2-1 provides a summary of the categorization of the assets. Table 2-1 categorizes the vehicles by their weight (light, medium, and heavy) and their functionality (emergency vehicles or transit), based on the classification used in the City's Asset Management Plan (AMP)[3]. The figure also highlights the number of leased vehicles in each specific category, accounting for over 25% of the fleet.

22 assets (approximately 42%) of the City's registered vehicles and equipment fleet is composed of light duty vehicles. These light duty vehicles are mainly pick-up trucks (15 vehicles) but also include ¾ ton trucks (3 vehicles), SUVs (2 vehicles) and Vans (2 vehicles). Table 2-1 provides detailed breakdown for a more granular understanding of how the assets were categorized.

[3] The Corporation of the City of Temiskaming Shores, "Asset Management Plan", 2024.

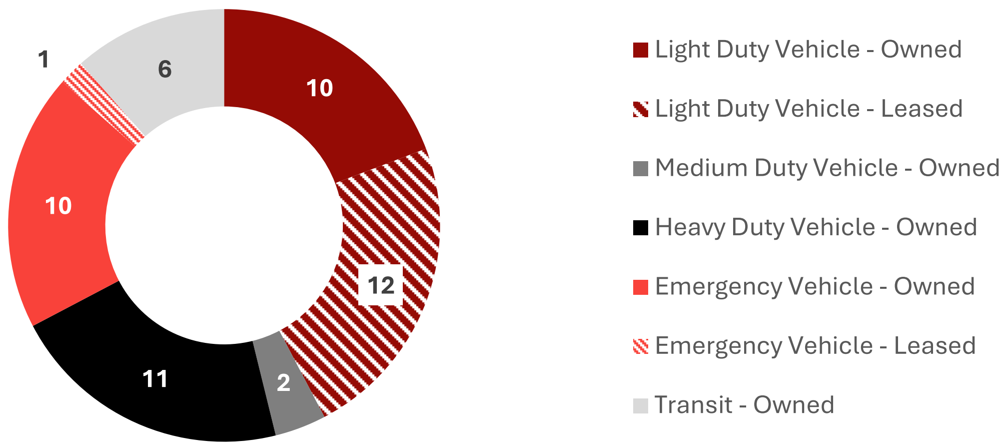

Figure 2-1 Number of assets by type

Table 2-1 Detailed Classification of Vehicle Types

AMP CLASSIFICATION	ASSET TYPE	TOTAL NUMBER OF ASSETS	COUNT OF LEASED ASSETS
LIGHT DUTY VEHICLE	Pick-up Truck	15	10
	SUV	2	2
	¾ ton	2	-
	Van	3	-
	Total	**22**	**12**
MEDIUM DUTY VEHICLE	2-ton dump	2	-
	Total	**2**	**-**
HEAVY DUTY VEHICLE	Vacuum Truck	1	-
	Plow / Tandem	4	-
	Single Axle Dump / Sander	2	-
	Patch Truck	1	-
	Dump Truck	2	-
	Sweeper	1	-
	Total	**11**	**-**
EMERGENCY VEHICLE	Pick-up Truck	2	1
	Fire Pumper	6	-
	Fire Rescue	3	-
	Total	**11**	**1**
TRANSIT	Transit	6	-
	Total	**6**	**-**
CITY OF TEMISKAMING SHORES TOTAL		**52**	**13**

The City of Temiskaming Shores is serviced through five departments, each of which has access to vehicles. Table 2-2 present the absolute number of vehicles associated with each group. This categorization helps assess fleet utilization and prioritize the transition based on departmental needs.

Table 2-2 Number of Vehicles by Department

DEPARTMENT	LIGHT DUTY VEHICLES	MEDIUM DUTY VEHICLES	HEAVY DUTY VEHICLES	EMERGENCY VEHICLE	TRANSIT	TOTAL
Corporate Department	2	0	0	0	0	***2***
Fire Services	0	0	0	11	0	***11***
Leisure Services	8	1	0	0	0	***9***
Public Works	12	1	11	0	0	***24***
Transit	0	0	0	0	6	***6***
Total	***22***	***2***	***11***	***11***	***6***	***52***

The Public Works department has the greatest number of assets, which are directly linked with the nature of their operations, as it is responsible for a wide range of essential municipal services supporting the community's infrastructure (including core operations in water and wastewater services, roads, solid waste and recycling, etc.). Of the 24 assets operated by the Public Works branch, 12 are classified as light duty vehicles (all pick-up trucks under 1 ton). This will have a great impact on the greening of the fleet, as low-carbon/zero-emissions alternatives are already commercially available for these vehicle types. Table 2-3 demonstrates the fleet distribution across the various user groups. It is important to understand who has the most assets and what category their assets fall into, as this makes an impact on the ease of technology transition.

Table 2-3 Fleet Distribution Across the Branches

	CORPORATE DEPARTMENT	FIRE SERVICES	LEISURE SERVICES	PUBLIC WORKS	TRANSIT	***TOTAL***
SUV	2	-	-	-	-	***2***
Pick-up Truck	-	2	5	10	-	***17***
Fire Pumper	-	6	-	-	-	***6***
Fire Rescue	-	3	-	-	-	***3***
3/4 ton	-	-	2	1	-	***3***
2-Ton Dump	-	-	1	1	-	***2***
Van	-	-	1	1	-	***2***
Vacuum truck	-	-	-	1	-	***1***
Plow / Tandem	-	-	-	4	-	***4***
Single Axle Dump / Sander	-	-	-	2	-	***2***
Patch Truck	-	-	-	1	-	***1***
Dump Truck	-	-	-	2	-	***2***
Sweeper	-	-	-	1	-	***1***
Transit	-	-	-	-	6	***6***
Total	***2***	***11***	***9***	***24***	***6***	**52**

2.1.2 VEHICLE AGE

As part of their AMP the City of Temiskaming Shores has set certain age limits for the various fleet assets as part of their vehicle replacement plan, which varies between 9 to 30 years, depending on the particular asset type. All of the assets are currently running under the expected useful life (EUL) planned by the City. This reflects good asset management practices from the City's fleet department, as running assets past their useful life could lead to more frequent maintenance requirements, higher operational costs, and lower fuel efficiency when compared to vehicles running in their prime life (under their determined end of useful life). There may also be other negative consequences, such as reduced reliability and safety concerns.

Figure 2-2 presents the average years before the next replacement. This is particularly interesting to consider in the context of transitioning the vehicles to zero emissions. Generally, this transition occurs when a vehicle reaches its useful life. As presented in the figure, the ones with the lowest number of years until the next replacement (SUVs, pick-up trucks and vans) are all vehicle classes for which commercially available alternatives already exist. On the other hand, some of the assets with the highest number of years until replacement are more energy-intensive vehicles (fire vehicles, vacuum trucks, dump trucks, etc.). This presents an interesting opportunity, as it is expected that technology will develop further, and be able to accommodate the operational requirements before they need to be replaced.

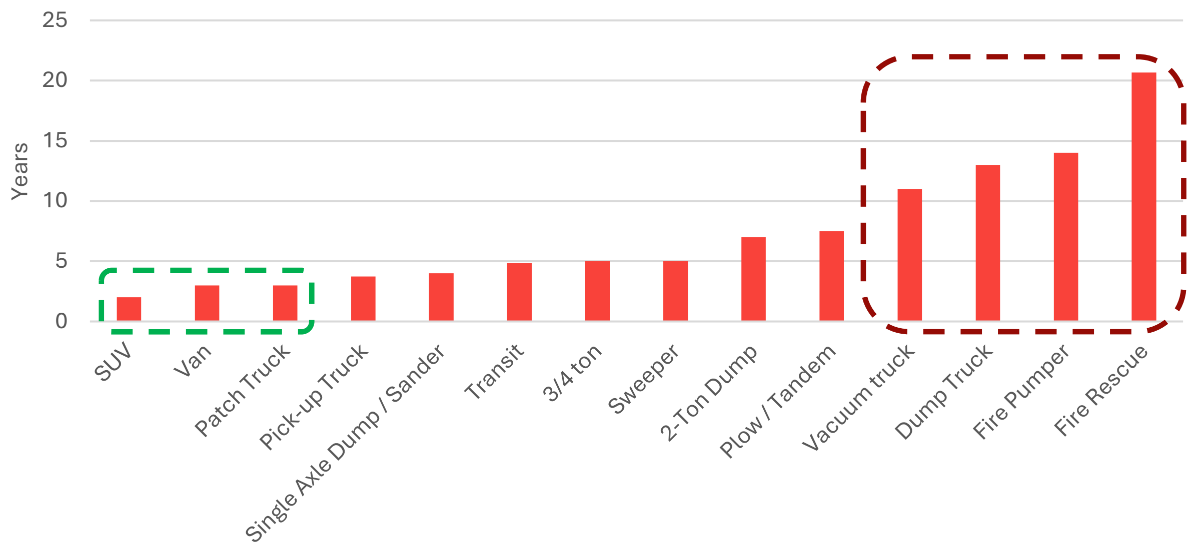

Figure 2-2 Average Years Before Next Replacement

The median age of the fleet is six years, meaning that over half of the City's assets have been in service for less than six years. This lower median age might be attributable to the number of vehicles managed through Enterprise, and therefore required to be replaced when the lease contract ends. Maintaining a fleet with a relatively low average age indicates that the vehicles in the fleet are relatively new and have been acquired or replaced within the past few years. This demonstrates the City's commitment to investing in its assets and ensuring that the vehicles used for public services and other municipal operations are relatively young. It can also contribute to improved service delivery, as newer vehicles are less prone to breakdowns and are more likely to meet the evolving needs of the community.

2.1.3 LEASED VEHICLES

The City of Temiskaming Shores is working with Enterprise Fleet Management for all their leased vehicles. Enterprise works closely with the City and focuses on optimizing fleet operations through cost reduction, vehicle right-sizing, and technology implementation to help monitor their fleet. Although not currently implemented within the City's fleet, Enterprise works alongside industry partners (Geotab, for example) to monitor GHG emissions and vehicle performance. Enterprise's approach emphasizes total cost of ownership (TCO), factoring in resale value, fuel, and maintenance to select the right vehicle to be replaced for the most optimal period. Based on the discussion, Enterprise expects that EVs might typically be on shorter lease cycles due to the rapid technology evolution. While they don't provide driver training, they offer general recommendations and collaborate with local shops and charging infrastructure providers, primarily for light- and medium-duty vehicles.

The current fleet is comprised of 13 leased vehicles, all light duty vehicles:

- 11 pick-up trucks (10 classified as light duty vehicles, 1 classified as an emergency vehicles)
- 2 SUVs

On average, the leased vehicles are cheaper to operate on a kilometre basis. Based on the available information, the average operational cost (fuel cost and maintenance cost) for leased light duty vehicles amounts to **0.44$/km travelled**, compared to **0.54$/km travelled** for the owned light duty vehicles. This difference can be explained by the number of years the vehicles have been in operations; all of the leased vehicles have less than 2 years of operations (the average being 1.6 years), while 80% of the owned vehicles have been in operations for more than 5 years (the average being 6.1 years). More information on the cost of operating the fleet is presented in section 3.2.

Leased vehicles are all on a 5-year lease agreement; their shorter lease terms will allow the City to adopt the latest propulsion technologies more frequently, keeping pace with rapid advancements in performance, range, and charging capabilities. Leasing the new technology will also mitigate any concerns about the unknown long-term costs of newer technologies, and could potentially be leverage for future planning.

2.2 FLEET UTILIZATION

The use of vehicles can typically be measured by the distance travelled (in kilometres) as well as by its operating time (in hours). Table 2-4 presents the primary metering unit used throughout this analysis for each of the vehicle classes.

Table 2-4 Primary Metering Unit by Vehicle Class

ASSET TYPE	METERING UNIT	ASSET TYPE	METERING UNIT
SUV	KM	Fire Pumper	KM*
Pick-up Truck	KM	Fire Rescue	KM*
¾ ton	KM	Vacuum Truck	H
2-ton Dump	KM	Single Axle Dump / Sander	H
Van	KM	Patch Truck	H
Plow / Tandem	KM	Dump Truck	H
Transit	KM	Sweeper	H

**The nature of operations for the Fire Pumper and Fire Rescue can require extensive idle times. However, the data available to complete this analysis was based on kilometres travelled.*

2.2.1 DISTANCE TRAVELLED

Figure 2-3 below illustrates the breakdown of vehicle kilometres travelled (VKT) on an annual basis across the different asset types. This is based on the data available at the time of analysis. To estimate the annual distance travelled, the lifetime odometer was divided by the years of service of the specific asset. In total, the City of Temiskaming Shores' fleet travels over 700,000 kilometres annually, distributed across 46 assets that are primarily metered through kilometres. The average vehicle travels approximately 15,602 kilometres yearly.

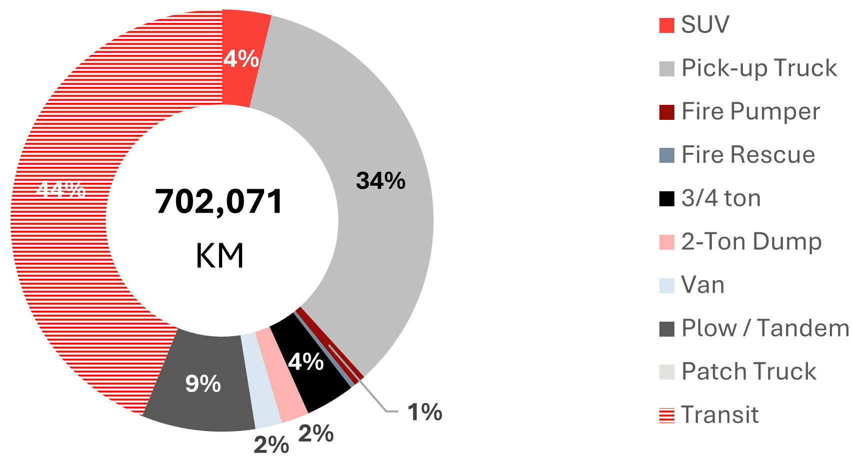

Figure 2-3 Yearly Utilization by Asset Type

The total annual kilometres per vehicle is greatly influenced by the Transit vehicles, which account for 44% (307,716 km) of the total distance travelled. This amounts to an average of over 51,000 km per transit bus, considering the six (6) active assets in this category. Pick-up trucks are the second most-driven vehicle type, accounting for over 34% (242,187 kilometres) of the total annual distance travelled. This proportion is consistent with their representation in the fleet, as pick-up trucks make up 38% of the assets metered by distance.

Figure 2-4 presents the average annual travelled distance for each vehicle class. Transit vehicles and Plow / Tandem vehicles both present high VKT due to the nature of their operations; transit vehicles are servicing a large area and are running an hourly service 7 days a week throughout the region, while Plow / Tandem vehicles can be used periodically for a large amount of time, during winter events. Emergency vehicles, such as Fire Rescue and Fire Pumper, have the lowest average distance travelled annually. This is primarily because the metric used for this analysis only captures the distance travelled and does not account for the idle times that are inherent to their nature of operations. From an operational perspectives, Fire Rescue and Fire Pumper can spend a significant amount of time idling during emergency responses, training exercises, and/or when stationed at various locations. Because the Fire Pumpers and Fire Rescues are metered through distance, the idle time (which is essential for their readiness and quick deployment) is not captured through this data and the distance metric alone does not fully represent their actual usage and operational demands. When thinking about transitioning the emergency vehicles, a consideration will need to be made for the emergency vehicles, as the available range from possible electric alternatives will not capture all the operational requirements for this vehicle type.

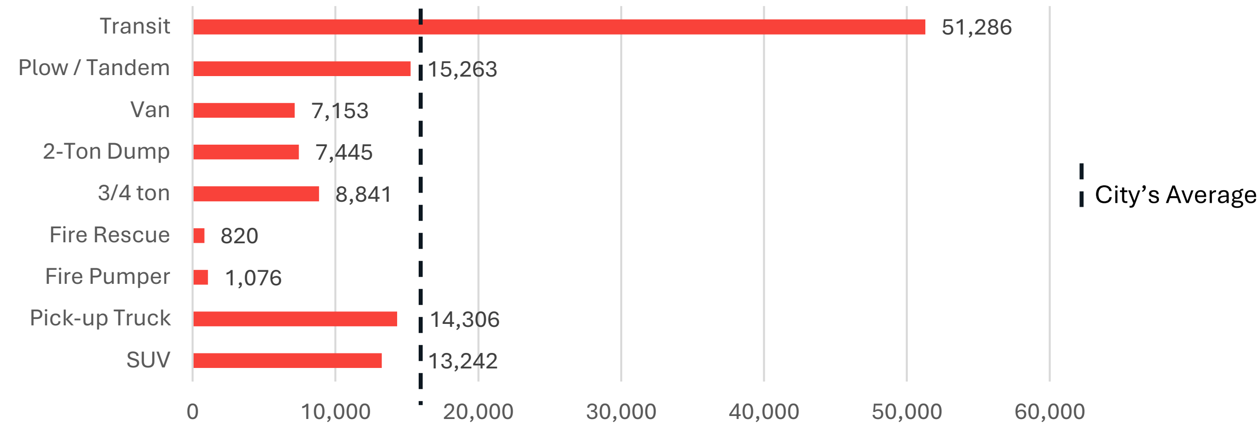

Figure 2-4 Average Annual Travelled Distance by Vehicle Class

2.2.2 *OPERATING HOURS*

Figure 2-5 below is a breakdown of the hourly utilization between the different asset types. The City of Temiskaming Shores operates over six thousand hours on a yearly basis, distributed across seven (7) vehicles and equipment that are primarily metered through hours.

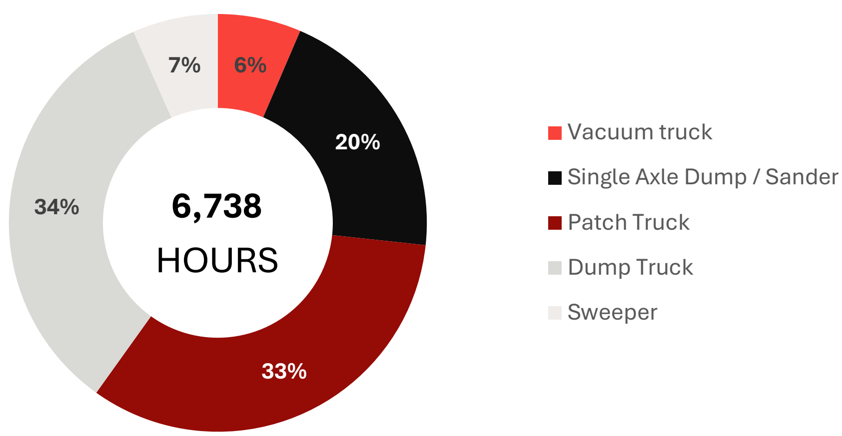

Figure 2-5 Hourly Utilization by Asset Type

It is interesting to compare the total utilization with the number of assets in each category. For instance, while Patch Truck is the second-most utilized asset category (33% of the annual hours of operations – 2,235 hours), there is only one (1) vehicle in this categorization, making it the most utilized vehicle on an hourly basis.

As mentioned in section 2.2.1, the emergency vehicle (Fire Pumper and Fire Rescue) utilization data has been captured through distance traveled, even though their operations require idle time. This underestimates the total hours of operation. Through discussion with the Fire Services department, it has been captured that the Pumper has been utilized for over 363 hours (spread across 6 units), while the Rescue vehicles have been utilized for over 208 hours (divided across 3 assets). These hourly considerations will be captured when planning for the specific vehicle transition.

3 BASELINE

3.1 GREENHOUSE GAS BASELINE

By conducting this comprehensive assessment, this section of the study aims to establish a solid baseline that accurately reflects the current state of the City of Temiskaming's corporate assets. This baseline serves as a crucial reference point against which the success of future initiatives, aimed at achieving net-zero corporate emissions by 2050 with an interim objective of 40% below 2019 levels by 2033, can be measured. The data-driven insights gleaned from this evaluation will aid the City in understanding any optimization opportunities or transition strategies to reduce its carbon footprint and operational costs.

3.1.1 FUEL USAGE

The City of Temiskaming Shores' assets are entirely fueled by fossil fuels, both gasoline and diesel. Figure 3-1 shows the breakdown of fuel based on asset type. As part of their Energy Conservation and Demand Management Plan, the City plans on developing a network of EV charging options and explore biodiesels as an interim solution for its medium and heavy-duty fleet vehicles[4], however, there is currently no carbon-efficient fuel used as an alternative. Figure 3-1 below presents the fuel breakdown by asset type.

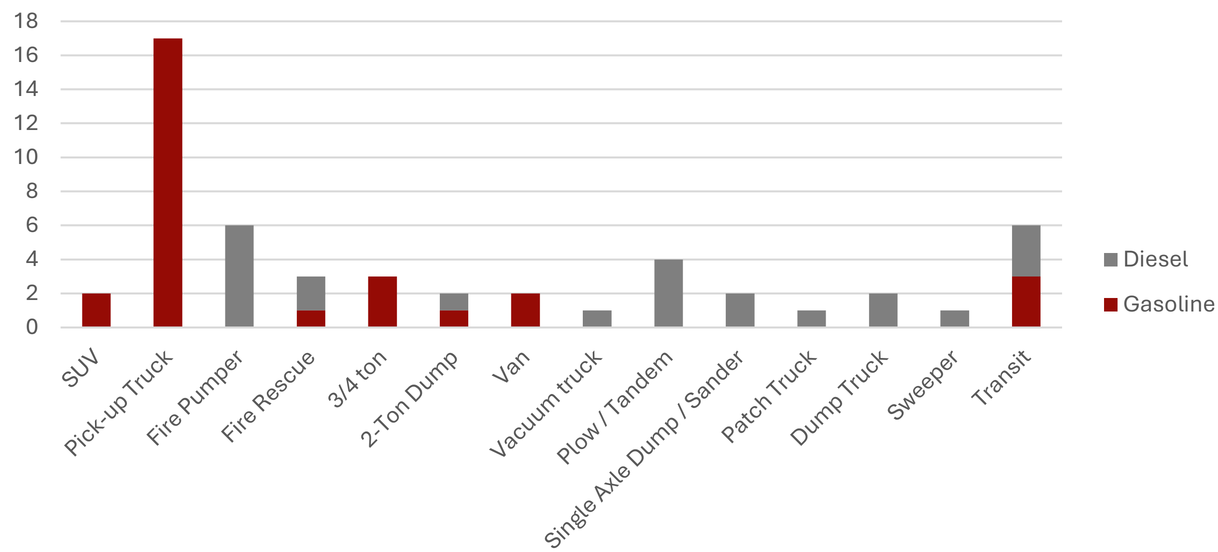

Figure 3-1 Fuel Breakdown by Asset Type

Table 3-1 below presents the average fuel consumption by vehicle class, based on the data provided by the City. The data received is in line with what can be expected; SUVs are the most efficient vehicles, followed by light-duty pick-up trucks, while heavier vehicles, including fire trucks and 2-ton dump trucks, consume the most fuel.

[4] City of Temiskaming Shores, Energy Conservation and Demand Management Plan 2024-2029, 2024.

Table 3-1 Average Fuel Consumption by Asset Type

ASSET TYPE	FUEL CONSUMPTION	ASSET TYPE	FUEL CONSUMPTION
SUV	0.26 L/KM	Fire Pumper	0.77 L/KM*
Pick-up Truck	0.39 L/KM	Fire Rescue	1.12 L/KM*
¾ ton	0.60 L/KM	Vacuum Truck	21.45 L/H
2-ton Dump	1.71 L/KM	Single Axle Dump / Sander	9.70 L/H
Van	0.69 L/KM	Patch Truck	4.07 L/H
Plow / Tandem	0.82 L/KM	Dump Truck	18.07 L/H
Transit	0.33 L/KM	Sweeper	22.48 L/H

Based on previous projects conducted with municipalities in Ontario, WSP acknowledges that some of the fuel consumption results observed in Temiskaming Shores appear elevated compared to typical benchmarks[5]. These higher figures may be attributable to the recently implemented data gathering (historical data not available) and/or the City's distinct northern climate, which can impact vehicle efficiency—particularly in colder months—as well as its geographically dispersed configuration, which often requires longer travel distances and more frequent vehicle use across amalgamated communities. This elevated fuel consumption will have a direct impact on the estimation of the annual GHG emissions, the financial baseline (annual cost of fuel) and consequently, on the impact of the transition.

3.1.2 EMISSIONS FACTORS

Each fuel presents a specific emissions factor representing the amount of carbon dioxide equivalent produced per unit of fuel burned. The values used in the study are presented in Table 3-2.

Table 3-2 Emission Factors for Each Fuel

FUEL	EMISSION FACTORS (KG CO_2E/L)	SOURCE
Diesel	2.689	Emission Factors and Reference Values, Government of Canada[6]
Gasoline	2.315	Emission Factors and Reference Values, Government of Canada[7]

[5] For instance, SUVs are typically around 0.10 L/KM, Pick-up truck around 0.20L/KM, heavier pick-up around 0.25 L/KM, Cargo Van around 0.20 L/KM and Heavy duty vehicles around 0.60 L/KM
[6] Emission factors and reference values - Canada.ca
[7] Emission factors and reference values - Canada.ca

3.1.3 EMISSIONS

Combining the fuel distribution (Figure 3-1), the fuel consumption provided by the City and the emission factors (Table 3-2), it is estimated that the City of Temiskaming Shores' assets produce over 975 tonnes of CO2e annually. A breakdown of these emissions by the asset management plan categorization is presented in Figure 3-2.

While light-duty vehicles accounts for 42% the City's assets (see Figure 2-1), due to the nature of their work (often less energy-intensive than medium- or heavy-duty vehicles) they only produce 26% of total fleet emissions. Heavy duty vehicles, however, emit the largest amount of emissions, despite their low contribution to the absolute asset count (21% - 11 vehicles). While Figure 3-2 present the breakdown for the broad categorization, Table 3-3 presents a more granular breakdown of the emissions produced by the City's assets.

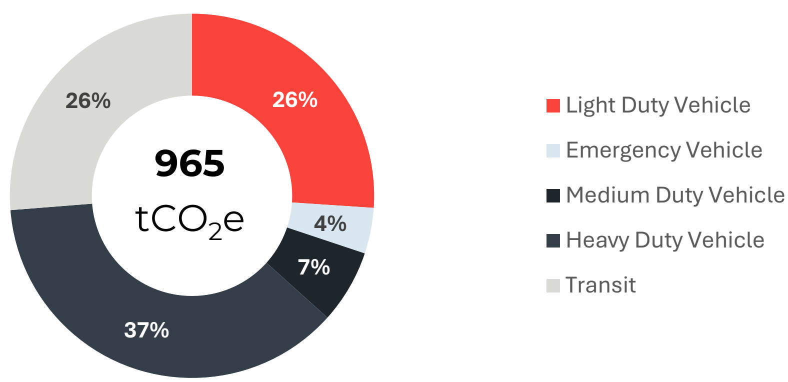

Figure 3-2 Breakdown of Annual Emissions per Asset Type

Table 3-3 presents the difference fuel efficiency can make in a corporate fleet. On average, a pick-up truck produces 0.82 kg of CO_2e for every kilometre travelled, while an SUV produces 0.60 kg of CO_2e over the same distance. This demonstrates the fuel efficiency of SUVs, compared to pick-up trucks, and the potential impact of selecting a vehicle with lower fuel consumption can have on the emissions, if it can accommodate the operational requirements of the pick-up truck.

This is important to take into consideration when renewing corporate fleet vehicles. While there are some operational needs that require specific vehicle types, it could be beneficial to conduct similar exercises through the whole fleet to understand if optimization is operationally possible. For instance, based on the data available for the analysis, on average, changing a pick-up truck to an SUV could reduce annual CO_2e emissions by 3.27 tonnes. A similar optimization could be completed for ¾ ton pick-ups (which produces 1.35 kg of CO_2e for every kilometre travelled), compared to light-duty pick-up trucks. Applying a similar methodology reveals that transitioning a ¾ ton pick-up to a lighter pick-up trucks, if operationally viable, could reduce the emissions by approximately 5 tonnes, annually.

Table 3-3 Breakdown of the Annual Emissions per Detailed Asset Type

AMP CLASSIFICATION	ASSET TYPE	TOTAL EMISSIONS (KG CO2E)	EMISSIONS PER KM (KG CO2E)	EMISSIONS PER HOUR (KG CO2E)
LIGHT DUTY VEHICLE	Pick-up Truck	201,900	0.83	
	SUV	15,758	0.60	
	¾ ton	35,782	1.35	
	Van	18,218	1.27	
	Total	**271,658**	**1.01**	
MEDIUM DUTY VEHICLE	2-ton dump	63,048	4.23	
	Total	**63,048**	**4.23**	
HEAVY DUTY VEHICLE	Vacuum Truck	24,993		57.51
	Plow / Tandem	135,177	2.21	
	Single Axle Dump / Sander	35,472		26.00
	Patch Truck	24,375		10.90
	Dump Truck	110,916		49.15
	Sweeper	26,871		60.27
	Total	**357,804**	**2.21**	**40.77**
EMERGENCY VEHICLE	Fire Pumper	12,236	1.90	
	Fire Rescue	6,746	2.74	
	Total	**18,982**	**2.32**	
TRANSIT	Transit	253,307	0.82	
	Total	**253,307**	**0.82**	
TOTAL		**964,798**	**-**	**-**

Presenting the emissions from the different asset types at a granular level helps to understand which asset types would be the most impactful to transition towards zero-emission alternatives. Light duty pick-up trucks, for instance, accounts for 21% (202 tCO_2e) of the City's corporate emissions; the transition of these vehicles is crucial to reach the environmental objectives of the corporate fleet. While different alternatives for light duty pick-up trucks are emerging on the market, buy-in from the operators and defined practices for electric alternatives will be crucial to accelerate this transition and achieve the expected results.

Figure 3-3 illustrates the GHG emissions projection for the BAU scenario. To estimate this projection the usage per year is given either by the vehicle-kilometers travelled per year, or the hours of use per year. The expected rate of improvement for the period 2024-2050 of the fuel economy is based on the EIA report[8]. The expected rate of improvement of carbon intensity is based on the Clean Fuel Regulations that mandate a continuous improvement of fossil fuels from 2025 to 2030 at a rate of -1.5 gCO2e/MJ[9].

[8] Energy Information Administration, Annual Energy Outlook 2022, 05 AEO2022 Transportation

[9] Government Of Canada, What are the Clean Fuel Regulations? https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-regulations/about.html

Note that the expected rate of reduction is for the lifecycle of the fossil fuel, from production to usage. Appendix A presents assumptions made to present a realistic overview of the expected GHG reduction from the Clean Fuel Regulations.

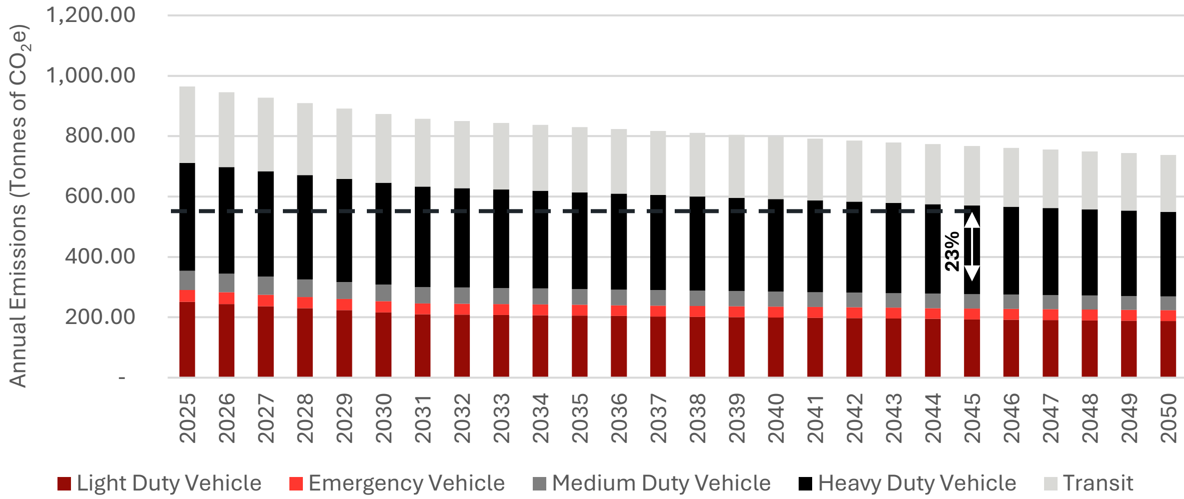

Figure 3-3 GHG Emissions by Year per Asset Type

- **Reduction in Total GHG Emissions**: The total greenhouse gas (GHG) emissions are projected to decrease from an equivalent of 975 tonnes of CO2e in 2025 to over 747 tonnes of CO2e by 2050. This signifies a notable reduction in emissions over the study period.
- **Factors Driving the Reduction**: The decline in GHG emissions is primarily attributed to two key factors. First, the expected improvement of Internal Combustion Engines (ICE) plays a significant role in reducing emissions by enhancing fuel efficiency and reducing carbon-intensive outputs. Second, the mandated constraints imposed by the Clean Fuel Regulations contribute to the reduction by promoting the use of cleaner and lower-emission fuels.

3.2 COST BASELINE

Using the data provided by the City, a financial snapshot of annual operations was created. Based on the data[10], the annual operational expenses accounted for approximately $867,713, of which, 48% ($0.42M) was allocated towards maintenance costs, while the remaining 52% ($0.45M) were fuel costs.

A breakdown of the operational cost by vehicle type is provided in Table 3-4. Heavy Duty vehicles and Transit vehicles present the highest annual operational costs; combined, they represent over 72% ($0.623M) of the total yearly operational costs, while accounting for 31% of the total fleet. This is linked to the higher fuel consumption of the heavier vehicles (17.93 L/H of operations) and the frequent and costly maintenance of the transit vehicles.

[10] The City of Temiskaming Shores provided the fuel cost. Diesel: 1.168$/L. Gasoline: 1.126$/L.

Table 3-4 Operational Cost by Vehicle Category«

VEHICLE CATEGORY	ANNUAL FUEL COST	ANNUAL MAINTENANCE COST	ANNUAL OPERATIONAL COST	AVERAGE FUEL COST	AVERAGE MAINTENANCE COST	AVERAGE OPERATIONAL COST
Light Duty Vehicle	122,696.74	20,173.62	142,870.36	5,577.12	916.98	6,494.11
Medium Duty Vehicle	29,590.97	7,678.04	37,269.01	14,795.49	3,839.02	18,634.51
Heavy Duty Vehicle	155,880.11	142,272.39	298,152.50	14,170.92	12,933.85	27,104.77
Emergency Vehicle	23,271.81	40,394.64	63,666.45	1,939.32	3,366.22	5,305.54
Transit	115,664.51	210,090.73	325,755.24	19,277.42	35,015.12	54,292.54
Total	***447,104.14***	***420,609.42***	***867,713.56***	***11,152.05***	***11,214.24***	***22,366.29***

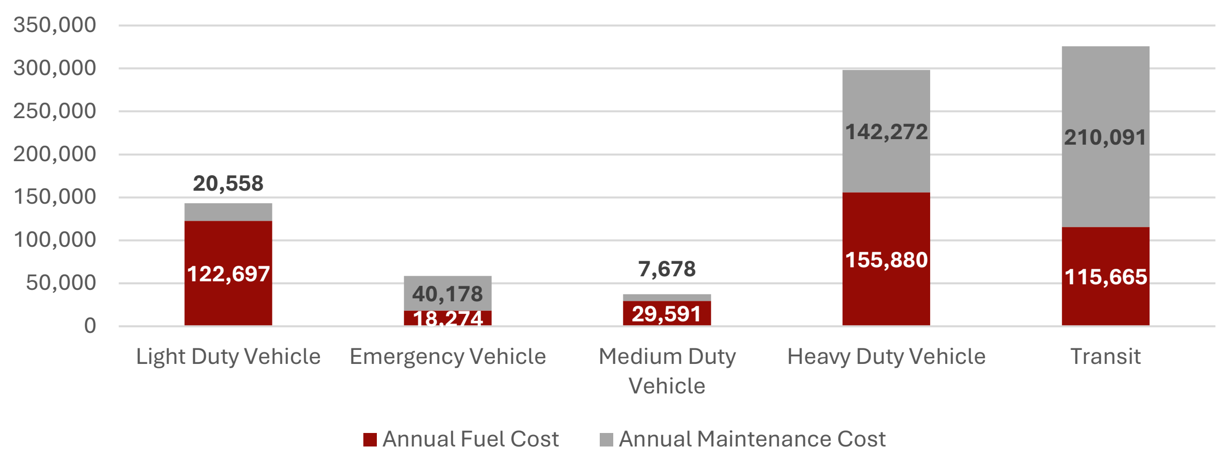

Figure 3-4 Total annual Breakdown of Operational Costs (Maintenance and Fuel) by Asset Type

Figure 3-4 presents the **total annual operational cost** for each vehicle category, offering a breakdown of the **average operational cost**, to consider the volume of vehicles undergoing maintenance by different classifications. This showcases how much more it costs to operate heavier vehicles and equipment (transit, plow/tandem and dump truck) when looking at it on a per-vehicle basis. This might be linked to the higher maintenance requirements for these types of vehicles (heavier vehicles). On average, the annual maintenance cost accounts for approximately 60% of the operational cost for the Emergency Vehicle, the Heavy Duty Vehicle and the Transit assets. Comparatively, the annual maintenance cost for Light Duty Vehicles accounts for 14% and 21% for the Medium Duty Vehicles. This might be linked to the business model, with over 55% of the assets being in a lease agreement. For Medium Duty Vehicles, the low maintenance cost might be linked to their lower utilization (averaging less than 1% of the annual traveled distance per vehicle).

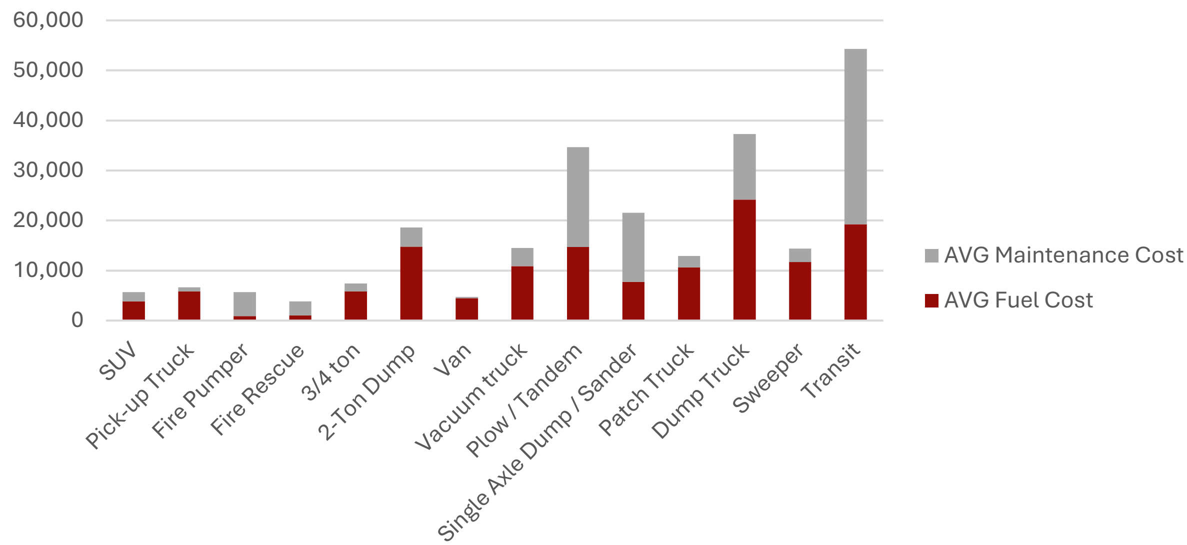

Figure 3-5 Average Annual Operational Costs (Maintenance and Fuel) by Vehicle Type

Figure 3-6 presents the **operational cost per kilometre travelled or hour operated (*grey background*)**. These indicators are more representative as they can help identify the vehicle types which are the costliest to operate, to strategically optimize the fleet.

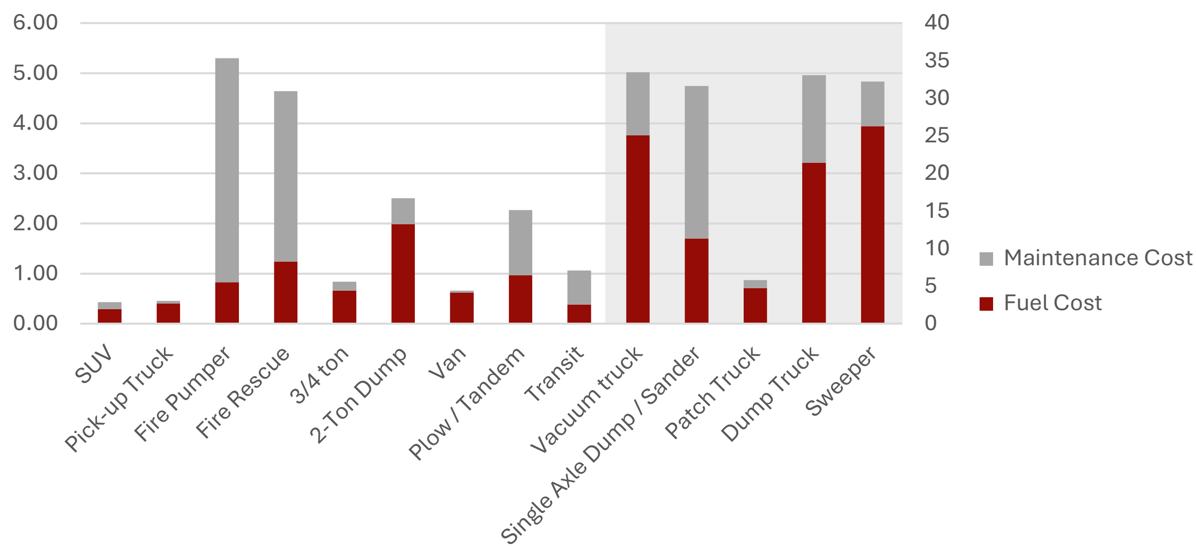

Figure 3-6 Operational Cost per Utilization

SUVs and pick-up trucks are relatively cost-effective to operate compared to other vehicle types listed. As expected, medium-duty pick-up trucks and heavier vehicles tend to have a higher operational cost per km travelled (2.39 $/km or 27.23$/H on average). Fire pumper and fire rescue present the highest operational cost on a kilometre basis (4.97 $/km, on average), due to the nature of their operation and the preferred metering unit (kilometres) not accounting for idle times. Additionally, routine and planned maintenance are still required to ensure viable operation, even when the asset is not the most utilized. This demonstrates that optimizing the number of vehicles to better respond to their actual operational needs could be financially beneficial and would allow the City to efficiently use the entirety of its corporate fleet.

4 TECHNOLOGIES OVERVIEW

The City of Temiskaming Shores is exploring alternative fuels that support corporate direction toward a Zero-Emissions Fleet. Zero emissions technologies as well as low-emission technologies have been considered to provide the City with the most cost-effective and operationally viable strategy. The ensuing section provides an overview of the different technologies considered.

4.1 ZERO EMISSIONS TECHNOLOGIES

Zero-emission technologies are sourcing energy from fuel, or technologies, which emit no waste products that are harmful to the environment. These technologies are the most impactful when it comes to reducing corporate GHG emissions.

4.1.1 BATTERY ELECTRIC VEHICLES

Battery electric vehicles (BEVs) are powered by motors that draw electricity from on-board storage batteries. BEVs do not produce tailpipe emissions, which means they can reduce direct GHG emissions and other air pollutants. If the source of electricity is clean (such as solar or hydroelectric power) the vehicle will have minimal lifetime GHG emissions. The scope of this analysis is centred around tailpipe emissions, allowing the classification of battery electric vehicles as zero-emission alternatives.

Battery-electric vehicles also typically require less maintenance than internal combustion engine vehicles due to their:

- Battery electric motor, which requires little to no regular maintenance
- Reduced need for engine oil and other fluids that require maintenance
- Brake wear is significantly reduced due to regenerative braking
- Fewer moving parts compared to a fuel engine

While battery technology is constantly improving year over year, and comprehensive battery data is not yet available, many manufacturers offer 8-year or 160,000km warranties for their batteries for major failure. However, similar to most batteries, electric vehicle batteries will degrade over time as they have a limited number of charging cycles (number of times a battery can be charged and discharged).

Most batteries are designed for durability and will outlast the usable life of a vehicle, only losing about 2 to 3% capacity each year. When a battery degrades, it affects the battery's state of health usually going from a 100% state of health to a lower percentage. At the end of its useful life, the state of health of the battery may have deteriorated to the point where the electric vehicle may be better suited to shorter-distance operations. Where needed, a battery replacement may occur. While the cost of the battery replacement can vary greatly depending on the size of the battery pack, it can be expected to cost between 20% to 60% of the vehicle's retail price[11]. In some instances, some battery replacements require large investments, one example would be the battery replacement of a Ford E-Transit Cargo Van, with an expected replacement cost of CAD $48,000. Some of these batteries, the pack for the Ford e-Transit, for instance, are made of multiple separated modules. While replacing these separated modules would be a cost-effective solution, the separated modules are often not available through original manufacturers (as of 2024), but innovation and development in this specific field will contribute to the availability of

[11] Cost derived from https://mygarageairdrie.ca/from-an-ev-mechanic-what-does-it-truly-cost-to-replace-an-electric-vehicle-battery/, and compared to the battery size and MSRP price from the market scan.

these modules in the future. It is also important to note that the price of the batteries is rapidly declining. Since 2010, the price of an average Lithium-ion battery pack has decreased by over 80%.[12]

4.1.2 HYDROGEN FUEL CELL VEHICLES

Hydrogen fuel cell vehicles are vehicles that use hydrogen gas as a fuel to generate electricity through a chemical process. The electricity generated is then used to power an electric motor, which propels the vehicle. Hydrogen can be produced through various methods and is stored directly in the vehicle. Hydrogen, when combined with oxygen in a fuel cell, undergoes an electrochemical reaction to produce electricity, emitting only water vapour as a byproduct. This makes hydrogen used in fuel cells a zero-emission process, contributing to improved air quality and reduced greenhouse gas emissions.

Various Methods of Hydrogen Production

- **Grey hydrogen:** is the most common form and is generated from fossil fuels, it is generated from natural gas or methane through a process called "steam methane reforming". SMR involves reacting natural gas to produce hydrogen gas and carbon dioxide.
- **Blue Hydrogen:** is labeled blue whenever the carbon generated from steam reforming is captured and stored underground through industrial carbon capture and storage (CSS). Blue hydrogen is, therefore, sometimes referred to as carbon neutral as the emissions are not dispersed in the atmosphere.
- **Green hydrogen:** is produced by using clean energy from surplus renewable energy sources, such as solar, hydro, or wind power used to split water into hydrogen and oxygen through a process called electrolysis. It currently makes up about 0.1% of overall hydrogen production, but this is expected to rise as the cost of renewable energy continues to fall.

Hydrogen can be produced from a range of resources including fossil fuels, nuclear energy, biomass, and renewable energy sources. The production of hydrogen through fossil fuels is considered "grey hydrogen" – "blue hydrogen[13]" if the carbon generated is captured – while production from renewable sources is called "green hydrogen". The transition to a hydrogen municipal fleet could potentially lead to financial savings due to economies of scale for large fleets. FCEVs offer a comparative advantage in terms of fuel efficiency when compared to ICE vehicles. FCEVs utilize an electrochemical process to convert hydrogen into electricity, which powers the vehicle's electric motor. This process results in a higher energy conversion efficiency compared to the combustion process in traditional ICE vehicles. ICE vehicles burn fuel (gasoline or diesel) to generate power, with a considerable amount of energy lost as waste heat. In contrast, FCEVs generate electricity through the chemical reaction between hydrogen and oxygen, producing only water vapor as a byproduct. Additionally, FCEVs out-perform battery-electric vehicles under cold temperature[14]. The performance of battery-electric and hydrogen fuel cell vehicles can vary greatly in sub-freezing temperatures. A study compared the two technology under cold temperatures and found that BEV's efficiency reduced by 32.1% and range reduced by 37.8%, while FCEV performed better, with 28.6% efficiency drop and a range decrease of 23.1%[15].

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[12] A Behind the Scenes Take on Lithium-ion Battery Prices | BloombergNEF

[13] Greenhouse gas emissions from the production of blue hydrogen can sometimes be quite high, particularly due to the release of fugitive methane from the increased use of natural gas to power the carbon capture. Note that blue hydrogen can be considered carbon neutral if all the emissions are captured.
R. W. Howarth, M. Z. Jacobson, "How green is blue hydrogen?", *Energy, Science & Engineering*, vol. 9, no. 10, pp. 1676-1687. [Online] Available: https://doi.org/10.1002/ese3.956

[14] North American Clean Energy - Running Hot and Cold: Hydrogen fuel cells pass the test

[15] The study focused on bus technology, measuring their performance when from ambient temperatures of 50-60°F to 22-32°F.
Mark Henning, Andrew R. Thomas and Alison Smyth. "An Analysis of the Association between Changes in Ambient Temperature, Fuel Economy, and Vehicle Range for Battery Electric and Fuel Cell Electric Buses", Cleveland State University. November 2019. Available: https://img.fuelcellsworks.com/wp-content/uploads/2020/01/An-Analysis-of-the-Association-between-Changes-in-Ambient-Tempera.pdf

4.2 LOW EMISSIONS TECHNOLOGIES

Low emissions technologies are sourcing energy from fossil fuel that still emits products harmful to the environment.

4.2.1 *NATURAL GAS*

Natural gas is used as an alternative fuel primarily in heavy-duty applications such as trucking, municipal waste collection, and transit. It is transported and distributed through an established network of pipelines and tanker trucks operated by utility companies. Canada is the fifth largest producer of natural gas globally, which supports its domestic availability in the near term[16].

In terms of cost, Natural Gas, particularly Compressed Natural Gas (CNG), has generally been less expensive than gasoline and diesel over the past decade, with price differences occasionally exceeding 60%.[17]

Conventional natural gas is extracted from underground rock and shale formations. Renewable Natural Gas (RNG), a lower-carbon alternative, can also be produced from sources such as landfills and wastewater treatment plants, reducing reliance on fossil-based production.

Both CNG and RNG vehicles operate similarly to gasoline-powered vehicles, using spark-ignited engines to generate power. While natural gas vehicles can reduce certain tailpipe emissions, the overall environmental benefit depends on lifecycle emissions, including methane released during production, distribution, and use. Careful accounting of additional gas emissions, such as methane, is necessary to accurately assess the environmental impact of CNG technology[18].

An example of RNG integration in fleet operations can be found in the City of Surrey, BC, where CNG and dual-fuel vehicles are used. The City's Biofuel Facility produces RNG from organic waste, which is used to fuel its collection vehicles.

4.2.2 *BIODIESEL*

Biodiesel, a special type of renewable diesel fuel, is manufactured through the transesterification process, which converts vegetable oils, animal fats, and recycled restaurant grease into a sustainable energy source.

This fuel can be blended and used in varying concentrations, denoted by nomenclature such as B5, B10, B20, indicating the percentage of biodiesel in the blend. Transesterification involves a reaction between the oil (or animal fat), an alcohol, and a catalyst. When creating biodiesel blends, pure biodiesel (B100) is combined with petroleum diesel. Among the most common blends are B5, containing up to 5% biodiesel, and B20[19].

However, it is important to consider certain concerns associated with higher concentrations of biodiesel (above B5), particularly during winter months, as filter plugging in cold weather can be a performance issue. This concern can be mitigated by using lower blends, such as B5, or incorporating fuel additives. Additionally, higher blends are typically not compatible with current engines – the usage of high-blends biodiesel could void the warranty.

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[16] Government Of Canada, https://natural-resources.canada.ca/energy/energy-sources-distribution/natural-gas/5639
[17] US. Department of Energy, https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_january_2022.pdf
[18] Rodriguez et al., https://theicct.org/lng-trucks-a-bridge-to-nowhere/
[19] U.S. Department of Energy, https://afdc.energy.gov/fuels/biodiesel_blends.html

In Canada, biodiesel is produced using agro-industry residues, with the country hosting 12 biodiesel plants boasting a combined production capacity of 912 million litres[20]. Natural Resources Canada (NRCan) references the BQ-9000 certified list of producers and marketers in North America, ensuring high standards of biodiesel processing.

The distribution of biodiesel occurs through various means, including truck, train, or barge transportation from the production point to fuel terminals and wholesalers. In some cases, lower blend B5 is even shipped through pipelines, showcasing the versatility of its distribution methods.

It is worth noting that biodiesel may come at a slightly higher cost compared to regular diesel. According to the US Department of Energy, there can be an incremental cost of 20 cents per gallon for B20 fuel, representing approximately an 8% premium when compared to conventional fossil fuel.

4.2.3 RENEWABLE DIESEL

Renewable diesel (RD), derived from similar sources as biodiesel, offers comparable reductions in greenhouse gas emissions. The key distinction lies in the chemical process used to produce the fuel. Renewable diesel undergoes processing that aligns it more closely with conventional diesel and adheres to the ASTM D975 standard for petroleum fuels.

When renewable diesel is blended with 5% biodiesel, it is referred to as R5. Various technology pathways can be employed to produce renewable diesel, with the hydrotreating pathway being the predominant method in commercial production facilities. Fats, oils, and greases serve as the most common feedstocks in this process[21].

While the chemical process to create RD is different than the one to create Biodiesel, the feedstocks are the same. Renewable Diesel is similar in composition to petroleum diesel, characterized largely by saturated straight-chain hydrocarbons, allowing for this fuel to be a transitional option requiring minor operational changes. However, one of the main challenges is its availability. The EIA (U.S. Energy Information Administration) projects that renewable diesel will only make up about 5% of the U.S. diesel capacity production by 2024[22]. Production of renewable diesel is expanding, but it is still outpaced by its fossil fuel counterparts.

The significant advantage of renewable diesel is its capacity to be used in higher concentrations, enabling it to directly replace conventional diesel without encountering major compatibility issues with existing engines. Furthermore, concerns regarding cold weather performance, which can be a limitation with higher blend biodiesel fuels, are largely mitigated with renewable diesel.

However, it is important to note that renewable diesel is not currently as readily available in the commercial market in Canada as biodiesel. Nonetheless, there has been recent interest and investment from the Canadian government to expand the production of renewable diesel, signaling promising developments in this field.

4.2.4 HYDROGEN-DIESEL DUAL FUEL (H2DF)

Hydrogen-Diesel Dual Fuel (H2DF) represents a blend of hydrogen and diesel fuel, used to power internal combustion engines. This technology serves as a transitional solution, facilitating the gradual integration of hydrogen into existing diesel infrastructure, encompassing vehicles and fueling stations. Notably,

[20] United States Department of Agriculture – Foreign Agricultural Service, DownloadReportByFileName
[21] US. Department of Energy, https://afdc.energy.gov/fuels/renewable_diesel.html
[22] Energy Transition Deep Dive: Top 6 Challenges Renewable Diesel Producers Face

H2DF enables fleet owners to transition away from high-carbon intensity regular diesel without necessitating extensive infrastructure refurbishment.

An advantage of H2DF lies in its ability to serve as a stepping stone towards full hydrogen fuel cell vehicles. By fostering the development of hydrogen infrastructure and driving demand for hydrogen production, H2DF plays a pivotal role in paving the way for a hydrogen-powered future.

However, it is essential to acknowledge some challenges associated with this technology. Firstly, the integration of hydrogen storage tanks within vehicles requires additional space, resulting in a reduction in payload capacity, although not by a significant amount.

Moreover, as with other hydrogen-powered drivetrains, the limited availability of transport and distribution facilities poses a significant hurdle. The establishment of an extensive and efficient hydrogen delivery network remains a crucial objective for widespread adoption.

Furthermore, while H2DF exhibits lower carbon intensity compared to diesel[23], it is important to note that the emissions factor is anticipated to remain within the realm of business-as-usual technologies. Continued efforts are required to optimize the emissions profile and further enhance the environmental benefits of H2DF. Additionally, while a higher hydrogen blend reduces further the CO2 and CO gaseous emissions, it is being observed that there is an emissions increase in other unburnt hydrocarbons and nitrogen oxides[24].

Despite these challenges, H2DF presents an opportunity for fleet operators seeking a cleaner alternative to traditional diesel, acting as a bridge towards a hydrogen-powered future.

4.3 TECHNOLOGY MATURITY ASSESSMENT

The high-level comparative table below shows short-term (< 5 years), medium-term (5 to 10 years) and long-term (10+ years) maturity/availability of low-carbon fleet vehicles and equipment, the maturity of low-carbon fleet vehicles and equipment will depend on the availability of the fuel type and the adoption of the technology in the market.

[23] "An improvement of 23.4% to 38.7% with 50% [blend of] hydrogen", according to Karagoz et al. 2016, "Effect of hydrogen–diesel dual-fuel usage on performance, emissions and diesel combustion in diesel engines", See https://journals.sagepub.com/doi/10.1177/1687814016664458

[24] Karagoz et al. 2016, "Effect of hydrogen–diesel dual-fuel usage on performance, emissions and diesel combustion in diesel engines", See https://journals.sagepub.com/doi/10.1177/1687814016664458

Table 4-1 Alternative Fuels Vehicles Maturity Assessment

TECHNOLOGY / FUEL	NOTES ON MATURITY ASSESSMENT	SHORT TERM (< 5 YEARS)	MEDIUM TERM (5 TO 10 YEARS)	LONG TERM (10+ YEARS)
Natural Gas	• Mature technology with the City of Surrey having a large number of CNG and dual fuel CNG/gasoline vehicles. • CNG is still a fossil fuel source and should ultimately be targeted for reduced usage over the long term. However, RNG can present a stronger case for longer-term use due to lower emissions factor. RNG is still not a true long-term solution as it still produces emissions.	✓	✓	
Biodiesel	• Currently viable as an alternative low-carbon fuel substitute for diesel vehicles/equipment, up to 20% blends. • Can be an interim approach to reducing emissions from diesel fuel use.	✓	✓	
Renewable Diesel	• Currently viable as an alternative low-carbon fuel substitute for diesel vehicles/equipment. However, the commercial scale of fuel production and availability still needs to improve. • Can be an interim approach to reducing emissions for diesel fuel use and considered over the longer term for select vehicles/equipment where other zero-emission alternatives do not emerge. Not a true long-term solution as it still produces emissions.	✓	✓	
Hybrid (light-duty vehicles)	• Mature technology and market for various types of light-duty vehicles (i.e. cars, SUVs, vans and pickups). • Can be a very good bridge to begin the transition to battery electric vehicles as near term concerns on range and charging can be addressed.	✓	✓	
Hybrid (Heavy-duty vehicles)	• Limited number of medium-heavy (Class 4,5, and 6) and heavy-duty hybrid battery electric vehicles in Canada. The reason is that OEMs have focused on developing CNG and CNG Biofuel alternatives[25] for these segments.	✓	✓	
Electric (light-duty vehicles)	• A rapidly maturing market for several types of light-duty vehicles (i.e. cars, SUVs, vans and pickups). • Battery electric technology has momentum as the preferred zero-emissions technology with a strong effort into policy, research and development.	✓	✓	✓

[25] U.S. D.O.E Alternative Fuel And Advance Vehicle Search, Alternative Fuels Data Center: Vehicle Search

Electric (heavy-duty vehicles)	• Limited number of heavy-duty full-battery electric vehicles in Canada. However, this is a rapidly emerging market sector with lots of research and development activity along with investment (i.e. Government of Canada's investment in Lion Electric plant in Quebec). • Battery electric technology is gaining momentum as the preferred zero emission technologies for heavy-duty vehicles, along with hydrogen fuel cell vehicles for some applications (i.e. longer distance transportation).	✓	✓	✓
Electric (heavy equipment)	• Limited number of heavy equipment models available in North America. Manufacturers are still early in the development and trial stage with a small number of assets in operation. • Can become a viable alternative to diesel for some types of heavy equipment in the medium/long term once more pilots and testing have been established.		✓	✓
Hydrogen	• Limited number of passenger vehicles currently available in Canada. Available fueling infrastructure, production of true renewable green hydrogen and the high purchase price of vehicles are barriers to adoption. • There are ongoing programs and trials for hydrogen vehicles in the heavy-duty sector (i.e. AZETC pilot in Alberta) to progress this technology. • May become a viable alternative in the medium/long term if vehicle price points, green hydrogen availability and infrastructure all continue to improve.			✓

5 TRANSITION SCENARIOS

The City of Temiskaming Shores is seeking a long-term and fiscally responsible green fleet strategy. This Green Municipal Fleet Study will provide the City with a roadmap to reduce corporate emissions to reach its target of carbon neutrality by 2050, with the interim objectives of 40% reduction below 2019 levels by 2033. Battery electric technology would be the technology of choice City's operations due to its more extensive infrastructure, lower costs, and established technological maturity.

The green fleet strategy presents an agile replacement strategy with two horizons in mind. Given the rapid development of battery electric vehicles over the last few years, there is a degree of uncertainty about what will dominate the heavy-duty vehicle sector. A short and long-term agile approach allows the City to start transitioning its fleet in the near-term while having an eye on the future and preparing itself for long-term emissions reduction. This agile approach includes a periodic review (at least every five years or budget cycle) of the zero-emissions vehicle technology readiness and market position to adapt the strategy to what is available at the time of inquiry.

This approach can be visualized in Figure 5-1.

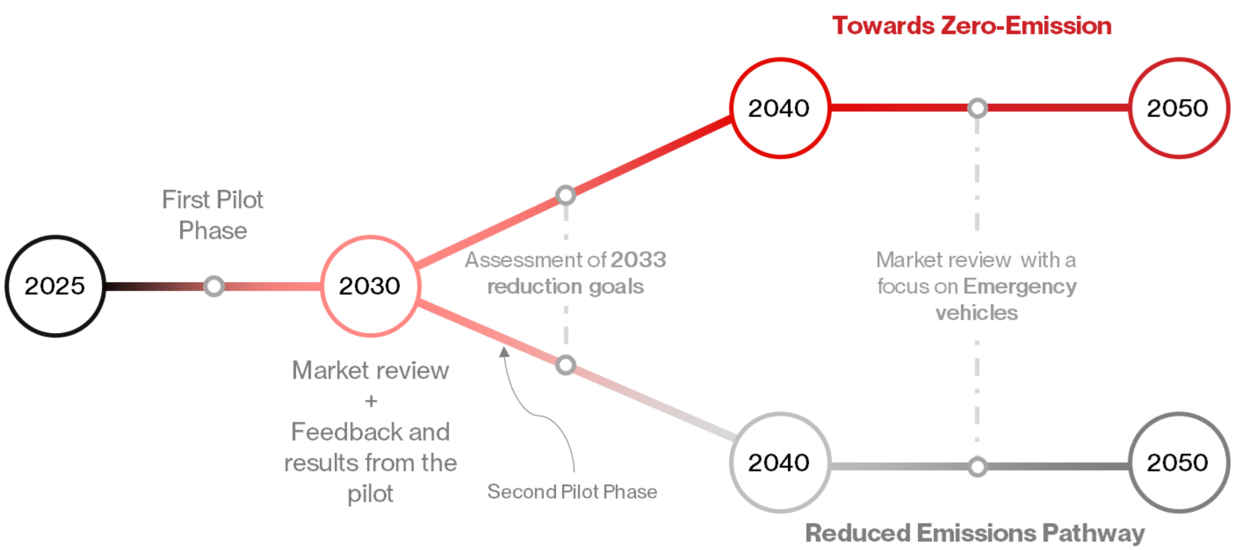

Figure 5-1 Approach to the Green Fleet Transition

5.1 DESCRIPTION OF THE PATHWAYS

FIRST PILOT PHASE

The proposed approach to the transition allows for a pilot period for the short-term (2025-2030). This project phase would be ideal to begin the electrification of the municipal fleet, while focusing initially on rentals and the most accessible opportunities for transition (light-duty vehicles). This period will allow the City to build foundational experience with battery electric technologies, optimize operational practices, and evaluate real-world performance in municipal operations. By targeting vehicles that are easier to convert and leveraging temporary or rental arrangements, the City can minimize upfront risks while laying the groundwork for broader electrification in subsequent phases.

REDUCED EMISSIONS PATHWAY

The Reduced Emissions Pathway spans across a medium- to long-term period (2030-2050), as this pathway could be followed until 2050, leveraging only today's existing technologies. While this path will not allow for a zero-emissions fleet by 2050, it is expected to reduce fleet emissions. This pathway could also be considered as the "worst-case scenario", in the event the technology development does not advance as expected. The conditions for the selection of the assets under this path are:

1. **Market option requirement** – The assets to be replaced should have an equivalent BEV option currently in the market. Market review (conducted in 2030 and 2045) should provide information to the commercial availability of the technology.
2. **Range requirement** – The BEV technology selection should have a battery capacity that could support the required daily needs before returning to base for recharging. This energy requirement also accounts for the energy-intensive operation during winter that could reduce the effective energy capacity ("range"). This range reduction could be by as much as 46%.
3. **Energy supply chain requirement** – The energy supply chain should be reliable from generation, transport, distribution and refuelling. Currently, from the electric network and utilities to the electric vehicle supply equipment, the refueling infrastructure for battery electric vehicles does not pose major challenges for the adoption of this technology.

TOWARDS ZERO-EMISSION

The Towards Zero-Emission presents an optimistic pathway, assuming technological advancement and adoption of this technology. This path presents a medium- to long-term (2030-2050) strategy, with a pivotal market availability review in 2030, in order to confirm that the assets suggested as potentially available (based on current market research projections) are indeed commercially available by that year.

The assets to transition include those that meet the conditions listed above for the Reduced Emissions Pathway. Moreover, to maximize the size of the fleet to transition to the Towards Zero-Emission path consider the following conditions:

4. **Advanced market option requirement** – In addition to the equivalent BEV options with current market availability, this pathway considers good technology development. It is important to note that the recommended 2030 market scan is intended to identify the recent development in market availability so that it can be confirmed as part of the transition. If it is not available at the time of the 2030 update review, the City should follow the Reduced Emissions Pathway for this asset.
5. **Advanced range requirement** – The projected reduction in electric vehicle (EV) range loss has been adjusted from 46%, as initially assumed in the Reduced Emissions Pathway, to 75%. This adjustment aligns with the recognized battery degradation ratio observed at the end of batteries' life in transportation applications, along with a recommended buffer for optimal operation of lithium-ion batteries[26]. This adaptation is grounded in the expectation of a gradual integration of services and operations with the newly adopted technologies. In this scenario, it is anticipated that, following technology testing and piloting by the City, the utilization of battery electric vehicles (BEVs) will improve over time. This improvement is envisioned through operator training initiatives (e.g., enhancing driving and operational habits) and service schedules designed to accommodate battery capacities and constraints (e.g., battery preheating, and trip planning)[27]. These enhancements are anticipated to contribute to a reduction in future energy losses.

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[26] Geotab, What 6,000 EV batteries tell us about EV battery health, https://www.geotab.com/blog/ev-battery-health/
[27] Electric Autonomy Canada, Operating EVs in Winter, https://evfleets.electricautonomy.ca/topics/operating-evs-in-winter/

5.2 TECHNOLOGY UPTAKE RATE

The anticipated zero-emission uptake rate (or "purchase rate") is used to define the rate at which an internal combustion vehicle is replaced by a zero-emissions vehicle. This uptake rate can be seen in the form of a percentage, meaning the percentage of vehicles that will be replaced by a zero-emissions vehicle compared to internal combustion vehicles, for that specific year. The ZE uptake rate reflects the typical gradual increase of zero-emissions vehicles with increasing adoption as the vehicles reach cost parity between the ZE and ICE technologies. The uptake rate for each vehicle class is based on the exponential-like (logistic) behaviour referred to in the literature as the diffusion model or S-curve[28]. This mathematical model[29] is intended to simulate the behaviour of any new technology adoption, which typically includes:

1. **Innovators and early adopters** – an early slow adoption during which the technology is studied, and practices are restructured to adapt to the new conditions.
2. **Early and late majority** – a continuous and constant uptake as the technology and its implications become known.
3. **Laggards** – the slow process trending to full dependence on the new technology.

As seen in the adoption curves in the following sections, it is assumed that there will be a majority adoption at the time at which cost parity to BAU technologies is reached.

5.2.1 COST CONSIDERATIONS

The uptake rates are consistent with the expected year in which the zero-emissions vehicle technologies are expected to reach cost parity to their ICE counterparts. The cost-parity year is defined as the year in which a ZEV technology's total cost of ownership (TCO) equals the TCO of the ICE technologies within the market. Table 5-1 summarizes the assumptions for cost-parity for the different vehicle categories and technologies considered within this Green Fleet Strategy.

There is a higher degree of certainty regarding the light-duty vehicle sector due to the federal mandate for all light-duty vehicle sales to be electric by 2035 (and 60% by 2030). This proposed regulation allows for better clarity of vehicle availability, as it will require auto manufacturers to invest in this technology and ensure that there are sufficient light-duty electric vehicles within Canada to meet the needs of its population.

[28] Beal, George M. Bohlen, Joe M.; The Diffusion Process, 1956, https://ageconsearch.umn.edu/record/17351

[29] To set-up the uptake model, it is required to define: 1) two points in time, and 2) two expected adoption rates at these times.

Table 5-1 Cost Parity Assumptions

ASSET CATEGORY	YEAR OF COST PARITY	SOURCE
Light Duty Vehicle	2032	ICCT – see note 30
Medium Duty Vehicle	2035	ICCT, NREL – see notes 32 and 33
Heavy Duty Vehicle	2035	ICCT, NREL – see notes 32 and 33
Emergency Vehicle	2035	Assumed to follow the trend for Heavy Duty Vehicles, but pushed further to ensure resiliency for safety operations
Transit	2035	Assumed to follow the trend of a mix of Medium Duty and Heavy Duty Vehicles

5.2.2 VEHICLE UPTAKE RATE

As presented in Table 2-1, **light-duty vehicles** include SUVs, light-duty pick up trucks and cargo vans. The uptake rate has been updated to reflect the current electrification market of light-duty. Additionally, all segments of the LDV market are expected to reach cost parity with ICE technologies in 2032[30].

The **medium-duty vehicle** fleet includes larger pick-up trucks, while the **heavy-duty vehicle** fleet includes heavier vehicles. It has been assumed that the uptake rates for the MDV segment will be earlier than the adoption of electric HDV, due to the strong presence of electric cargo vans on the market and the pressing need for decarbonization of urban operations[31]. A slower adoption of heavy-duty zero-emissions vehicles has multiple benefits. Firstly, the deferred adoption will allow the technology to improve over the next couple of years and become more established in the market, by the time of the asset replacement. Secondly, the deferred adoption will provide time for the City to implement a pilot trial to test and plan deployments prior to expanding its zero-emissions fleet. Thirdly, by the time the City is ready to start purchasing a large number of zero-emissions vehicles to reach its targets, a market review and analysis update prior to investing in the technology will have been completed.

As reported by the ICCT and the National Laboratory on Renewable Energy (NREL), the battery electric MDV and HDV technology for urban applications (typically characterized by shorter distances with multiple stops) may reach a significant share in the Canadian market between 2030 and 2035, with cost parity to diesel assumed to be reached after 2035[32,33]. As presented in the Figure 5-2, the purchases of zero-emissions heavy-duty vehicles will start much later than light-duty-vehicles. The analysis assumes

[30] International Council on Clean Transportation (ICCT), Assessment Of Light-Duty Electric Vehicle Costs And Consumer Benefits In The United States In The 2022–2035 Time Frame, See https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035- oct22.pdf

[31] NREL, Spatial and Temporal Analysis of the Total Cost of Ownership for class 8 Tractors and class 4 Parcel Delivery Trucks, https://www.nrel.gov/docs/fy21osti/71796.pdf

[32] ICCT, Heavy-Duty Zero-Emission Vehicles: Pace and Opportunities For a Rapid Global Transition https://theicct.org/publication/hdv-zevtc-global-may22/

[33] NREL, Decarbonizing Medium- & Heavy-Duty On-Road Vehicles: Zero-Emission Vehicles Cost Analysis, https://www.nrel.gov/docs/fy22osti/82081.pdf

that the City will start to purchase a few electric vehicles in between 2030 and 2033, piloting the technology for a few years, before accelerating its BEV purchases in 2034.

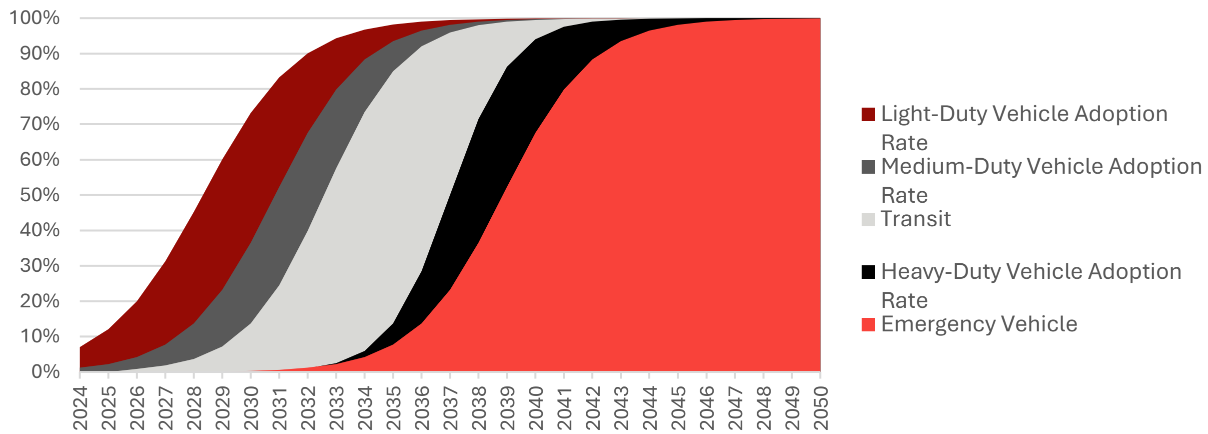

Figure 5-2 Vehicles Technology Uptake Rate

6 GREEN FLEET STRATEGY

The Green Fleet Strategy presents an agile roadmap in which the City can start to adopt known technologies while monitoring emerging vehicle technology developments.

As presented in Section 5, the strategy is designed with two pathways due to vehicle technology market readiness, technology adoption and availability. This approach will allow the City to financially plan ahead to reduce its corporate fleet-associated GHG emissions by 2050.

The ensuing section covers the GHG reduction and cost benefits of each pathway.

- The short-term foreseeable feasible pathway that could be followed from 2025 onwards based on what is currently available in the market today is referred as the **Reduced Emissions Path.**
- The potential pathway that could lead to a zero emissions fleet, should a market review in 2030 successfully reveal improvements and market share growth of ZEV technologies is referred as the **Zero Emissions Path**.

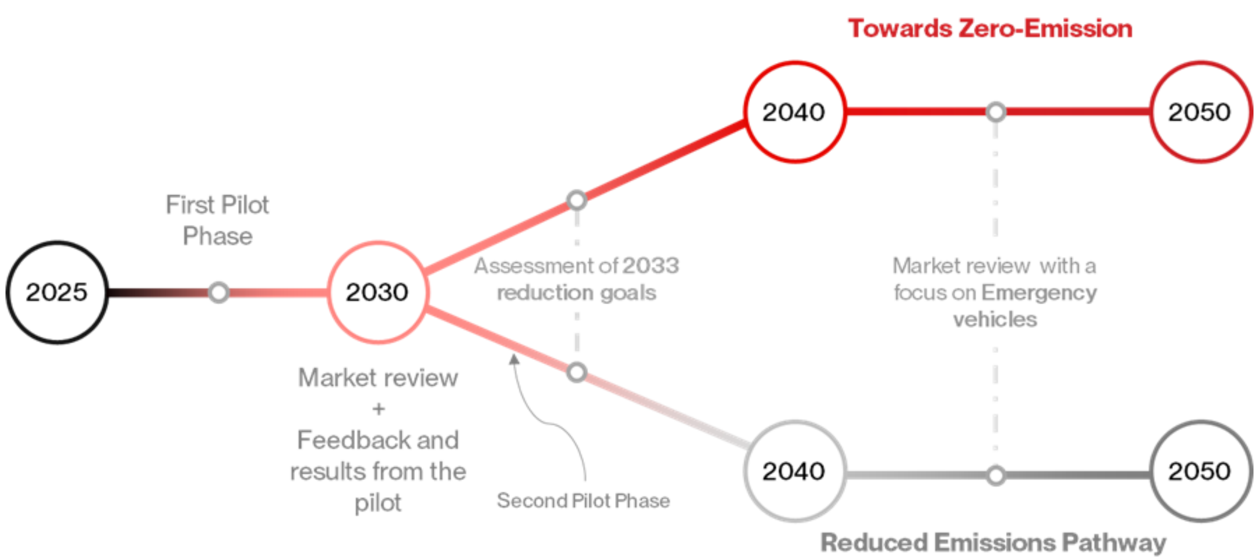

Figure 6-1 Green Fleet Strategy to 2050

Table 6-1 Key Statistics for the Two Pathways

	REDUCED EMISSIONS PATH	ZERO EMISSIONS PATH
Count of electric assets in the fleet	27 (52% of the fleet)	49 (94% of the fleet)
Total GHG Emission (2024-2050)	15,318 tCO_2e	9,281 tCO_2e
Total GHG Emission Reduction	***6,112 tCO_2e***	***12,149 tCO_2e***
Total Cost of Ownership (2024-2050)	**$M 46.88**	**$M 42.12**
Total Costs Savings to 2050 (million)	***$5.07***	***$9.84***

6.1 REDUCED EMISSIONS PATH

As established in Section 5, the Reduced Emissions path is characterized by:

4 Only assets for which there is a ZEV option that is commercially available or currently being piloted will be considered for transition.

5 The ZEV technology of choice should have a reliable energy supply chain.

Battery electric is the technology of choice for the Reduced Emissions pathway. The following sections present the findings on the implementation of this path.

6.1.1 REPLACEMENT PLAN

The purchase plan is illustrated in Figure 6-2. This plan reflects the replacement cycles expected, following the end-of-useful life previously dictated by the City. It has been assumed that useful life remains constant, independently of the technology.

The BEV technology share shown in the purchase plan reflects the technology transition marked by the uptake rates for each vehicle category as described previously. The annual purchase plan presents the count of assets purchased on a yearly basis, for both internal combustion vehicles (indicated in grey) and battery electric vehicles.

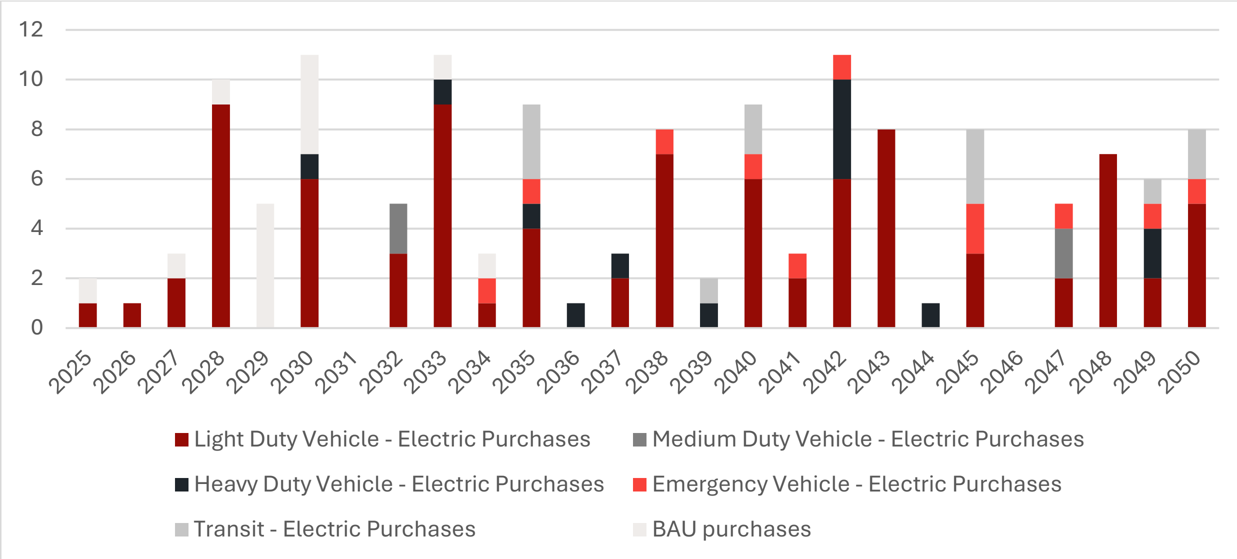

Figure 6-2 Purchase Plan per Year - Reduced Emissions Pathway

6.1.2 *FLEET STOCK*

Based on this purchase plan, Figure 6-3 shows the yearly total fleet stock share with regard to zero-emissions and internal combustion vehicles. It illustrates the diminishing number of ICE vehicle shares over time, eventually transitioning the City's asset stock to a battery electric share of 50% by 2050, with the majority of zero-emissions assets being light duty vehicles. Following this pathway, the City's corporate asset stock would be approximately 50% electrified by 2041.

Of the 50% assets expected to be electric by 2050, 81% (21 assets) are light duty vehicles, 8% (2 assets) are medium duty vehicles, 4% (1 asset) are heavy duty vehicles, and 8% (2 assets) are pick-up trucks from the Fire Department (Emergency Vehicles).

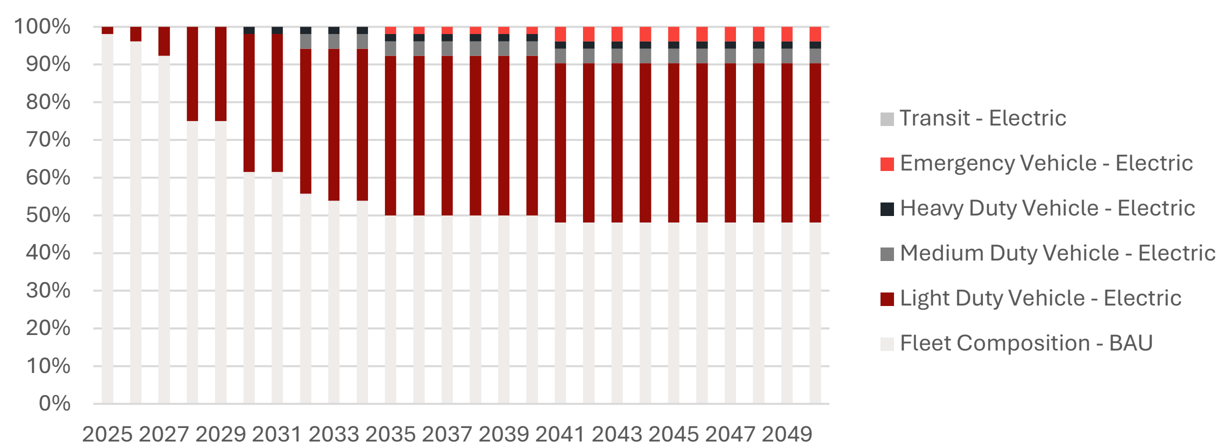

Figure 6-3 Yearly Fleet Make-up - Reduced Emissions Pathway

6.1.3 *GHG EMISSIONS REDUCTIONS*

The tailpipe GHG emissions from the implementation of the Reduced Emissions path are shown in Figure 6-4. Vehicle fuel efficiency and the rate of improvement of fossil-fuel carbon intensity via the federal

Clean Fuel Regulations have been accounted for. It is important to note that BEVs are not shown in this figure, as they have zero tailpipe emissions. Therefore, only the vehicles remaining in the fleet that produce tailpipe emissions will be shown.

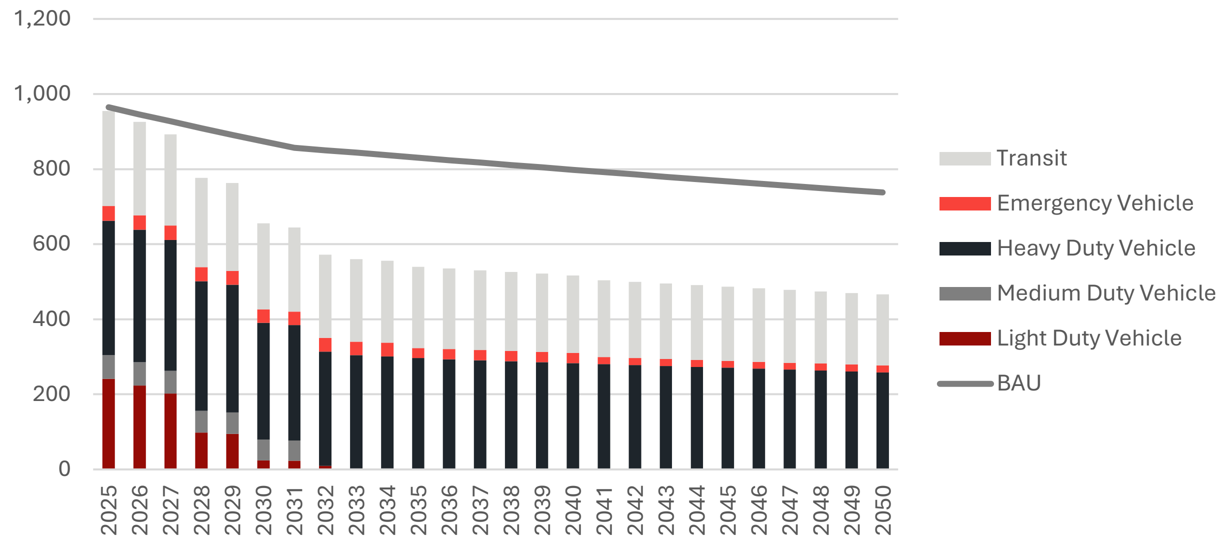

Figure 6-4 Yearly GHG Emissions - Reduced Emissions Pathway

The vehicle replacement plan, which consists primarily of light-duty vehicle replacement, will lead to GHG savings of approximately 37% compared to the expected business-as-usual 2050 emissions. Even if 50% of the assets are transitioned toward emission-neutral alternatives (i.e., electric), this pathway presents no alternatives for the most-emitting assets (heavy duty vehicles, accounting for 37% of the City's emissions). Transitioning heavy-duty vehicles and transit would have a higher impact on overall emissions, therefore only transitioning vehicles that are currently available today leads to conservative emissions reduction. This disproportional share of GHG emissions savings is due to the higher tailpipe emissions seen in heavier vehicles. When compared to the 2025 GHG emissions (965 tCO2e), the reduced emissions pathway will allow for a reduction of 51% of the emissions, in 2050.

6.1.4 CAPITAL INVESTMENTS

FLEET VEHICLES

Figure 6-5 provides a breakdown of the annual investment required under the reduced emissions path. The replacement costs for the BEV fleet are based on current ICE costs, BEV asset rate of change projections and a trend toward cost parity over time[34].

[34] U.S. DOE, 2022 Incremental Purchase Cost Methodology and Results for Clean Vehicles, https://www.energy.gov/sites/default/files/2022-12/2022.12.23%202022%20Incremental%20Purchase%20Cost%20Methodology%20and%20Results%20for%20Clean%20Vehicles.Pdf

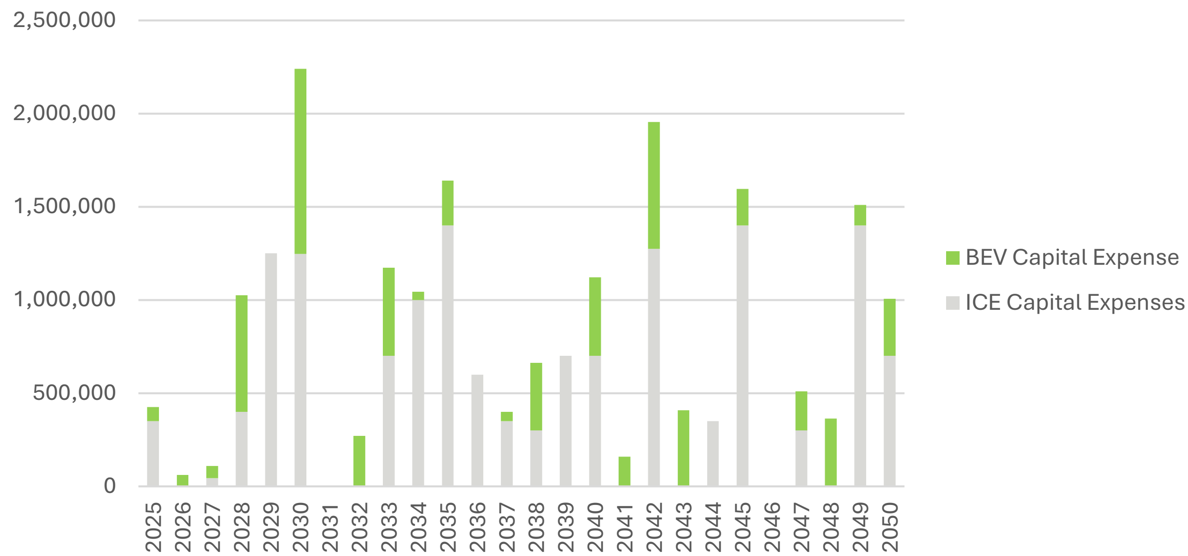

Figure 6-5 Yearly Capital Fleet Investment – Reduced Emissions Pathway

While the battery technology for the light-duty vehicle segments is the most significant driver of the transition between 2024 and 2030, the additional CAPEX per year is marginal for the fleet vehicles. The reason for this is that the current gap between the cost of an ICE vehicle compared to a BEV has been closing rapidly, and is assumed reach cost parity in the early 2030s.

CHARGING INFRASTRUCTURE

An analysis of the charging infrastructure needed to operate the electrical fleet was completed, based on the vehicles' estimated power requirements. An 8-hour charging window and a charging factor of 90% were assumed to ensure resiliency in the modelling.

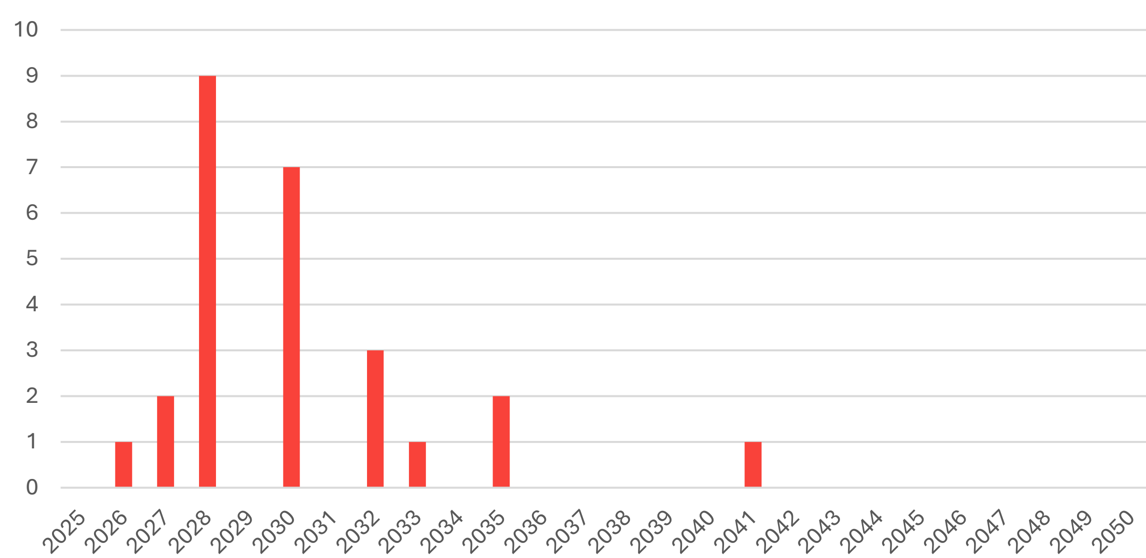

Figure 6-6 Count of New Charging Ports

Table 6-2 Total Capital expenses for chargers

CHARGING LEVEL	TOTAL CAPITAL EXPENSES
Level 2	$363,300.00
Level 3	-
TOTAL	**$363,300.00**

6.1.5 OPERATING COSTS

The operating costs include maintenance and fuel costs, which may be subject to change based on market conditions and technology evolution. The ensuing sections detail the findings on these costs and assume a continuation in the current operations.

FUEL AND ELECTRICITY COST

Based on electricity prices in Ontario, combined with the energy consumption of different electric alternatives, the fuel and electricity for the Reduced Emissions Pathway were approximated[35]. The fuel consumption and price are based on data from the current operations. Incremental growth of electricity and fossil fuels were factored in to present a realistic portrait of what can be expected.

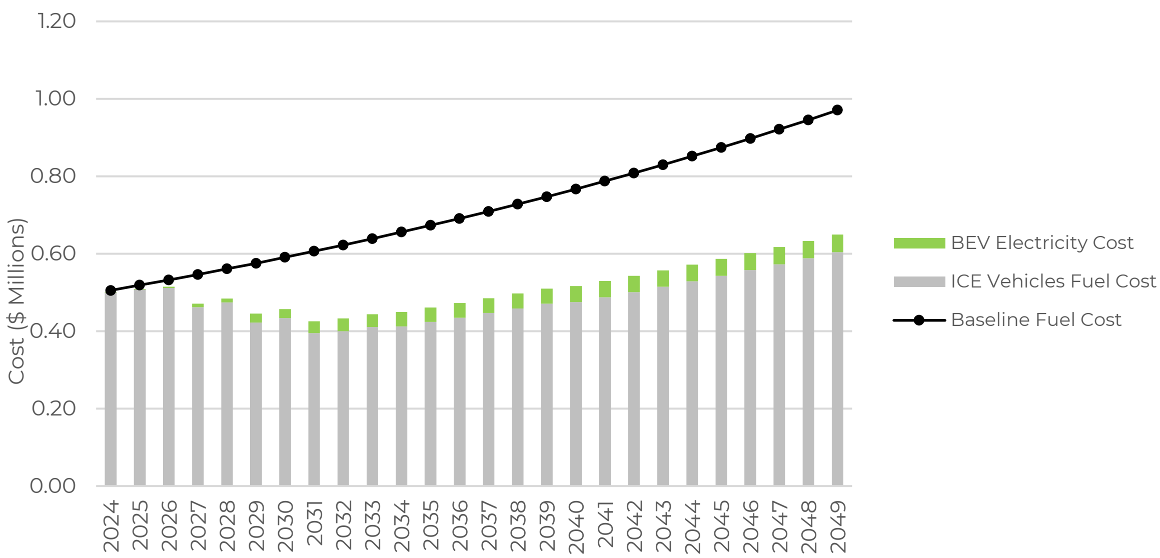

Figure 6-7 Asset Fuel and Electricity Cost by Year - Reduced Emissions Pathway

As presented in Figure 6-7, fuel costs are expected to increase until 2050. Replacing vehicles that consume a large amount of fuel would have the biggest impact on fuel costs. Transit and Heavy Duty Vehicles are not replaced by electric alternatives following this scenario, which explains the remaining fuel costs. By 2050, the reduced emissions pathway would lower total fuel and electricity costs by approximately 33%.

[35] The electricity price was assumed to be $0.15/kWh in 2024, with an annual escalation rate of 2% applied through 2050.

MAINTENANCE COST

Based on annual operational data provided by the City, yearly maintenance costs for individual assets were approximated, factoring in the asset type and age. This yearly maintenance cost can be used to forecast the financial impact of the aging fleet, combining it with the replacement plan and the transition of assets[36]. As shown in Figure 6-8, the maintenance costs reduce as more vehicles are replaced by battery electric vehicles. It is assumed that the maintenance cost is approximately 60% of the BAU maintenance cost per asset[37].

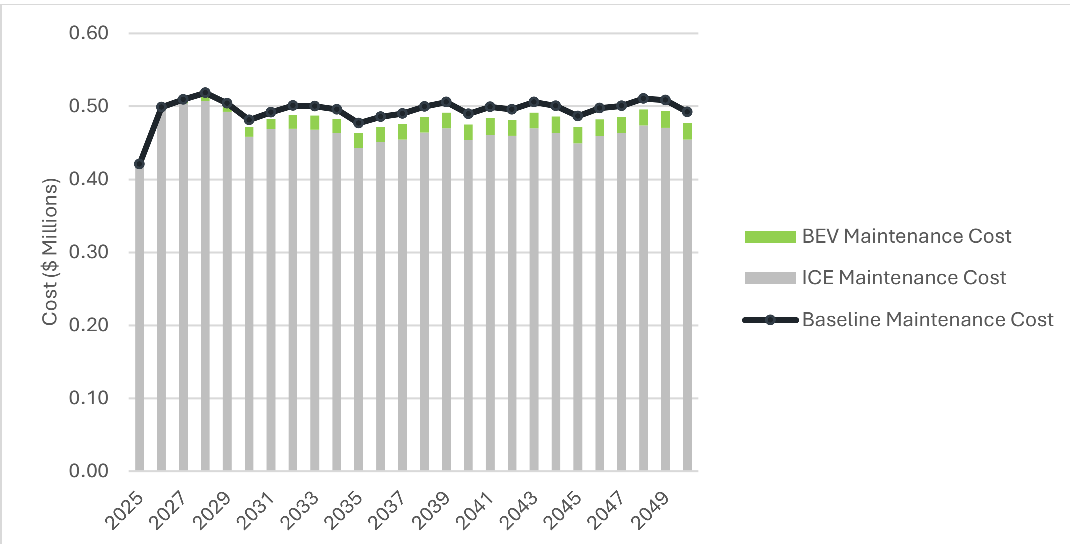

Figure 6-8 Asset Maintenance Cost by Year - Reduced Emissions Pathway

By 2050, the reduced emissions pathway would reduce total maintenance costs by approximately 4%. The maintenance cost savings are not significant, due to the majority of the transit vehicles, heavy-duty vehicles and heavy equipment (more maintenance-intensive assets) remaining ICE. Over the study period, the transition of the assets under the reduced emissions pathway could potentially help save over $300,000 in maintenance cost alone.

6.1.6 TOTAL COST OF OWNERSHIP

The total fleet capital expenses (CAPEX) and operating expenses (OPEX) from the Reduced Emissions Pathway are presented in Table 6-3. The net savings can be seen in the light duty fleets and the medium duty vehicles equipment where most of the replacements with BEV occur. The savings from the HDV and equipment portions of the fleet will be minimal as they have fewer zero-emissions vehicle replacements. However, upon a re-evaluation of the market in 2030, when migrating to the Zero Emissions path and

[36] To create a portrait of the impact of aging assets in the fleet, ratio (%) of cost increase on a kilometre basis from similar jurisdiction was used. This allowed to mitigate the lack of historical data on the maintenance costs and the development of a maintenance cost forecast, capturing the aging of the fleet.
[37] U.S. DOE, Battery-Electric Vehicles Have Lower Scheduled Maintenance Costs than Other Light-Duty Vehicles, https://www.energy.gov/eere/vehicles/articles/fotw-1190-june-14-2021-battery-electric-vehicles-have-lower-scheduled

more heavy-duty vehicles are replaced, greater savings might be expected as operational cost savings will increase the yield.

Table 6-3 Total Cost of Ownership - Reduced Emission Pathway

$MILLIONS	Light Duty Vehicles		Medium Duty Vehicles		Heavy Duty Vehicles		Emergency Vehicles		Transit		Fleet Total	
	BAU	Reduced Emission	BAU	Reduced Emission	BAU	Reduced Emission	BAU	Reduced Emission	BAU	Reduced Emission	BAU	Reduced Emission
CAPEX Fleet	4.73	4.91	0.32	0.33	6.35	6.58	3.18	3.18	5.60	5.60	**20.18**	**20.59**
Maintenance	0.60	0.38	0.22	0.15	4.61	4.47	1.45	1.42	6.34	6.14	**13.22**	**12.57**
Fuel and Electricity	4.94	0.96	1.19	0.29	6.79	6.36	0.84	0.61	4.80	4.80	**18.55**	**13.02**
CAPEX Infra		0.36		0.36		0.36		0.36		0.36	-	0.36
Peak Demand Charges		0.35		0.35		0.35		0.35		0.35	-	0.35
TOTAL	*10.27*	*6.96*	*1.74*	*1.49*	*17.74*	*18.12*	*5.47*	*5.91*	*16.73*	*17.25*	***51.95***	***46.88***

6.2 ZERO-EMISSIONS PATH

As established in Section 5, the Zero-Emissions path is characterized by an optimistic pathway, which is defined by:

1. The essential need for a technology review and market scan in 2030. This path should be followed only if after reviewing the technology readiness and performing a market scan to ensure the assets suggested as potentially available are indeed commercially available in the Canadian market.
2. Taking into consideration expected technology development, allowing for more vehicle types to be considered for the transition towards zero-emissions alternatives.
3. The ZEV technology of choice should have a reliable energy supply chain.

The following sections presents the findings on the implementation of the Zero Emissions pathway. This section presents an idealistic scenario for the transition of all vehicles to zero emissions by 2050, which the City should strive for, following successful market sounding and conclusive pilot projects.

6.2.1 REPLACEMENT PLAN

The purchase plan is illustrated in Figure 6-9. This plan reflects the replacement cycles expected, following the original end-of-useful life dictated by the City. It has been assumed that useful life remains constant, independently of the technology.

The BEV technology share shown in the purchase plan in Figure 6-9 reflects the technology transition marked by the uptake rates for each vehicle category as described previously. The annual purchase plan presents the counts of assets purchased on a yearly basis, for both internal combustion vehicles and battery electric vehicles. The purchase plan reflects the uptake rates described in Section 6.

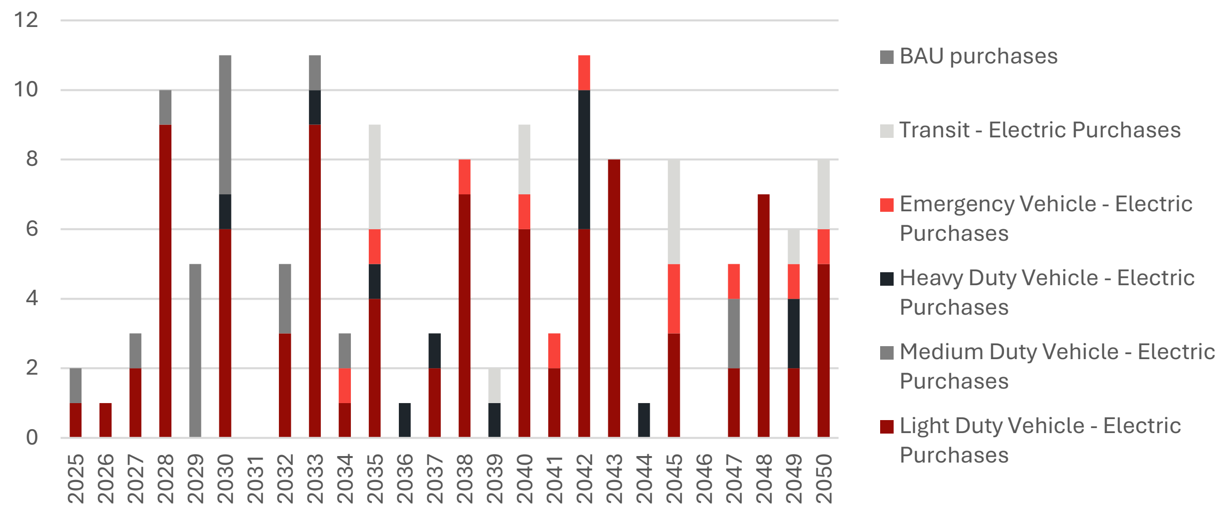

Figure 6-9 Purchase Plan per Year - Zero Emissions Pathway

6.2.2 *FLEET STOCK*

Based on this purchase plan, Figure 6-9 presents the yearly total fleet stock share concerning zero-emissions and internal combustion vehicles. It illustrates the diminishing number of ICE vehicle shares over time, following a standard adoption curve, eventually transitioning the City's asset stock to a battery-electric share of 94% by 2050. The remaining 6% (3 assets) includes two (2) fire pumper (emergency vehicles) and one (1) fire rescue (emergency vehicle)[38]. Following this pathway, the City's corporate assets reach 50% electrification by 2034.

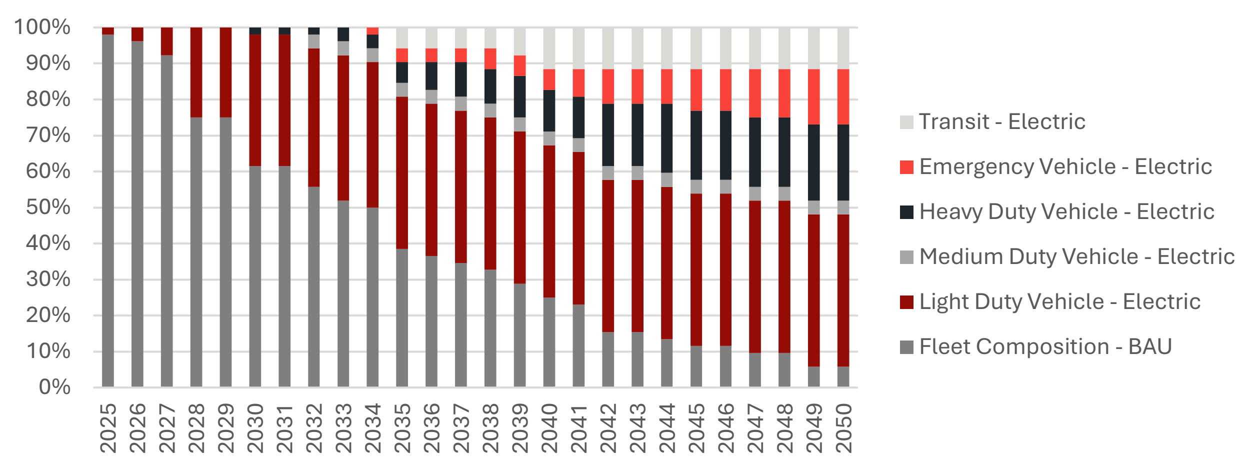

Figure 6-10 Yearly Fleet Make-up - Zero Emissions Pathway

[38] It is possible to achieve electrification of these specific assets by adopting a more aggressive transition schedule for these vehicle types. The long-expected service life of these vehicles (up to 30 years) affects the feasibility of timely replacement. For example, Fire Rescue #08-22 is not scheduled for its first replacement until 2052, which exceeds the 2050 target.

6.2.3 GHG EMISSIONS REDUCTIONS

The tailpipe GHG emissions from the implementation of the Reduced Emissions path are shown in Figure 6-4. Vehicle fuel efficiency and the rate of improvement of fossil-fuel carbon intensity via the federal Clean Fuel Regulations have been accounted for. It is important to note that BEVs are not shown in this figure, as they have zero tailpipe emissions. Therefore, only the vehicles remaining in the fleet that produce tailpipe emissions will be shown.

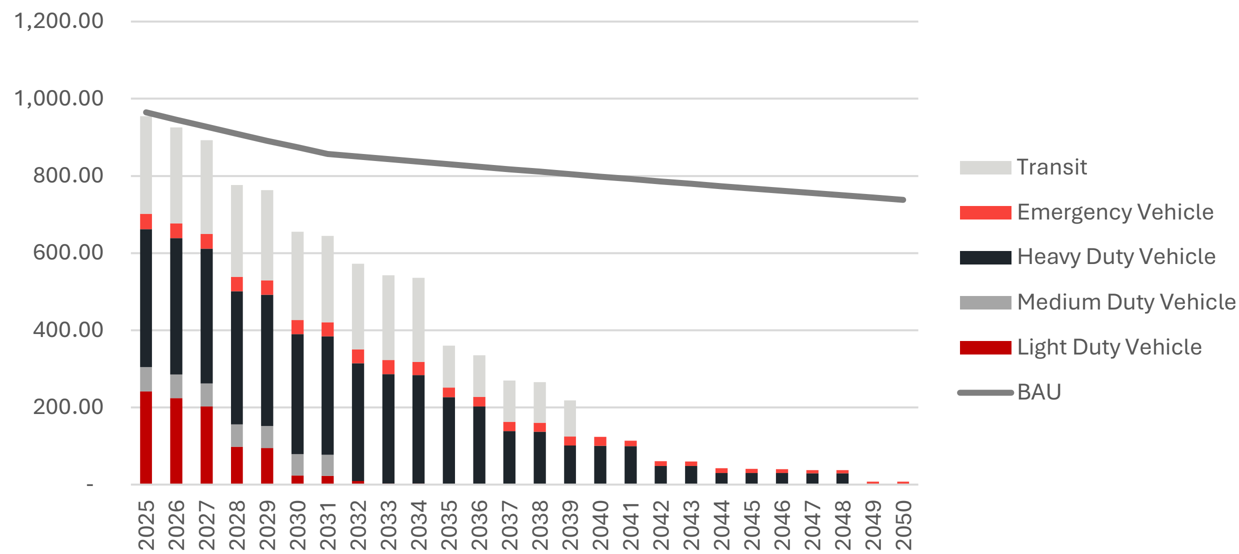

Figure 6-11 Yearly GHG Emissions - Zero Emissions Pathway

This zero-emissions pathway is expected to lead to GHG savings of approximately 99% compared to the business-as-usual scenario. The electric adoption of heavy duty vehicles, specifically Plow / Tandem and Dump Truck, will have the greatest impact on the GHG emissions, as the transition of 12% of the fleet (6 vehicles), will reduce the emissions by over 26%.

When compared to the GHG savings expected from the Reduced Emissions Pathway, the Zero Emissions Pathway clearly demonstrates that transitioning the heavier vehicles and transit will have the largest impact on GHG reduction. The adoption of the ZEV technologies under the Zero Emissions Pathway has a significant impact on GHG emissions because a considerable share of the energy-intensive assets has the potential to be transitioned.

6.2.4 CAPITAL INVESTMENTS

FLEET VEHICLES

Figure 6-12 provides a breakdown of the annual investment required under the reduced emissions path. The replacement costs for the BEV fleet are based on current ICE costs, BEV asset rate of change projections and a trend toward cost parity over time[39].

[39] U.S. DOE, 2022 Incremental Purchase Cost Methodology and Results for Clean Vehicles, https://www.energy.gov/sites/default/files/2022-12/2022.12.23%202022%20Incremental%20Purchase%20Cost%20Methodology%20and%20Results%20for%20Clean%20Vehicles.Pdf

Initial CAPEX investments are higher than the CAPEX required for the BAU fleet, due to the superior costs of battery electric vehicles for the next years, and the number of vehicles being transitioned to electric alternatives. Capital cost parity is expected for the years following 2035.

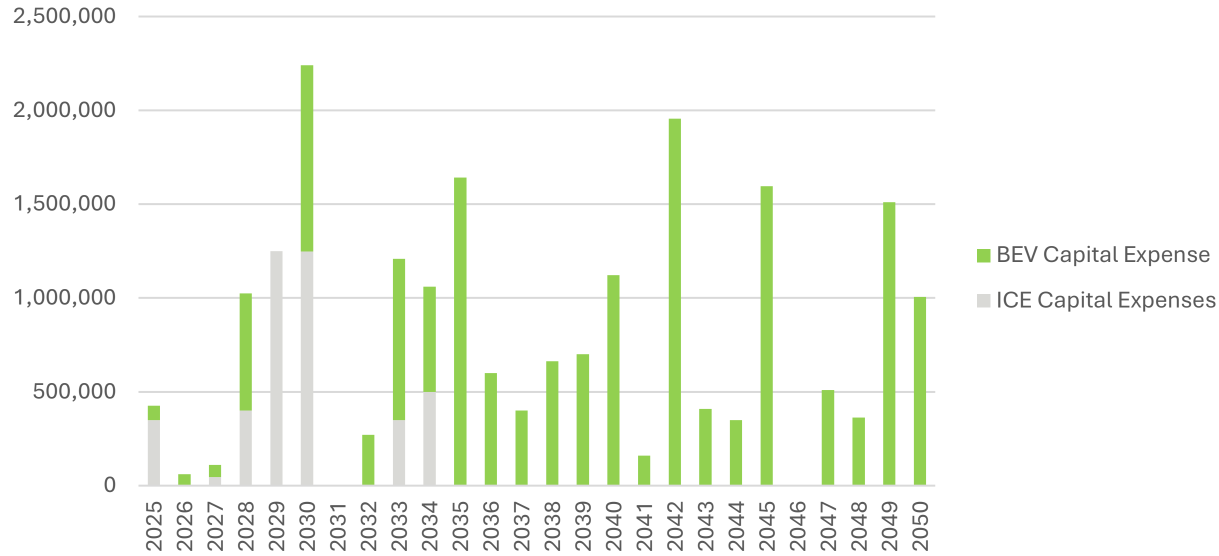

Figure 6-12 Yearly Capital Fleet Investment – Zero-Emissions Pathway

CHARGING INFRASTRUCTURE

An analysis of the charging infrastructure needed to operate the electrical fleet was completed, based on the vehicles' estimated power requirements. An 8-hour charging window and a charging factor of 90% were assumed to ensure resiliency in the modelling. The peak charging acquisition will be happening in 2028, with over 9 new charging ports required.

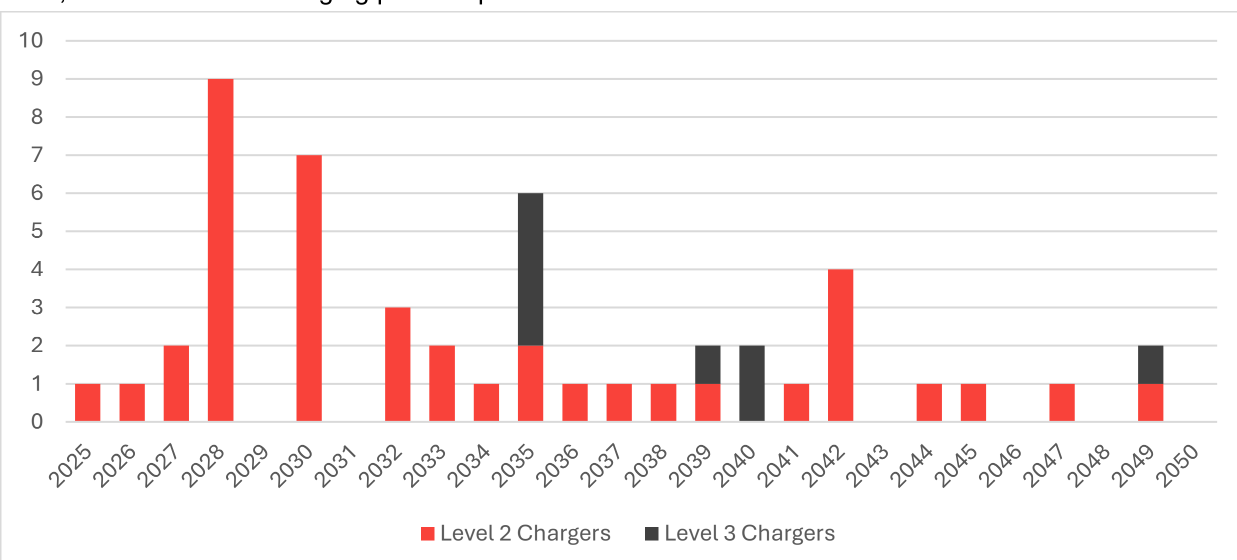

Figure 6-13 Count of New Charging Ports

Table 6-4 Charging Infrastructure Investment

CHARGING LEVEL	TOTAL CAPITAL EXPENSES
Level 2	$544,950.00
Level 3	$714,000.00
TOTAL	**$1,258,950.00**

6.2.5 *OPERATING COSTS*

The operating costs include maintenance and fuel costs, which may be subject to change based on market conditions and technology evolution. The ensuing sections detail the findings on these costs and assumes a continuation in standards operations.

FUEL AND ELECTRICITY COST

Based on electricity prices provided, combined with energy consumption of different electric alternatives, the cost of fuel and electricity for the Zero Emissions Pathway was approximated[40]. The fuel consumption and fuel price are based on data from the current operations. Incremental growth of electricity and fossil fuels were factored in to present a realistic portrait of what can be expected.

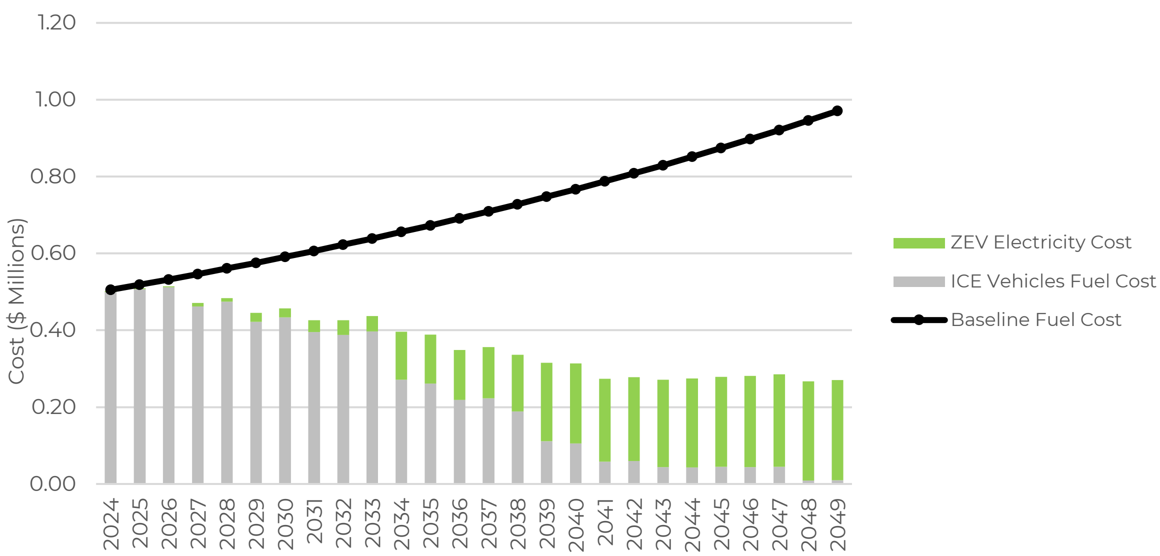

Figure 6-14 Fuel and Electricity Cost - Zero-Emissions Pathway

As presented in Figure 6-14, fuel costs are expected to increase until 2050. This is where the fleet transition would have its biggest financial impact; by 2050, the zero-emissions pathway would lower total fuel and electricity costs by approximately 60%.

[40] The electricity price was assumed to be $0.15/kWh in 2024, with an annual escalation rate of 2% applied through 2050.

MAINTENANCE COST

Based on annual operational data provided by the City, yearly maintenance costs for individual assets were approximated, factoring in the asset type and age. This yearly maintenance cost can be used to forecast the financial impact of the aging fleet, combining it with the replacement plan and the transition of assets[41]. As shown in Figure 6-15, the maintenance costs reduce as more vehicles are replaced by battery electric vehicles. It is assumed that the maintenance cost is approximately 60% of the BAU maintenance cost per asset[42].

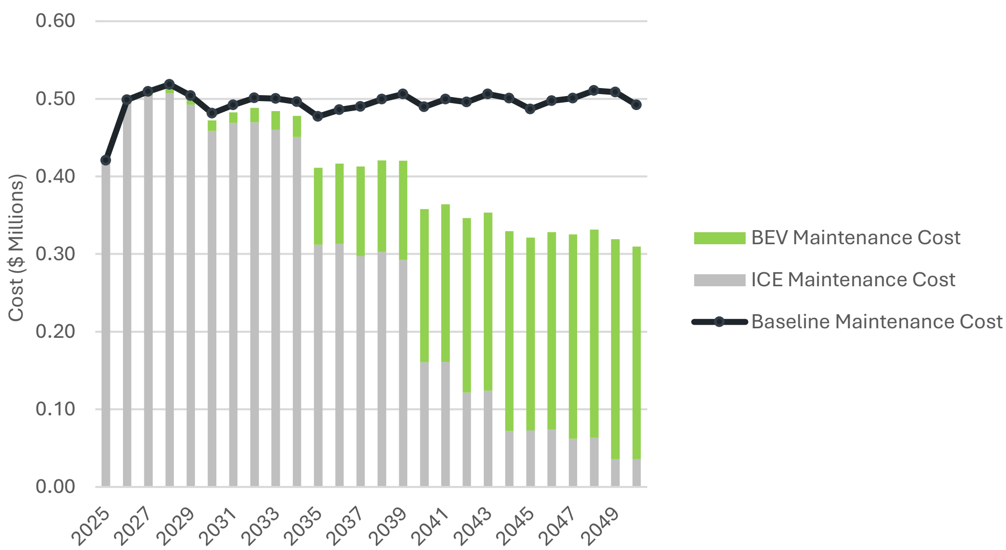

Figure 6-15 Asset Maintenance Cost by Year – Zero-Emissions Pathway

By 2050, the reduced emissions pathway would reduce total maintenance costs by approximately 37%. Over the study period, the transition of the assets under the reduced emissions pathway could potentially help save over $2.26 million in maintenance cost alone.

6.2.6 TOTAL COST OF OWNERSHIP

The total fleet capital expenses (CAPEX) and operating expenses (OPEX) from the Zero-Emissions Pathway are presented in Table 6-4. Because the net savings are maximized in the transit and heavy-duty vehicles, the replacements with BEV of these vehicles would have the most financial benefits, even if the barriers to adoption (technology, change management, etc.) might be the greatest.

[41] To create a portrait of the impact of aging assets in the fleet, ratio (%) of cost increase on a kilometre basis from similar jurisdiction was used. This allowed to mitigate the lack of historical data on the maintenance costs and the development of a maintenance cost forecast, capturing the aging of the fleet.

[42] U.S. DOE, Battery-Electric Vehicles Have Lower Scheduled Maintenance Costs than Other Light-Duty Vehicles, https://www.energy.gov/eere/vehicles/articles/fotw-1190-june-14-2021-battery-electric-vehicles-have-lower-scheduled

Table 6-5 Total Cost of Ownership – Zero-Emission Pathway

$MILLIONS	Light Duty Vehicles		Medium duty Vehicles		Heavy Duty Vehicles		Emergency Vehicles		Transit		Fleet Total	
	BAU	Zero-Emissions	BAU	Zero-Emissions	BAU	Zero-Emissions	BAU	Zero-Emissions	BAU	Zero-Emissions	BAU	Zero-Emissions
CAPEX Fleet	4.73	4.91	0.32	0.33	6.35	6.61	3.18	3.19	5.60	5.60	**20.18**	**20.64**
Maintenance	0.60	0.38	0.22	0.15	4.61	3.83	1.45	1.36	6.34	4.88	**13.22**	**10.61**
Fuel and Electricity	4.94	0.96	1.19	0.29	6.79	3.23	0.84	0.52	4.80	2.98	**18.55**	**7.98**
CAPEX Infra		1.26		1.26		1.26		1.26		1.26	-	1.26
Peak Demand Charges		1.63		1.63		1.63		1.63		1.63	-	1.63
TOTAL	10.27	9.14	1.74	3.66	17.74	16.56	5.47	7.96	16.73	16.35	**51.95**	**42.12**

7 GENERAL RECOMMENDATIONS

The recommendations in the ensuing section describe the tools within the City of Temiskaming Shore's Green Fleet Strategy. These recommendations build upon the analysis as described in detail in previous sections. The core recommendations to the City to maintain a sustainable transition towards a zero-emissions fleet by 2050 following an agile approach and a long-term outlook.

7.1 AGILE GREEN FLEET STRATEGY

The incorporation of agility in this strategy is driven by the need to align the fleet's transition plan with the uncertainties in asset markets, as well as the unpredictable nature of fuel, energy prices, and technological advancements. This strategic agility enables the City to proactively respond to short-term challenges, anticipate mid-term impacts on the plan, and remain focused on the overarching goal of achieving maximum greenhouse gas (GHG) emissions savings by 2033 and by 2050. The recommendation is for the City to continue reviewing the market of zero-emission vehicle (ZEV) technologies every three to five years:

- This periodicity is designed to account for the fact that infrastructure projects or procurement plans often extend beyond a three-year horizon, encompassing various stages such as design, planning, construction, and asset fabrication. The five-year cap serves to precisely define the market scan's scope, ensuring a focus on predominantly feasible options.
- The assessment should consider zero-emission vehicle (ZEV) options available in the market that align with the City's operational and service requirements. The market review aims to identify options that not only meet the majority of a class's requirements but also explore commercially proven upfit that reliably fulfill specific needs.
- The market scan must evaluate the reliability of the energy supply chain essential for the ZEV fleet. The additional cost associated with refueling infrastructure should be factored in when assessing the competitiveness of ZEV options against Internal Combustion Engine (ICE) alternatives. Furthermore, this added cost should be weighed against the long-term benefits of fostering continuous ZEV technology adoption.
- In the event that the market scan identifies fewer feasible ZEV options than anticipated, the strategy can pivot toward the Reduced Emissions Pathway. This alternative, as demonstrated in this study, adopts a more conservative transition plan based solely on currently available ZEV options, establishing a minimum GHG emissions reduction.
- The agile approach strives to keep the technology transition plan within predefined boundaries, fostering adaptability to evolving circumstances.
- To prepare the City for new ZEV technologies and assess specific functionalities, conducting pilot projects is strongly recommended. These projects should test the suitability of ZEV technologies under challenging conditions, such as winter, and should be implemented before the subsequent feasibility and market review study.

7.2 FOCUSSING ON THE NEAR TERM

Focusing on transitioning the on-road assets, will maximize the GHG emissions reduction in the timeframe of the study. Furthermore, enabling the replacement for the near term in the key segments of the on-road segment of the fleet, which SUVs and pick-up trucks, will produce greater effects on GHG emissions reduction to achieve the 2033 target.

7.3 SELECTIVE SWEATING OF ASSETS

To further enhance the adoption of new ZEV replacements from 2033 onwards, the City should contemplate establishing a selective sweating program. This involves prioritizing assets operating beyond their replacement cycle or those with minimal disruptions to service quality. Setting a maximum aging time, such as 2 to 3 years, is advisable to prevent escalating costs due to expensive maintenance. By selectively aging assets, the City can strategically defer purchases to years with higher uptake rates, facilitating replacement with ZEV options in the market. In contrast, without aging, replacements in low uptake rate years would prolong dependence on fossil fuels until the next replacement cycle. For some assets, the next replacement cycle may fall beyond 2050.

7.4 EXPLORE ALTERNATIVE PATHWAYS FOR THE NON-ELECTRIFIABLE ASSETS

For the assets that are not electrifiable based on the current utilization and energy efficiencies, consider alternatives to enable their electrification process:

- Consider reassessing and redesigning the tasks allocated to these assets. The purpose would be to break unfeasible duty cycles into feasible ones within the range of the BEV of the specific category. The resulting tasks should be optimally assigned by each service so that most of the assets have time for a mid-day charge event. For BEVs serving the transit, this process is called re-blocking.
- At an additional cost, consider BEVs with a bigger battery, within the same vehicle category (GVWR) or a suitable option in the immediate higher category.
- Consider a more complex charging infrastructure solution. For the non-electrifiable assets, the path towards electrification may come from both increasing the charging power, from the consider for the initial calculations and develop charging hubs, or on-route locations, around the City to ensure available charging at places other than the Depot. This consideration should be accompanied by a detailed study of the routes and duty cycles of the assets to estimate a charging process that does not create excessive dead-head trips. This solution will come at an additional cost.
- If nothing else proves feasible, consider reassessing the number of BEVs required to complete the duty cycle of the specific ICE that is not electrifiable. These means, in some cases more than one BEVs might be needed to complete a task that goes beyond the range of the BEVs. This might be the most costly solution but in the long term the integration of the extra asset to the fleet may prove useful to serve the service growth.
- Replacing existing transit vehicles with similar-sized BEBs requires detailed modeling. Smaller BEBs are equipped with smaller batteries, which limits their driving range. Adjusting service schedules to incorporate mid-day and opportunity charging can be an effective strategy to support fleet electrification.
- As part of a fleet right-sizing exercise, it may be prudent to consider replacing vehicle types with those that already have electric counterparts available today, thereby expediting the transition to fleet electrification.

7.5 INFRASTRUCTURE CONSIDERATIONS

The infrastructure supporting the energy supply is crucial to support a sustainable BEV fleet operation. For this reason, it is recommended that the City develops the energy supply and refueling infrastructure ahead of the operation of the BEV fleet. The following are key recommendations regarding the charging infrastructure:

- Initiate building-level upgrades and civil infrastructure to accommodate electric vehicle supply equipment (charging stations). This involves enhancements such as LV Distribution panel boards, power lines, distribution cables, junction boxes, etc. Adequate time should be allocated for the planning, design, and construction of these upgrades.
- Align the purchase of charging equipment (stations and dispensers) with the BEV purchase plan, ensuring acquisition ahead of the corresponding BEV fleet purchases. At worst make sure the charging equipment is acquired a year ahead of the commissioning of the BEVs these will serve. At best, define the lead time for the completion of the charging infrastructure and make sure this happens before the start of operation of the corresponding fleet. This ensures the seamless commissioning and operation of the charging infrastructure before serving the BEV fleet.
- Incorporate redundancies in the planning of electrical circuits to maximize the reliability of the BEVs.
- Prioritize sites that can readily accommodate chargers in the short term.
- Secure federal incentives to help reduce the overall cost of infrastructure.

7.6 LONG-TERM OUTLOOK

The following recommendations are provided to ensure a smooth transition towards a ZEV fleet:

- Keep a long-term outlook: While the upfront capital and infrastructure costs may be substantial, the overall long-term costs are anticipated to be significantly lower due to the reduction in fuel and maintenance expenses. It is recommended to proactively budget for these higher short-term costs and garner the acceptance of the council, emphasizing the distinction between short-term investments and long-term savings.
- Continuous Training and Skill Development: Provide ongoing training programs for fleet management and maintenance staff to ensure they are equipped with the necessary skills and knowledge to handle ZEVs, contributing to the efficient operation and maintenance of the fleet.
- Monitoring and Reporting: Implement robust monitoring and reporting mechanisms to regularly evaluate the effectiveness of the transition plan, enabling data-driven decision-making and adjustments as needed.

APPENDIX – ASSUMPTION MEMO

APPENDIX A

ASSUMPTIONS MEMO

This memo serves as a summary of all the assumptions utilized to complete the data analysis. It encompasses assumptions made from the utilization of specific assets, up to any value employed to complete calculations. The purpose of this document is to ensure clarity and transparency in the analytical process.

ASSET CLASSIFICATION

UNIT NO / ASSET ID	VEHICLE TYPE	MAKE	MODEL	AMP VEHICLE CATEGORY
101-23	SUV	Chevrolet	Equinox	Light Duty Vehicle
102-23	SUV	Chevrolet	Equinox	Light Duty Vehicle
14-25	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Emergency Vehicle
13-17	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Emergency Vehicle
01-00	Fire Pumper	GMC	C7H042	Emergency Vehicle
03-17	Fire Rescue	International	4400	Emergency Vehicle
02-19	Fire Pumper	International	HV607	Emergency Vehicle
08-22	Fire Rescue	Freightliner	M2-106	Emergency Vehicle
06-03	Fire Pumper	Freightliner	FL80	Emergency Vehicle
07-12	Fire Pumper	Freightliner	M2 106	Emergency Vehicle
11-03	Fire Pumper	International	7400	Emergency Vehicle
09-08	Fire Rescue	GMC	C4C042	Emergency Vehicle
10-15	Fire Pumper	International	4400	Emergency Vehicle
02-18	Pick-up Truck	Chevrolet	Silverado 1500 2WD	Light Duty Vehicle
93-17	Pick-up Truck	Chevrolet	Silverado 2500HD	Light Duty Vehicle
04-25	Pick-up Truck	Chevrolet	Silverado 1500	Light Duty Vehicle
06-20	3/4 ton	Chevrolet	2500HD	Light Duty Vehicle
08-17	2-Ton Dump	Ford	F-550	Medium Duty Vehicle
11-18	3/4 ton	Chevrolet	2500HD	Light Duty Vehicle
15-19	Pick-up Truck	Ford	F-150	Light Duty Vehicle
16-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
20-16	Van	Chevrolet	Express	Light Duty Vehicle
22-15	Vacuum truck	Western Star	4700SB	Heavy Duty Vehicle
23-14	Plow / Tandem	International	7600SBA	Heavy Duty Vehicle
24-18	Plow / Tandem	Freightliner	114SD	Heavy Duty Vehicle
25-16	Single Axle Dump / Sander	Freightliner	108SD	Heavy Duty Vehicle
26-18	Plow / Tandem	Freightliner	114SD	Heavy Duty Vehicle

UNIT NO / ASSET ID	VEHICLE TYPE	MAKE	MODEL	AMP VEHICLE CATEGORY
27-16	Single Axle Dump / Sander	Freightliner	108SD	Heavy Duty Vehicle
28-15	Patch Truck	Peterbilt	T220	Heavy Duty Vehicle
30-22	Dump Truck	Freightliner	114SD	Heavy Duty Vehicle
31-19	Plow / Tandem	International	HV	Heavy Duty Vehicle
35-24	Dump Truck	Kenworth	T-880 CON	Heavy Duty Vehicle
36-18	Sweeper	Freightliner	Sweeper	Heavy Duty Vehicle
500-20	Transit	ALEXANDER DENIS	E200	Transit
501-20	Transit	ALEXANDER DENIS	E200	Transit
503-15	Transit	NEW FLYER	MIDI	Transit
504-19	Transit	Ford	E-450	Transit
01-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
05-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
07-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
09-23	Pick-up Truck	Chevrolet	Silverado 1500 2WD	Light Duty Vehicle
10-18	3/4 ton	Chevrolet	Silverado 2500 2WD	Light Duty Vehicle
12-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
13-16	Van	Ford	E-350	Light Duty Vehicle
14-23	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
17-25	Pick-up Truck	Chevrolet	Silverado 1500	Light Duty Vehicle
18-25	Pick-up Truck	Chevrolet	Silverado 1500	Light Duty Vehicle
19-25	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
21-22	Pick-up Truck	Chevrolet	Silverado 1500 4WD	Light Duty Vehicle
29-17	2-Ton Dump	Ford	F-550	Medium Duty Vehicle
505-25	Transit	GMC	4500 – ARBOC Spirit of Freedom	Transit
506-25	Transit	GMC	4500 – ARBOC Spirit of Freedom	Transit

MISSING INFORMATION

To capture a comprehensive picture of the fleet utilization, it is important to gather as much information as possible. While the City of Temiskaming Shores (the "City") maintains data for their fleet, in some instances, specific information on individual assets was missing. This section provides an overview of the missing information, the assumptions made to complete this gap, and an explanation of the choice of the assumption.

USEFUL LIFE ASSUMPTIONS

ASSET ID	ASSUMPTION OF USEFUL LIFE	DESCRIPTION
14-25	5	Leased vehicle.
04-25	8	Other pick-up trucks from the Recreation department have a useful life of 8 years.

ASSET ID	ASSUMPTION OF USEFUL LIFE	DESCRIPTION
17-25	5	All pick-up trucks from public works are leased.
18-25	5	All pick-up trucks from public works are leased.
19-25	5	Leased vehicle.

ANNUAL UTILIZATION ASSUMPTIONS

To set the assumptions regarding any missing information, the approach presented in Figure 1 below was used. This approach leverages available information, prioritizing information from similar vehicle type in the same department.

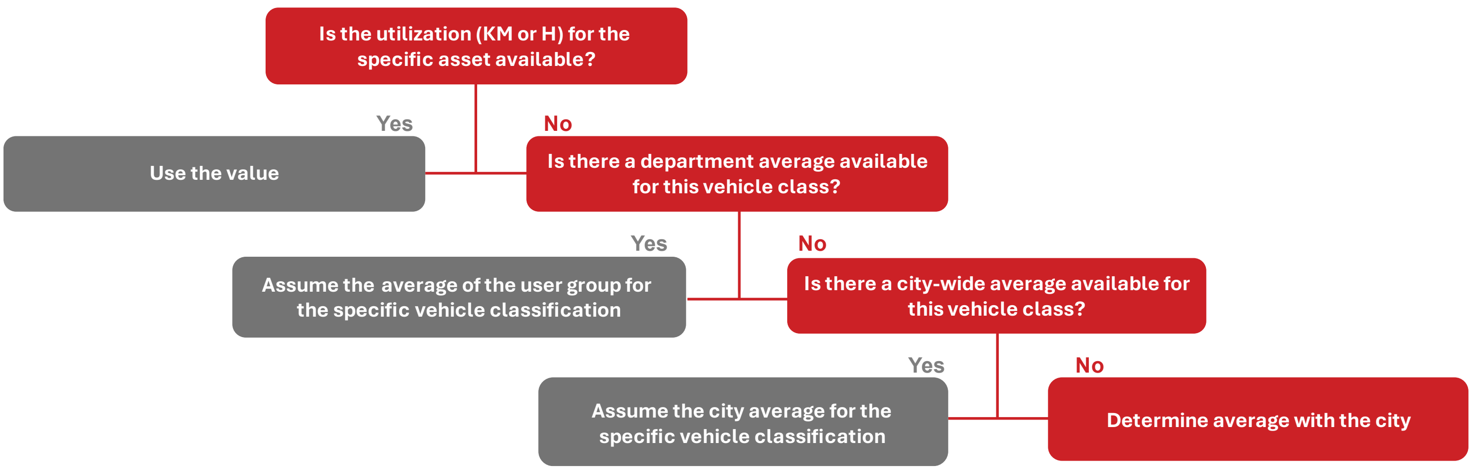

Figure 1 Missing Data Approach

ASSET ID	VEHICLE TYPE	DEPARTMENT	ANNUAL UTILIZATION ASSUMPTION (KM)
14-25	Pick-up Truck	Fire Services	12,938.25
04-25	Pick-up Truck	Leisure Services	10,876.43
17-25	Pick-up Truck	Public Works	16,431.17
18-25	Pick-up Truck	Public Works	16,431.17
19-25	Pick-up Truck	Public Works	16,431.17
25-16	Single Axle Dump / Sander	Public Works	6,139.00
102-23	SUV	Corporate department	13,241.50
31-19	Plow / Tandem	Public Works	15,263.35

FUEL ASSUMPTIONS

Ten (10) assets had no information regarding their annual fuel consumption. To mitigate those gaps, the average fuel consumption (L/km) for a similar vehicle (same vehicle type and department) was used. Combining this utilization-based fuel consumption with the annual utilization allowed the estimation of the annual fuel consumption.

ASSET ID	VEHICLE TYPE	DEPARTMENT	FUEL CONSUMPTION (L/KM) ASSUMPTION	ANNUAL FUEL CONSUMPTION (L)
14-25	Pick-up Truck	Fire Services	0.35	4,500.76
01-00	Fire Pumper	Fire Services	0.77	696.92

ASSET ID	VEHICLE TYPE	DEPARTMENT	FUEL CONSUMPTION (L/KM) ASSUMPTION	ANNUAL FUEL CONSUMPTION (L)
10-15	Fire Pumper	Fire Services	0.77	595.27
04-25	Pick-up Truck	Leisure Services	0.35	3,810.62
500-20	Transit	Transit	0.31	22,014.46
501-20	Transit	Transit	0.31	18,374.68
503-15	Transit	Transit	0.31	16,315.96
504-19	Transit	Transit	0.36	6,265.60
505-25	Transit	Transit	0.36	18,817.89
506-25	Transit	Transit	0.36	18,817.89

MAINTENANCE COST ASSUMPTIONS

To mitigate any missing information regarding the maintenance cost, assumptions based on the vehicle types were used. This was used for nine (9) assets, all pick-up trucks. Based on the information available, a maintenance cost per kilometre travelled was used.

VEHICLE TYPE	MAINTENANCE COST ($/KM)
Pick-up Truck	0.06

GENERIC ASSUMPTIONS

This section refers to generic assumptions used to complete the baseline estimates. These assumptions are based on a literature review.

2025 GHG EMISSIONS FACTORS

FUEL	EMISSION FACTORS (KG CO_2E/L)	SOURCE
Diesel	2.689	Emission Factors and Reference Values, Government of Canada[1]
Gasoline	2.315	Emission Factors and Reference Values, Government of Canada[2]

*Note that these are exhaust emissions and do not include the lifecycle emissions of the fuel.

2030 GHG EMISSIONS FACTORS

Canada's **Clean Fuel Regulations (CFR)** are a federal initiative aimed at reducing greenhouse gas (GHG) emissions from the transportation sector. These CFRs aim at reducing the carbon intensity of gasoline and diesel by 15% below 2016 levels by 2030. These regulations apply to fuel producers, importers, and suppliers of transportation fuels in Canada. For end-users,

[1] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html
[2] https://www.canada.ca/en/environment-climate-change/services/climate-change/pricing-pollution-how-it-will-work/output-based-pricing-system/federal-greenhouse-gas-offset-system/emission-factors-reference-values.html

such as the City, these regulations will mean that the fuel used for their daily operation could be cleaner, depending on the compliance option chosen by the producer (improve refinery efficiency, supply more low-carbon fuels, contribute to an emissions reduction fund, etc.). For this project, the CFRs' impact has been assumed as:

- **Diesel:** The Clean Fuel Regulation would allow to reach a 20% renewable diesel blend in 2030;
- **Gasoline:** Assuming a blend of 15% ethanol and 85% unleaded gasoline.

FUEL	EMISSION FACTORS (KG CO_2E/L)	SOURCE
Diesel	2.627	Based on the vehicle operation factors for a diesel mix D80/HDRD20, from GHGenius Version 5.02b9[3]
Gasoline	1.983	B.C Ministry of Environment and Climate Change Strategy[4]

*Note that these are exhaust emissions and do not include the lifecycle emissions of the fuel.

FUEL ECONOMY OPTIMIZATION

Internal combustion engines (ICE) fuel efficiency are expected to improve from 2025 to 2050. This improvement rate was captured to assess the baseline emissions and the expected cost.

VEHICLE TYPE	ANNUAL FUEL ECONOMY IMPROVEMENT	SOURCE
Light Duty Vehicle	0.6%	Annual Energy Outlook 2022 (AEO2022), U.S. Energy Information Administration[5]
Medium Duty Vehicle	0.9%	Annual Energy Outlook 2022 (AEO2022), U.S. Energy Information Administration
Heavy Duty Vehicle	0.9%	Annual Energy Outlook 2022 (AEO2022), U.S. Energy Information Administration
Transit	0.9%	Annual Energy Outlook 2022 (AEO2022), U.S. Energy Information Administration

[3] https://www.ghgenius.ca/index.php/downloads
[4] https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2023_pso_methodology_for_quantifying_greenhouse_gas_emissions.pdf
[5] https://www.eia.gov/outlooks/aeo/pdf/AEO2022_ChartLibrary_Transportation.pdf