Sustainable Fleet Strategy Report

Prepared for the City of Kelowna

June 9, 2025

Classification: KPMG Public

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Executive Summary

The Sustainable Fleet Strategy (SFS) for the City of Kelowna is a comprehensive plan designed to reduce corporate emissions, aiming for a 40% reduction from 2007 levels by 2030 and achieving net-zero municipal emissions by 2050. Fleet decarbonization is crucial as Kelowna's municipal fleet is responsible for 48% of the city's corporate greenhouse gas (GHG) emissions, making it a focal point for realizing these ambitious targets. To address this critical area, the City commissioned the Sustainable Fleet Strategy to explore various decarbonization opportunities and establish a clear pathway for implementation.

The key components of the Sustainable Fleet Strategy include several essential initiatives. First being fleet rightsizing, which aims to optimize the number and types of vehicles utilized, identifying the potential for a reduction of 30 to 50 vehicles to enhance fleet efficiency. This initiative aims to streamline operations while promoting sustainability.

The strategy incorporates a low carbon technology review, evaluating various alternative fuel technologies with potential for fleet decarbonization. Currently, electric vehicles (EVs) are recognized as a viable solution for light-duty needs due to their established technology and the advantage of city-managed charging infrastructure. Hydrogen is identified as a promising candidate for medium and heavy-duty vehicles due to its high energy density and payload capacity. However, challenges remain regarding hydrogen infrastructure, with the anticipated availability of hydrogen internal combustion engine (ICE) technology not expected until 2029. Hybrid range extenders are emerging as another potential solution for mid-sized trucks, providing improved fuel economy without additional city-owned fueling infrastructure, although market availability is not expected until 2029.

The development of a robust charging infrastructure is central to the strategy, proposing the installation of approximately 140 chargers to accommodate the expected increase in electric vehicle usage while ensuring efficient charging capabilities. This infrastructure is critical in supporting the transition to EVs and encouraging broader adoption. Moreover, the strategy underscores the importance of maintenance adaptations, emphasizing the need for specialized maintenance areas and technician training programs. Existing facilities are currently not equipped to service EVs or hydrogen vehicles effectively, which necessitates the establishment of these specialized facilities to maintain a sustainable fleet.

In terms of implementing both short and long-term strategies, renewable diesel is considered an interim solution currently in use by the City, offering immediate emissions reductions compared to traditional diesel. However, limitations exist from a lifecycle perspective due to transport emissions, particularly since the renewable diesel is sourced from Southeast Asia.

The strategy reflects a multifaceted approach to municipal fleet decarbonization, recognizing the distinct advantages and challenges that each technology presents depending on vehicle class. Such diversity is essential for creating a robust and sustainable fleet as the City of Kelowna embarks on its journey towards reducing emissions and achieving its environmental goals.

The scenario analysis conducted considers two timelines: one where hydrogen ICE technology becomes available as currently estimated by manufacturers, and another with delayed releases. The analysis shows that a 40% reduction in fleet emissions would not be possible until 2031 under the non-delayed scenario. However, both scenarios project an ~95% reduction by 2050. The remaining ~5% emissions are attributed to the provincial electricity grid's current emissions. Full fleet decarbonization depends on the province's ability to decarbonize its grid, which is beyond the City's scope and contingent on provincial and federal policies.

From a financial standpoint, transitions to electric vehicles consistently demonstrate the highest net present value (NPV) and lowest marginal abatement cost (MAC) due to emissions reductions as well as reduced maintenance and fuel expenses, and in some cases, even lower capital costs —saving the City approximately $100–$1,000 per tonne of emissions abated. For high-emission vehicles, particularly single axle and tandem axle trucks, the MAC of low-carbon alternatives is large, or the cost per tonne of carbon dioxide equivalent is high. However, the CAPEX and OPEX costs of low-carbon alternative technologies for these vehicle classes (such as hybrid range extenders, and co-combustion systems) are highly uncertain, given that these technologies are early-stage and largely untested in practice. This analysis used proxies and estimates for these costs and therefore results should be interpreted as highly preliminary.

The analysis to build the City of Kelowna's Sustainable Fleet Strategy structured a step-by-step approach in fleet right sizing and low carbon technology transition to the City's 447 vehicles. Conservative estimates see a potential reduction of 30-50 vehicles in the City's fleet through right sizing and fleet optimization strategies.

The charging analysis for the City's EV fleet evaluated two main charging configurations: a Daisy Chain Configuration, which optimizes charging organization, and a Prioritized Dedicated Charging approach, which requires more vehicle charging management. The analysis concludes that the Daisy Chain Configuration could potentially be more cost-effective while meeting the fleet's charging needs. A location-based approach, to further refine the results based on each department's needs, anticipated the City will require ~68 level 1 chargers, ~32 level 2 chargers and ~40 daisy chains[1] for a total of ~140 chargers. In summary, the strategic analysis of charging infrastructure is designed to ensure that the City can effectively support its growing fleet of electric vehicles while maximizing efficiency and minimizing costs.

The transition to hydrogen and EVs within municipal fleets necessitates significant adaptations in maintenance facilities and practices. Current maintenance infrastructure is primarily designed for ICE vehicles, which limits their capacity to service EVs and hydrogen-fueled vehicles. As the City of Kelowna moves towards a low carbon fleet, it is essential to expand facilities to accommodate the unique requirements of these vehicles. This includes creating dedicated maintenance bays equipped with specialized tools for high-voltage systems and hydrogen safety protocols. The need for comprehensive training programs for technicians is also critical, ensuring they are well-versed in the complexities of EV and hydrogen technologies, which differ significantly from traditional vehicle maintenance practices.

Moreover, the integration of advanced telematics systems and updated safety protocols will be vital in managing the evolving fleet. The City must prioritize the establishment of safety measures tailored to high-voltage and hydrogen systems, including fire suppression systems and emergency response plans. As the fleet transitions, it is crucial to implement a strategic approach that not only enhances operational capabilities but also aligns with provincial safety standards and environmental goals. This proactive planning will ensure that the City of Kelowna can effectively manage its fleet's maintenance needs while contributing to the reduction of GHG emissions.

[1] Each daisy chain charger can support between one to three electric vehicles based on conservative assumptions.

Contents

List of Acronyms

Acronym	Term	Acronym	Term
ASE	Automotive Service Excellence	MAC	Marginal Abatement Cost
ASTM	American Society for Testing Materials	NOx	Nitrogen Oxides
AWD	All-wheel drive	NPV	Net Present Value
B6.7	Model name of a 6-cylinder engine	OEM	Original Equipment Manufacturer
BAU	Business-as-usual	OPEX	Operating Expenditure
BCFC	British Columbia Fire Code	PHEV	Plug-in Hybrid Electric Vehicle
BEV	Battery Electric Vehicle	PM	Particulate Matter
CAPEX	Capital Expenditure	PPE	Personal Protective Equipment
CO	Carbon Monoxide	ROI	Return on Investment
CO2	Carbon dioxide	RTV	Rugged Terrain Vehicle
CRA	Canada Revenue Agency	SFS	Sustainable Fleet Strategy
DCFC	DC Fast Charger	SUV	Sport Utility Vehicle
EV	Electric Vehicle	tCO2e	Tonne of carbon dioxide equivalent
ESR	Electrical Safety Regulation	TRL	Technology Readiness Level
FCEV	Fuel Cell Electric Vehicle	UBC	University of British Columbia
GHG	Greenhouse gas	VOC	Volatile Organic Compounds
GSR	Gas Safety Regulation	X15	Model name of a 15-liter engine
H2 ICE	Hydrogen Internal Combustion Engine	YTD	Year-to-date
HRE	Hybrid Range Extenders	ZEV	Zero-emission vehicle
HTEC	Hydrogen Technology & Energy Corporation		
ICE	Internal Combustion Engine		
IT	Information Technology		
LDT	Light Duty Truck		

1 Introduction

1.1 Background and Context

The City of Kelowna (“City”) recognizes that nearly half of its corporate emissions in 2023 stemmed from its fleet. In response, the City looks to develop a Sustainable Fleet Strategy (SFS) to align its vehicle and equipment procurement and management practices with its goal of achieving net-zero by 2050.

The SFS also presents other benefits to the City and its residents, including improved air quality and reduced fuel and maintenance costs. As such, the SFS presents an opportunity to galvanize the net-zero transition in Kelowna and position the City as a leader amongst Canadian municipalities.

1.2 Scope and Objectives

The Sustainable Fleet Strategy (SFS) was developed in three streams: Fleet Strategy, Charging, and Maintenance. Each of these streams includes holistic and stakeholder-informed strategy for fleet transition towards zero-emission vehicles (ZEV), including:

- Asset management optimizing and right-sizing fleet, charging, and maintenance assets/resources.
- Capital investment strategy and planning, including funding options and business cases.
- Emissions reduction planning in-line with decarbonization targets.
- Additional considerations include policy and regulatory environment and current/anticipated technologies, with focus on decarbonization technologies and methods beyond electric vehicles.

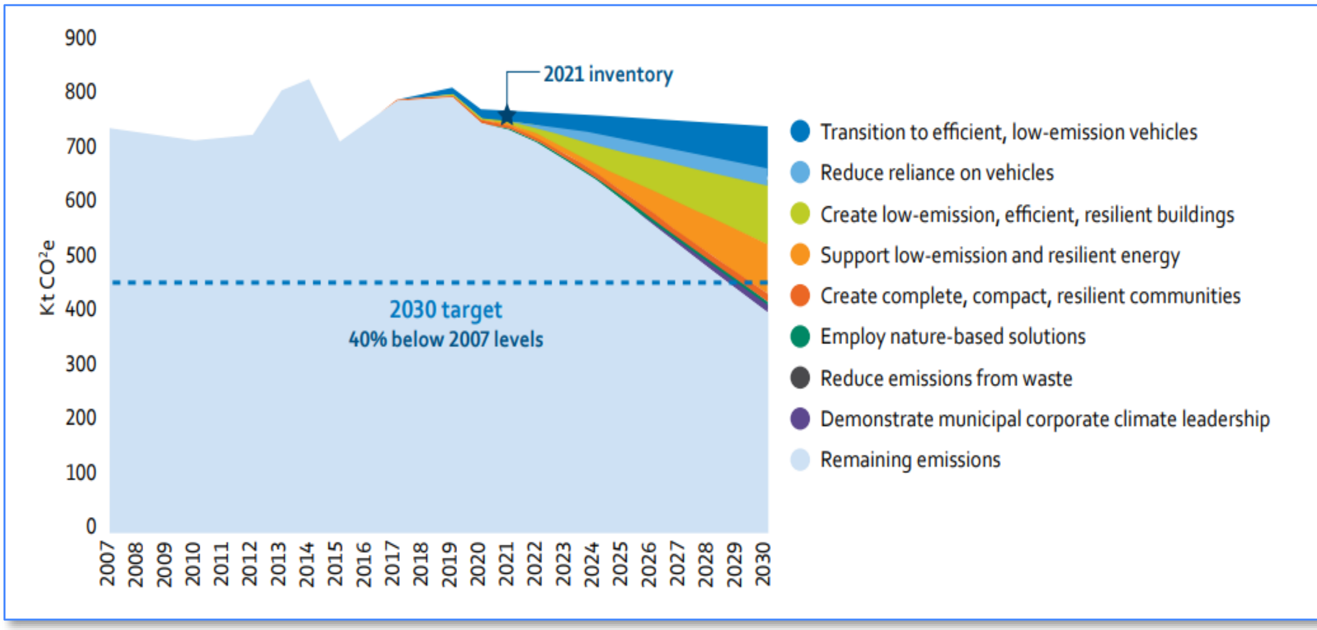
1.3 Kelowna’s GHG Targets

As part of its commitment to sustainability, the City of Kelowna has established GHG reduction targets, aiming to significantly decrease emissions across the community, including corporate operations and municipal fleets. These targets include:

- Reduction in GHG emissions by 40% below 2007 levels by 2030
- Alignment with the Province of British Columbia’s emissions reduction goals
- Net-zero emissions by 2050

Furthermore, Kelowna’s fleet accounts for 48%* of corporate GHG emissions, making fleet management a crucial part of achieving the City's GHG reduction goals.

FIGURE 1 KELOWNA'S GHG TARGETS



Based on Figure 1, transitioning to lower-emissions vehicles plays a significant role in the City's overall emissions reduction strategy

Already, the City has explored innovative solutions to reduce GHG emissions, such as:

- Using R100, a 100% renewable diesel fuel
- Piloting a hydrogen-fueled car
- Purchasing electric vehicles
- Investigating hydrogen options for decarbonizing heavy-duty vehicles

1.4 Alternative Technologies

To move Kelowna towards a net-zero municipal fleet, the following technologies and practices were employed to reduce GHG emissions from fleet operations based on a review of available fleet technologies. More detail on the related review and selection of these technologies can be found in "Low Carbon Fleet Technology Review" (refer page 20), however, the below table provides a high-level overview.

TABLE 1 DEFINITIONS OF ALTERNATIVE TECHNOLOGIES

Technology Name	Definition
Hydrogen Internal Combustion Engine (H_2-ICE)	A modified internal combustion engine that burns hydrogen fuel to generate power
Hydrogen Co-Combustion	A process where hydrogen is burned alongside another fuel (typically a fossil fuel) in an internal combustion engine to reduce emissions and improve efficiency
Electric Vehicles	Powered solely by electric motors using electricity stored in batteries, with no internal combustion engine
Hybrid Range Extenders	Systems that primarily use an electric motor for propulsion, with a smaller combustion engine serving as a generator to extend driving range.
Renewable Diesel	A fuel chemically identical to petroleum diesel but derived from renewable biomass sources through hydrotreatment, compatible with existing diesel engines
Rightsizing	Optimizing the size and composition of the fleet to meet specific needs efficiently, balancing vehicle types and numbers to minimize costs and maximize effectiveness
Fleet Sharing	Allows municipal employees to share fleet vehicles for work-related purposes

1.5 Vehicle Type Definitions

For the purposes of this study, the following definitions were allotted to the City's vehicles based on vehicle type.

TABLE 2 VEHICLE TYPE DEFINITIONS

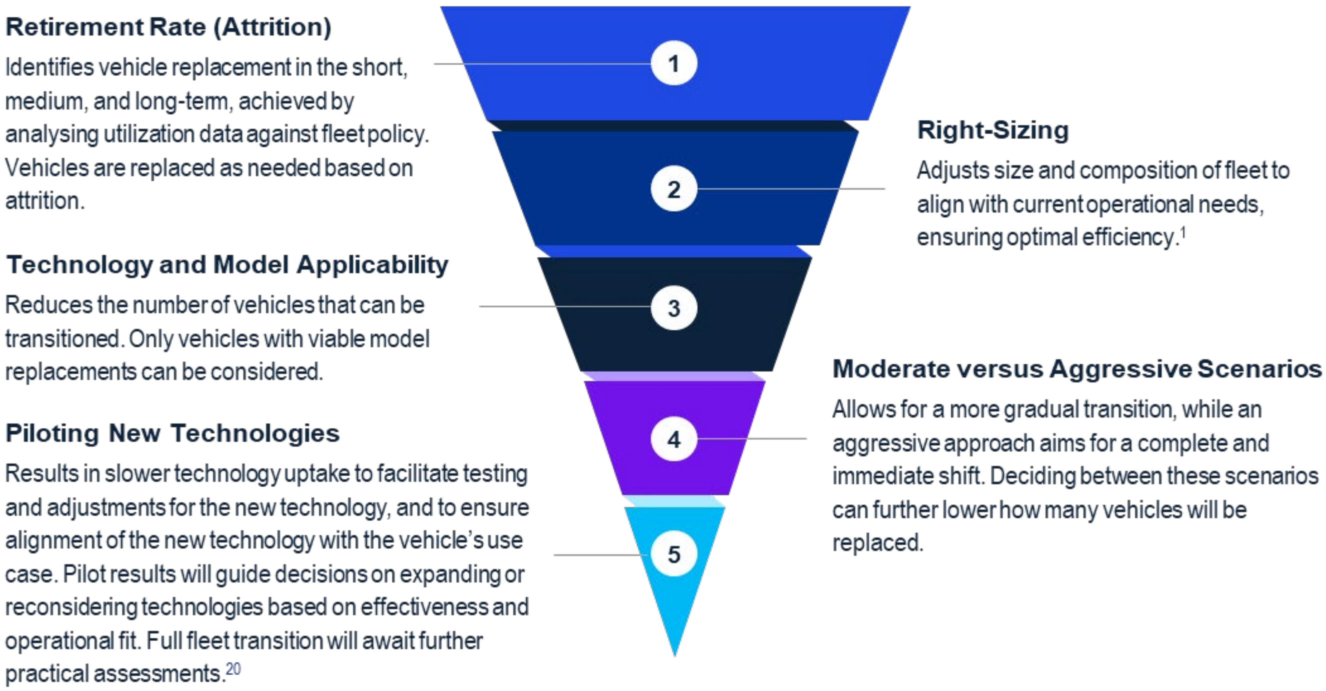
Vehicle Type (units)	Heavy Duty (85)		Medium Duty (43)			Light Duty Vehicles (290)				
	HD Equipment (68)	Tandem Axle Truck (17)	MD Equipment (12)2	Utility Vehicle (9)2	Single Axle Truck (22)	LD Equipment (69)	LD Truck (152)1	Van (31)	SUV (6)	Car (31)
Representative Vehicle	Freightliner M2, Volvo L110H	114SD, International 7500, 7600	Asphalt Recycler, Snow Rotor	Gators, RTVs	F-450, F-550, F600 Fuso Canter	Graco L Lazer, Olympia M	Ford F-150 to F-350	Ford Transit Connect	Ford Escape	Ford CMax
Main Functions	Snow, Mower, Landfill	Fire Truck, Sewer Jet, Gravel Hauling	Mowing, Snow removal, grading	Service, Fire, Hauling, Winter, Landfill	Fire, Heavy Towing, Dump, Tree, Snow Removal	Chipper, Paint, Snow Removal, Mowing	Hauling, Towing, Equipment mounting	Light hauling, Tool Transport	Inspection + People Transport	People Transport
Seating	2+	2+	2+	2+	2+	2+	4+	6+	5+	4+
On vs. Off-road			Off-road capable (AWD/4x4)	Off-road capable (AWD/4x4)	Roadside, Arena, Field		On & Off-road	On-road	AWD	On-road
Tow Rating	-	-	-	3500+ lbs	12,000+ lbs	-	~8,000 lbs	-	n/a	n/a
Payload Rating	-	-	-	-	-	-	~2,500 lbs	~2,500 lbs	n/a	n/a

Notes: [1]City's Light Duty Trucks: range from 1/2 Ton (e.g. F-150) to 1+Ton Pickup (e.g. F350, F450) with work requirements that can be met by an F-150 with the exception of a few trucks in the Fire and Wastewater department that require heavy towing (up to 12,000lbs) and fire truck operations [2]Categories: Include light & medium duty equipment that are EV-eligible

1.6 Fleet Optimization Approach

Several factors contributed to the fleet optimization and decarbonization approach. This analysis was conducted on a step-by-step basis as outlined below:

FIGURE 2 FLEET OPTIMIZATION APPROACH



Notes: [1] Right-sizing opportunities are recommended; however, the City will make the final recommendation on fleet size and composition adjustments. Fleet composition is taken into account for the modelling; however, fleet size is assumed to stay the same as it is currently.[2] For the sake of modelling, it is assumed that pilots are successful and result in full fleet transitions.

2 Current State

2.1 Fleet

2.1.1 Condition Assessment

Fleet Inventory: Utilization Review

The following tables provides an overview of alignment between fleet utilization metrics and annualized utilization targets. Most fleet vehicles across all vehicle classes are under-utilized based on annual target utilization targets. Vehicles in the Single Axle Truck, Light Duty Equipment and Medium Duty equipment classes are all under-utilized.

TABLE 3 ANNUAL UTILIZATION VS. TARGET

Class	Avg. km[1]	Avg. km[3]	Avg. hr[1]	Avg. hr[3]	Annual Utilization Targets[2]		Meets Target[1,2]
					KM	Hours	
Utility Vehicle	7,436	7,605	304	149	10,000		35%
Light Duty Truck	8,742	8,903	340	98	10,000		32%
Car	8,621	9,793	311	N/A	10,000		30%
SUV	6,288	8,063	216	N/A	10,000		30%
Tandem Axle Truck	12,142	18,093	590	678	20,000		23%
Trailer	10,214	N/A	306	22	20,000		17%
Heavy Duty Equipment	3,207	298	486	562		1,000	15%
Van	6,088	6,701	236	N/A	10,000		12%
Single Axle Truck	8,069	6,244	362	581	20,000		0%
Light Duty Equipment	1,121	N/A	149	96		750	0%
Medium Duty Equipment	491	N/A	36	518		750	0%

Notes:
1. Analysis based on 406 vehicle devices from Geotab data between Sep 1st, 2022 – Aug 31st, 2024
2. Analysis based on 412 vehicles and equipment from the Fleet List. This includes 270 vehicles and 142 equipment.
3. Utilization targets are based on annual utilization targets (appendix C) of the City of Kelowna's Corporate Fleet Sustainability Policy

Fleet Operations: Routes and Locations for Cars, Vans, SUVs, and Utility Vehicles

Cars, vans, SUVs and utility vehicles consists of 104 vehicles (34,488 daily trips in 2 fiscal years), including cars (37), vans (34), SUVs (10), and utility vehicles (23), which collectively represent 25.6% of the total fleet. Analysis of trip data reveals that 80% of trips fall within 66.5 km, duration of 2.4 hour. The remaining 20% of trips, which exceed this distance, are performed by 97 vehicles from all 4 vehicles classes.

FIGURE 3 LIGHT DUTY VEHICLES- ROUTE

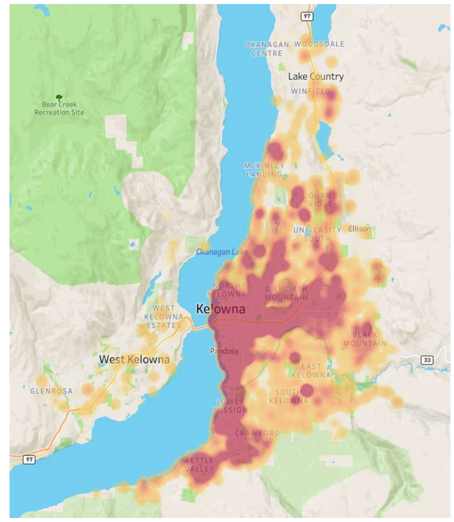


FIGURE 4 DAILY TRIP DISTANCE DISTRIBUTION (KM)- CAR, VAN, SUV, UTILITY VEHICLE

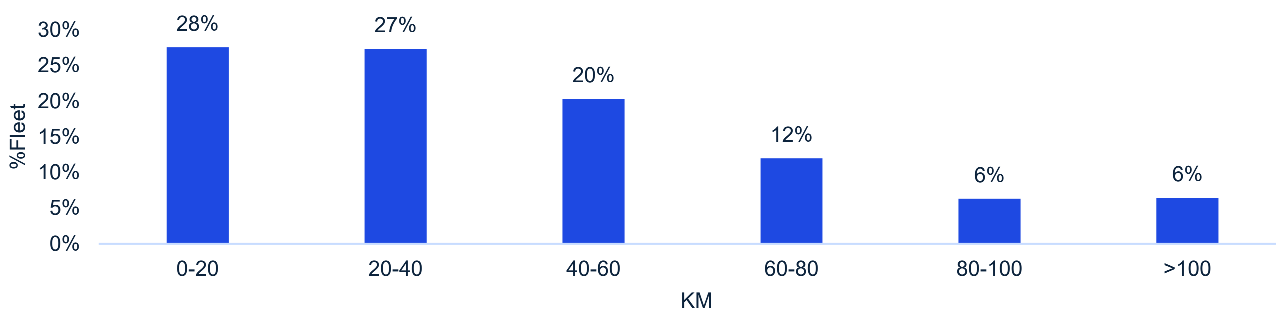
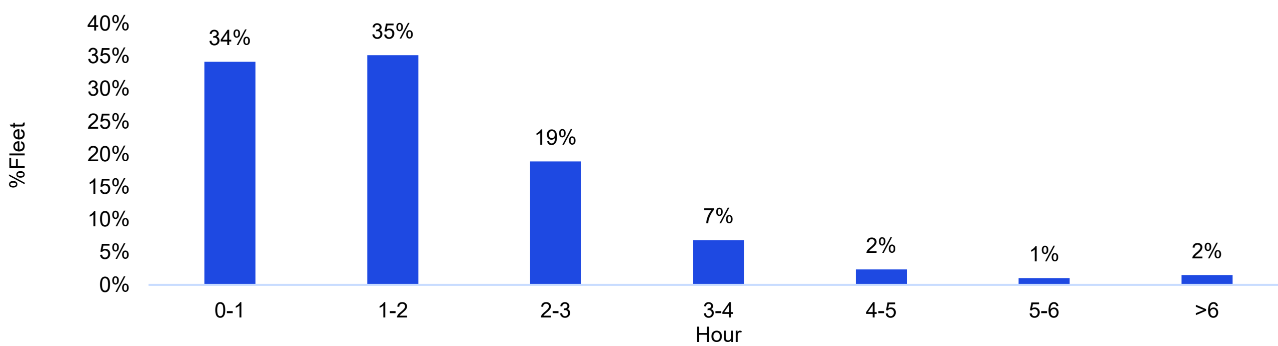


FIGURE 5 DAILY TRIP DURATION DISTRIBUTION (HOUR)- CAR, VAN, SUV, UTILITY VEHICLE



Based on the assessment above, the conclusion is that light duty vehicles rarely travel or operate more than 80km or more than 4hrs – making the case for electrification stronger.

Fleet Operations: Routes and Locations for Equipment

This sub-group consists of 69 vehicles (18,013 daily trips in 2 fiscal years), including Light Duty (9) Medium Duty (6) and Heavy-Duty Equipment (54), which collectively represent 17% of the total fleet. Analysis of trip data reveals that 80% of trips fall within 36.5 km, duration of 5.4 hour. The remaining 20% of trips, which exceed this distance, are performed mostly by 41 Heavy Duty Equipment.

FIGURE 6 EQUIPMENT- ROUTE

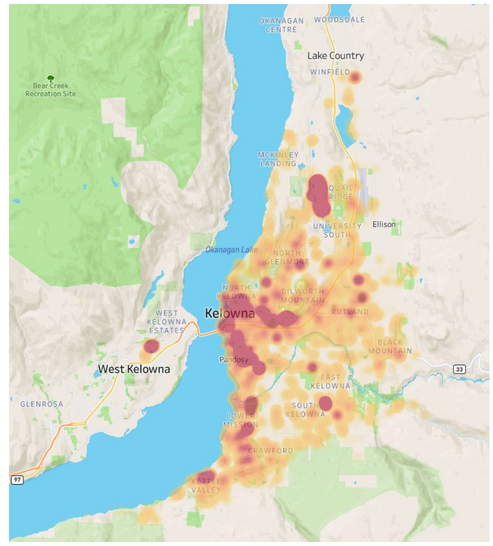


FIGURE 7 DAILY TRIP DISTANCE DISTRIBUTION (KM)- EQUIPMENT

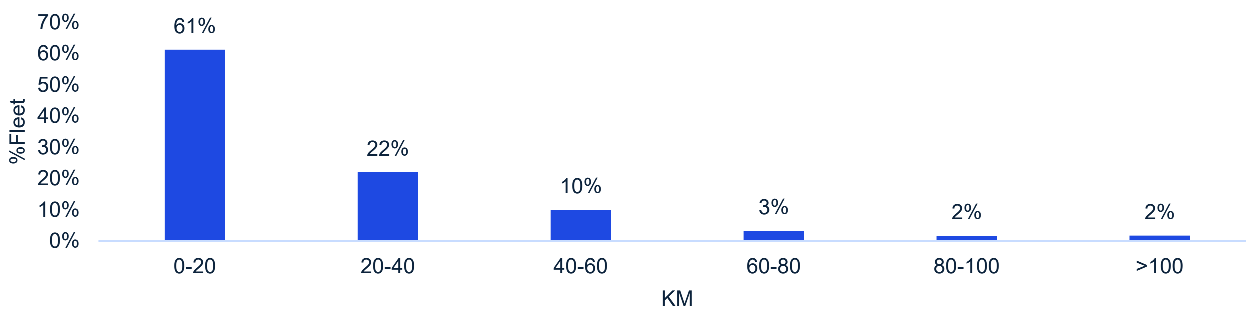
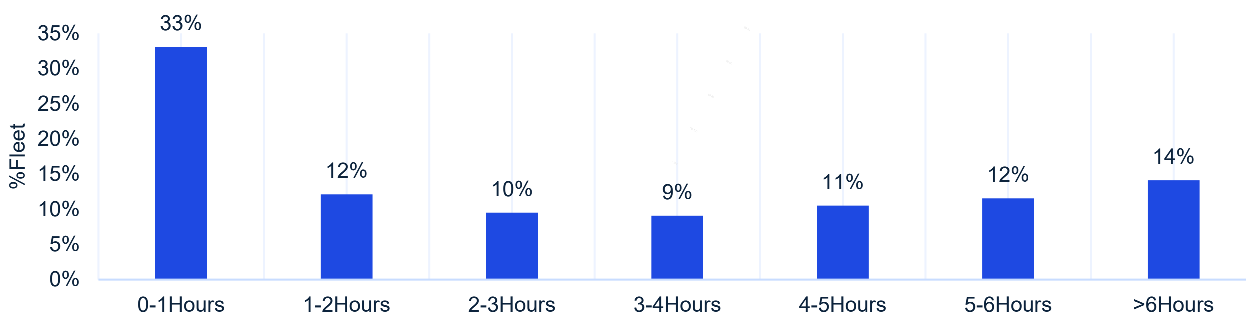


FIGURE 8 DAILY TRIP DURATION DISTRIBUTION (HOUR)- EQUIPMENT



Based on the assessment above, a significant fraction of the equipment operates for more than 5hrs – making the case for alternative technologies where electrification isn't feasible

Fleet Operations: Routes and Locations for Trucks[1]

This sub-group consists of 216 vehicles (77,675 daily trips in 2 fiscal years), including Light Duty Trucks (164), Single Axle Trucks (17) and Tandem Axle Truck (35), which collectively represent 53.2% of the total fleet. Analysis of trip data reveals that 80% of trips fall within 77.5 km, duration of 3.1 hour. The remaining 20% of trips, which exceed this distance, are performed mostly by 115 Light Duty Trucks.

FIGURE 9 TRUCKS- ROUTE

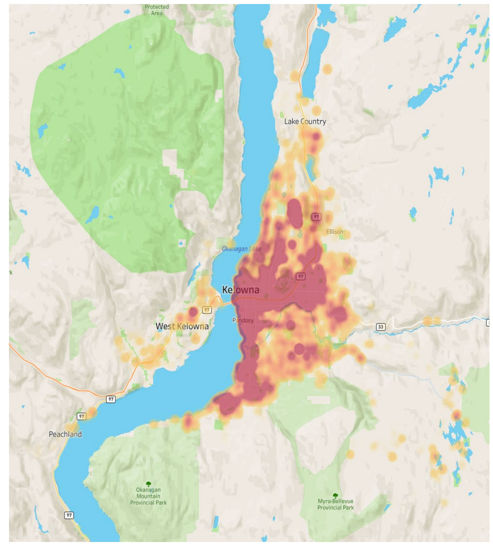


FIGURE 10 DAILY TRIP DISTANCE DISTRIBUTION (KM) - TRUCKS

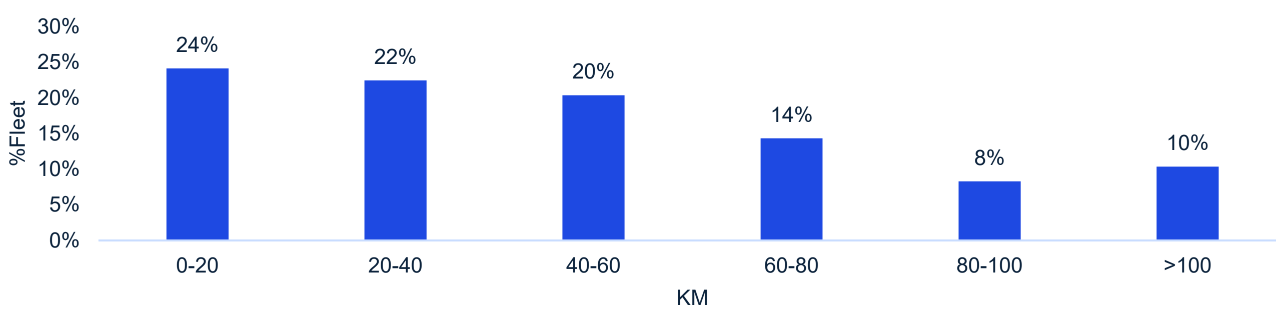
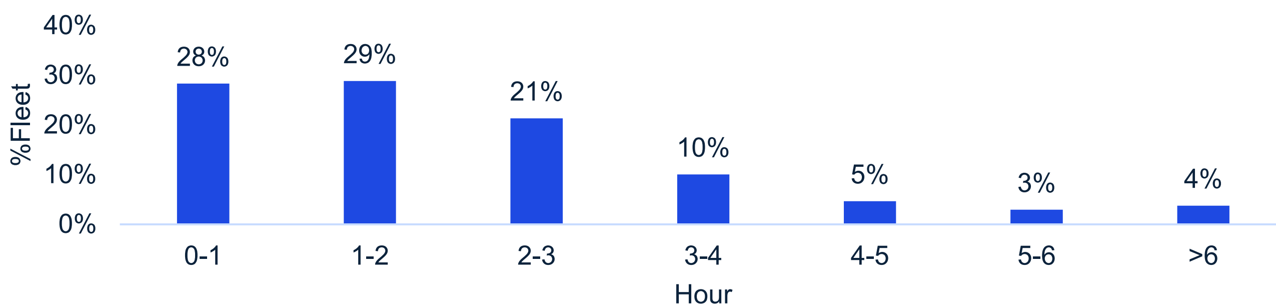


FIGURE 11 DAILY TRIP DURATION DISTRIBUTION (HOUR) - TRUCKS



Based on the assessment above, a signification proportion of trucks operate for more than 4hrs and > 80km – making the case for alternative technologies where electrification isn't feasible, especially in the winter.

Condition: Replacement Cycle

The following section identifies the condition of the current fleet relative to the replacement guide and compares the age of vehicles and equipment identified in the fleet list. Single Axle trucks and Light Duty Equipment have >60% of their fleet above guideline.

TABLE 4 CONDITION OF THE CURRENT FLEET RELATIVE TO THE REPLACEMENT GUIDE (WITH RESPECT TO AGE)

Vehicle Type	Replacement Guideline	Vehicles / Equipment Over Guideline	Percentage Over Guideline
Light Duty Truck	10 years	55 / 151	36%
Tandem Axle Truck	10 years	14 / 35	40%
Single Axle Truck	10 years	11 / 18	61%
Car	10 years	8 / 36	22%
Van	10 years	10 / 34	29%
SUV	10 years	2 / 10	20%
Utility Vehicle	10 – 15 years*	10 / 26	38%
Heavy Duty Equipment	10 – 15 Years*	23 / 75	31%
Light Duty Equipment	7 – 15 Years*	33 / 53	62%
Medium Duty Equipment	10 – 15 Years*	0 / 8	0%
Total		166 / 446	37%

Based on the above analysis, 166 out of 446 vehicles, or 37%, of the fleet are due for replacement based on age.

Condition: Replacement Cycle (Mileage-Hours)

The following section identifies the condition of the current fleet relative to the replacement guide and compares the mileage and hours used for vehicles and equipment identified in the fleet list. Tandem Axle trucks and Heavy-Duty Equipment (73%) have > 60% of their fleet above guideline.

TABLE 5 CONDITION OF THE CURRENT FLEET RELATIVE TO THE REPLACEMENT GUIDE (MILEAGE-HOURS)

Vehicle Type	Replacement Guideline	Vehicles / Equipment Over Guideline	Percentage Over Guideline
Light Duty Truck	150K KM	11 / 151	7%
Tandem Axle Truck	200K KM / 7500 Hours	22 / 35	63%
Single Axle Truck	200K KM / 7500 Hours	8 / 18	44%
Car	150K KM	5 / 36	14%
Van	150K KM	1 / 34	3%
SUV	150K KM	0 / 10	0%
Utility Vehicle	200K KM / 7,500 Hours	3 / 26	12%
Heavy Duty Equipment	10,000 – 15,000 Hours	55 / 75	73%

Vehicle Type	Replacement Guideline	Vehicles / Equipment Over Guideline	Percentage Over Guideline
Light Duty Equipment	500 – 2,500 Hours	24 / 53	45%
Medium Duty Equipment	7,500 Hours	1 / 8	13%
Total		130 / 446	29%

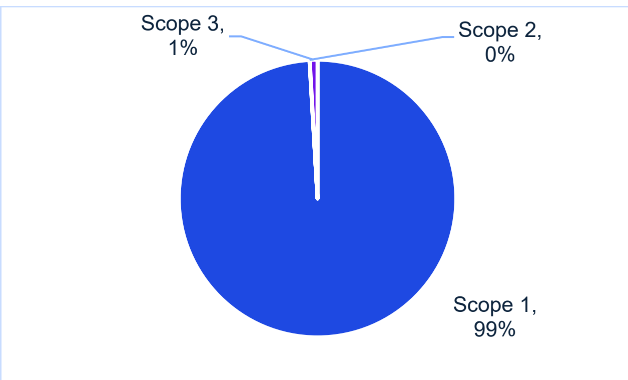
Based on the analysis above, 130 out of 446 vehicles, or 29%, of the fleet are due for replacement based on age.

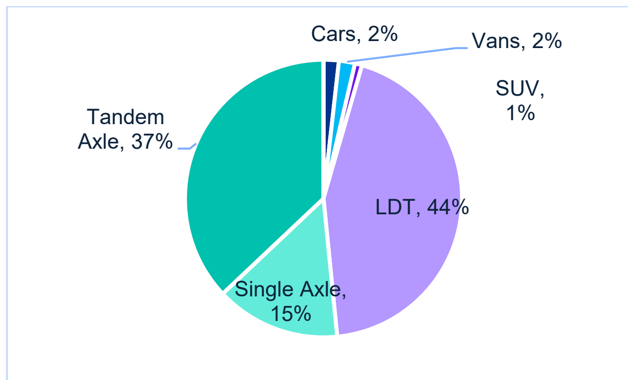
2.1.2 Emissions

Fleet Analysis: GHG Emissions (Percentage Terms)

Virtually all the City's fleet emissions are produced by City-owned vehicles (Scope 1 emissions). These Scope 1 emissions are concentrated in three vehicle classes: heavy duty equipment, light duty trucks, and tandem axle trucks, which make up 95% of total emissions or 1,450 tCO_2e.

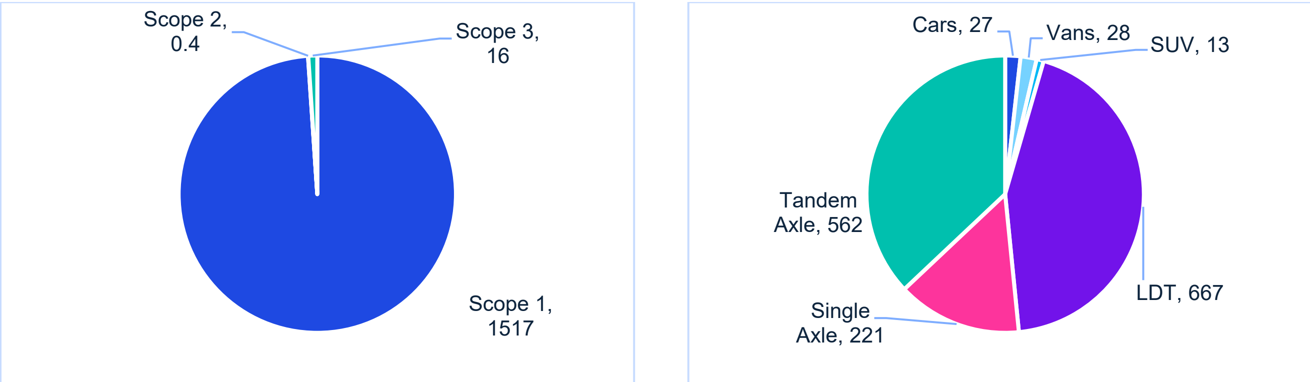
FIGURE 12 EMISSIONS BY SCOPE AND SCOPE 1 EMISSIONS BY VEHICLE CLASS (2024, TCO_2E)





Note: Analysis excludes scope 2 emissions from Flow 1 chargers. Scope 3 includes emissions from employee-owned vehicles and MODO fleet sharing vehicles.

FIGURE 13 EMISSIONS BY SCOPE AND SCOPE 1 EMISSIONS BY VEHICLE CLASS (2024, TCO2E)

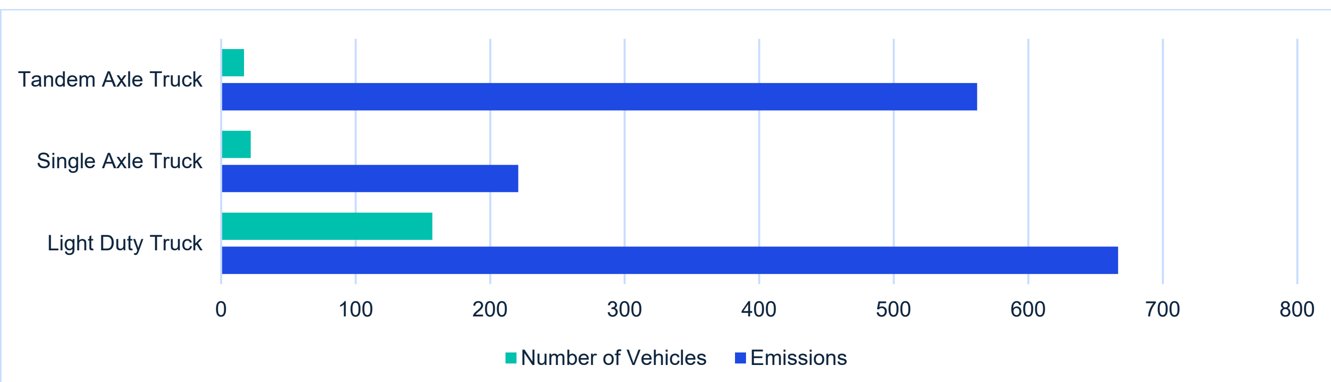


Note: *Analysis excludes scope 2 emissions from Flow 1 chargers. Scope 3 includes emissions from employee-owned vehicles and MODO fleet sharing vehicles.

Fleet Analysis: Vehicle Numbers

While 95% of the emissions are from the light duty truck, single axle truck, and tandem axle truck vehicle classes, there are significantly more vehicles in the light duty truck vehicle class – on a per vehicle basis, replacing vehicles in the single and tandem axle classes with lower-emissions alternatives offers the most significant emissions reduction potential.

FIGURE 14 FLEET ANALYSIS: VEHICLE NUMBERS



With an understanding of the fleet's emissions profile, a decarbonization analysis with two scenarios was conducted. The scenarios are elaborated in the section 3.2.1 Scenario Analysis.

2.2 Charging

2.2.1 Charging Infrastructure: Overview

The table below provides an overview of the level two charging infrastructure that has been installed to date or what is currently in progress and will be installed before the end of the year. The City currently has no Level 3 chargers installed and has no plans to install them.

TABLE 6 OVERVIEW OF LEVEL TWO CHARGING INFRASTRUCTURE

Location	Address	Current Chargers		Planned Chargers		Additional Notes
		Count	Type	Count	Type	
Public Works	1495 Hardy St, Kelowna, BC V1Y 7W9	12	Level Two	9	Level Two	Three (3) of the chargers are being relocated to the Parks Yard. The chargers are installed such that 3 chargers share a 40A circuit.
Parks Yard	1359 KLO Rd, Kelowna, BC V1W 3N8	0	Level Two	8	Level Two	Fortis BC approved a 7.2kW additional load per building, allowing four chargers to load share on a 40A circuit in each. This setup is due to capacity limitations from the existing 75kVA transformer
WWTP	951 Raymer Ave, Kelowna, BC V1Y 4Z7	12	Level Two	6	Level Two	Five (5) of the chargers are being relocated to the Parks Yard and one (1) of the chargers is being relocated to the Construction Yard (3235 Gulley Road). The chargers are installed such that 3 chargers share a 40A circuit.
Landfill	2710-2720 John Hindle Drive, Kelowna, BC V1V 2C5	2	Level Two & EV Kiosk	6	Level Two	A dedicated EV kiosk is installed at the landfill to support fleet EV chargers and an electric Volvo Loader. One Core+ charger is currently operational, but infrastructure is designed to accommodate up to five EV chargers along with the Loader.
Library Parkade	1360 Ellis St, Kelowna, BC V1Y 2A2	0	N/A	16	Level Two	These chargers will be configured with load sharing with 2 groups of 2 chargers sharing a 40A circuit and 4 groups of 3 chargers sharing a 40A circuit.
Field Office	3235 Gulley Rd, Kelowna, BC V1W 4E5	0	N/A	2	Level Two	One level two charger will be relocated from the City Works Yard and installed before the end of November. The electrical infrastructure was installed two support a second EV charger in the same area.

2.2.2 Summary of Current State: Billing Infrastructure

The City uses two main methods to access its charging data, explained below. Both options provide limited access to needed information, which could prove problematic as internal demand for this information grows.

FIGURE 15 OPTIONS TO ACCESS CHARGING DATA

1. Charging Department:	2. Geotab Data:
• At the end of the year, the City's charging department receives a bill for all of the kilowatts used. • There is no submetering in place, Flow provides total usage data. • Flow is the software system responsible for monitoring the Level 2 chargers owned by the City. • This bill is not itemized and is unable to be broken up by department or vehicle.	• To access Geotab data, the City must contact a third-party representative who must write a code to access the Geotab data, every time. • This process is time-consuming and inconvenient, which results in a lack of use and hinders timely decision-making. • The lack of direct access to Geotab data may prevent the City from leveraging this information for strategic planning and operational improvements.

2.3 Maintenance

2.3.1 Key Take-Aways: Challenges & Opportunities

Maintenance Infrastructure

- **Current State:** Asset management is primarily focused on facilities rather than vehicles, which are not clearly identified as assets. The city has a lifecycle replacement plan for vehicles outlined in the 'Corporate Fleet Sustainability Policy-2012,' which also includes utilization targets. While this policy provides a solid foundation, there are opportunities for improvement and updates to ensure it remains effective and relevant.
- **Challenges:** The maintenance shop faces significant constraints due to limited space across all facilities, including ceiling heights that are too low for cranes on larger equipment and a facility that cannot accommodate today's larger vehicles. Outdated infrastructure, such as fuel stations from the 1990s and an unheated equipment barn, leads to inefficiencies. Additionally, minimal storage and only one wash bay, along with repurposed and insufficient office spaces, impact overall operations.
- **Opportunities:** Leverage the 2025 Yards Master Plan to establish benchmarks for the required yard and facility space, accounting for current capacity constraints and future needs, which should be informed by the City's strategic direction and comparative analysis of infrastructure benchmarks of other municipalities.

IT Systems

- **Current Challenges:** The CityWorks system is highly customized which has limited the ability to update the system the result is the fleet team not being able to access system for their needs. The team has limited direct access to conduct their own analysis using the system.
- **Opportunities:** Explore dedicated fleet management software that integrates with CityWorks to meet Fleet's needs while providing necessary data for Asset Management. Evaluate the long-term cost-benefit of transitioning to a modern system versus continuing with CityWorks customizations.

Technician Capacity

- **Current State:** The facility operates with a dozen (12) number of technicians year-round, utilizing shift work during the winter months to manage workloads effectively.
- **Challenges:** Cramped maintenance bays with low ceiling heights lead to difficulties accommodating larger vehicles. A lack of dedicated training and office spaces also impede efficient maintenance operations.
- **Opportunities:** Modernize office and training spaces in future facility planning to support workforce efficiency.

Facility Benchmarking

The objective of Facility Benchmarking is to assess the current dimensions of the facility, and the equipment present at the city, as well as to evaluate whether these resources are adequate relative to industry benchmarks.

- **Current State:** There are 10 bays in total. This includes eight standard bays, one bay for weld & fabrication, one bay for the fire department. The bays have a standard size of **49'L x 13'W X 15'-19'H** and door width of **12'W x 14'H.**
- Key Equipment Include:

- Overhead gantry crane (x1)
- Service Pit (x1)
- Drive-on Hoist (27,000 lb) (x1)
- Jib Crane (x1)

The city currently faces challenges due to insufficient space for managing essential equipment and vehicles, which negatively impacts operational efficiency as noted through engagement sessions.

The existing spatial limitations result in difficulties maneuvering equipment, heightening the risk of vehicle damage, and creating potential operational delays stemming from overcrowded working conditions.

This situation is concerning, especially because industry standards as notes in the next slide highlight the necessity of adequate space not just for storage, but also for safe and efficient access and movement of resources. Hence, it is imperative for the city to reassess its space allocation and explore possibilities for expansion or reorganization to fulfill both present and anticipated operational demands.

Industry Benchmarks – Space

Based on the City's maintenance facility, the following industry benchmarks are applicable:

Bays

- **Space:** 49'L x 13'W X 15'-19'H is inadequate in compared to standards for mixed fleets with extended sizes of: Length: 60-75 feet, Width: 20-25 feet and Height: 20-25 feet. (APWA, NAFA)

Service Pits

- **Space:** Typically, 40'L x 4'-4" D x 3'-6" W (12.2, L x 1.22 D x 1.07 W). The current maintenance bay at the city meets requirements

- **Length:** Should allow technicians to exit from both sides, even with a vehicle positioned over the pit
- **Safety:** Pits should be protected when not in use to prevent falls, and proper lighting and ventilation are essential
- **Clearance:** Allow clearance needed for technicians to move comfortably under vehicles

Crane and Hoist

- **Space:** Depending on the size, cranes require 2.5 to 4.5 meters (8 to 15 feet) of headroom to accommodate their larger size and complex mechanisms. While the current city infrastructure meets many industry benchmarks, there are specific areas that require attention, such as the ceiling height, which is too low for the use of cranes on larger equipment. Addressing these constraints will help ensure the facility can fully accommodate the operational needs of heavy-duty vehicles and equipment.
- **Clearance:** Maintain a minimum clearance of 3 inches overhead and 2 inches laterally from any obstructions like pipes, beams, or walls

Vehicles / Trucks / Trailers

- **Space:** The industry standard for a municipal mixed fleet maintenance facility typically requires larger bay sizes to accommodate heavy-duty vehicles. A minimum width of **20-25 feet** and a length of **60-75 feet** are recommended to ensure sufficient space for maintenance operations. Additionally, ceiling heights should be at least **20-25 feet** to allow for the use of cranes and other equipment. While the current space falls short of meeting some industry benchmarks, the number & capacity of bays available are not sufficient for the size and diversity of the fleet.

Industry Benchmarks – Resourcing

The below table details the current state maintenance staffing with a total of 12 staff. This data is used to benchmark industry best practices using Vehicle Equivalent Units (VEUs) in the next section.

TABLE 7: RESOURCE BENCHMARKING

Shift	Summer July 1 - September 15			Winter - September 15 to July 1		
	Schedule	# Technicians on Duty	Description	Schedule	# Technicians on Duty	Description
Shift 1 (morning) (2-week rotation with shift 2)	6AM - 2:30PM	3 plus Serviceperson and Apprentice	2 - Heavy Duty Mechanics 1 - Automotive Mechanic 1 - Serviceperson 1 - Apprentice (Heavy Duty)	6AM - 2:30PM	3 plus Serviceperson and Apprentice	2 - Heavy Duty Mechanics 1 - Automotive Mechanic 1 - Serviceperson 1 - Apprentice (Heavy Duty)
Shift 2 (afternoon) (2-week rotation with shift 1)	7AM - 3:30PM	3 plus Serviceperson and Apprentice	2 - Heavy Duty Mechanic 1 - Automotive Mechanics 1 - Serviceperson 1 - Apprentice (Heavy Duty)	7AM - 3:30PM	3 plus Serviceperson and Apprentice	2 - Heavy Duty Mechanic 1 - Automotive Mechanics 1 - Serviceperson 1 - Apprentice (Heavy Duty)
Shift 3 (Field Mechanics)	Monday - Thursday 6AM - 4:30PM	1	Heavy Duty Mechanic	Same shift all year round		

Shift	Summer July 1 - September 15			Winter - September 15 to July 1		
	Schedule	# Technicians on Duty	Description	Schedule	# Technicians on Duty	Description
Shift 4 (Field Mechanics)	Tuesday - Friday 6AM - 4:30PM	1	Heavy Duty Mechanic	Same shift all year round		

Resourcing Industry Standard – Vehicle Equivalent Unit-VEU Analysis

Technician/Staff Requirement

Industry standards suggest that each technician can handle approximately **100-120** VEUs.

Using the upper limit for a conservative estimate:

- Required Technicians = Total VEUs / VEUs per Technician
- Required Technicians = 1818 / 120 ≈ **15 technicians**

Using the lower limit for a more demanding estimate:

- Required Technicians = Total VEUs / VEUs per Technician
- Required Technicians = 1818 / 100 ≈ **18 technicians**

TABLE8: VEU ANALYSIS

Vehicle Type	Quantity	VEU per Vehicle	Total VEUs
Car	**32**	**1**	32
Heavy Duty Equipment	68	7	476
Light Duty Equipment	65	3	195
Light Duty Truck	159	2.5	397.5
Medium Duty Equipment	12	3.5	42
Single Axle Truck	34	2.5	85
SUV	12	1.5	18
Tandem Axle Truck	20	5	100
Trailer	2	0.5	1
Utility Vehicle	11	2	22
Van	33	1.5	49.5
Additional Vehicles	100	4	400
Aggregate (VEUs)			**1,818**

Based on the above VEU calculation, a maintenance staff of 12 technicians is insufficient to handle the City's fleet of vehicles (including additional vehicles currently out of scope for this study).

3 Enhanced Future State

3.1 Fleet

3.1.1 Right sizing

A summary of a general right-sizing approach is provided in the table below.

TABLE 9 SUMMARY OF RIGHT-SIZING APPROACH

Definition	Optimizing the number and types of vehicles to meet operational needs efficiently (based on annual utilization benchmarks). Optimizing the number of vehicles refers to removing vehicles from the fleet, while optimizing the types of vehicles refers to changing the vehicle make/model to better suit the requirements of that unit.
Emissions (not including lifecycle emissions)	Generally, leads to lower total GHG emissions by better matching operational needs to vehicle type
Fleet Composition	Optimizes mix for current and future needs by matching the fleet composition to actual usage patterns and demand
Utilization Rates	Maximizes utilization by aligning fleet composition with operational needs and eliminating underutilized assets
Lifecycle Cost Analysis	Typically achieves a lifecycle cost reduction of 10-20%
Maintenance and Repair Costs	By eliminating underutilized vehicles, fleets can lower overall maintenance costs, as fewer vehicles mean less routine maintenance and fewer repairs over time
Public Perception and Community Needs	Seen as favourable by achieving environmental objectives and cost efficiencies
Cost-Benefit Analysis	Benefits generally far exceed the costs and a positive return on investment (ROI) is usually achieved
Impact of Technology on Service Delivery	Optimized technology to enhance operational efficiency
Future Growth Projections	Accounts for future growth projections

Rightsizing Methodology

To deploy right-sizing practices on the City of Kelowna’s municipal fleet, a four-step process was employed: baselining of existing fleet; apply forecasted growth to determine an increase in number of vehicles overtime; adjust for rightsizing; and assign low carbon technologies. Unique situations where vehicles are critically important to specific departments, regardless of utilization rates, were considered. Information from the city ensured essential vehicles were accounted for, rand not candidates for reduction.

FIGURE 16 RIGHTSIZING METHODOLOGY

	Baseline scenarios for comparison		Impact of Optimization/Right Sizing	
Scenario	**01** **Current State / Status Quo**	**02** **Status Quo + Forecast Growth**	**03** **Optimize/Right Size + Forecast Growth**	**04** **Decarbonize + Forecast + Optimize**
Assumptions	Reviewed existing fleet size and related data and how utilization performs against fleet policy guidelines for vehicle replacement/ retirement	Applied a 2% increase in operations (hr & km), absorbed by existing fleet to represent an estimate of growth in municipal operations	Assessed each vehicle within a departmental context for fleet rightsizing optimization The result should be higher average utilization, a fleet optimized for the required service with an improved cost per km	Assessed electric and hydrogen fuelled vehicles (co-combustion and H2-ICE) replacements based on vehicle class availability of technology

Rightsizing Survey Methodology

The rightsizing exercise is preceded by a survey of the City's fleet needs where departments completed a survey describing their operations, payload, towing, passenger and driving requirements. The output of that survey guided the analysis to right-size some of the City's fleet in tandem with best practice utilization benchmarks for each of vehicle class. The methodology for the rightsizing analysis is summarized below.

- **Survey Distribution:** The survey was distributed to all City departments, ensuring comprehensive coverage of the entire municipal fleet.
- **Operational Assessment:** Departments were asked to describe their specific operational requirements, including details on the types of tasks performed and the frequency of vehicle use.
- **Vehicle Specifications:** They survey collected information on payload requirements, towing capability, and passenger capacity for each department's vehicles based on their needs, allowing for a thorough understanding of the necessary vehicle specifications.
- **Driving Requirements:** Departments provided information on their unique driving requirements, such as off-road capabilities, specialized equipment needs, or specific terrain challenges they encounter.
- **Rightsizing Analysis:** The data collected from the survey informed the rightsizing analysis, which was used to inform fleet optimization aligned with best practice utilization benchmarks and validated by City of Kelowna representatives.

Rightsizing Results Summary

This summarized rightsizing analysis is presented on a per department basis. Departments with highly utilized vehicles were not considered when making suggestions for removal or repurposing.

TABLE 10 RIGHTSIZING RESULTS SUMMARY

Scenario		Current State / Status Quo	Status Quo + Forecast Growth	Optimized / Right sized / Electrified
Cars	Units Utilization (km)	32 9,393	32 9,581	30* (18 EV replacements) 10,220
Vans	Units Utilization (km)	31 5,700	31 5,814	18* (18 EV replacements) 10,014
SUV	Units Utilization (km)	13 6,197	13 6,321	8* (8 EV replacements) 10,271
Light Duty Truck	Units Utilization (km)	157 8,581	157 8,753	141* (100 EV replacements) 10,000
Single Axle Truck	Units Utilization (km) Utilization (hr)	22 11,517 442	22 11,747 450	13* (13 Green replacements) 19,970 750
Tandem Axle Truck	Units Utilization (km) Utilization (hr)	17 20,270 996	17 20,676 1016	17* (17 Green replacements) 20,676 1016

Note: *Refers to the total number of vehicles in the fleet required to meet the policy. The value in parathesis indicates how many new EV's or green replacements would be required in the optimized / electrify / rightsized scenario.

Based on the results of the analysis, the suggested path forward for the City could be to reduce or repurpose the number of Cars by two, Vans by 13, Light Duty Trucks by 20, SUV by five, Single Axle trucks by nine and maintain the status quo for Tandem Axle Trucks. These reductions / repurposing in units may contribute to the City reaching fleet target utilization benchmarks as noted in the City's fleet policy. It's important to note that this analysis is conducted at a strategic level and does not consider operational constraints. The key purpose is to identify the optimal number of vehicles to meet the target utilization benchmarks set by the City.

Having completed the right-sizing analysis, we can now review the available low-carbon alternative technologies for each vehicle class to identify decarbonization pathways for the fleet.

3.1.2 Low Carbon Fleet Technology Review

The low carbon fleet technology review provides the basis for the City of Kelowna's Sustainable Fleet Strategy.

- **Hydrogen-based technologies –** For medium and heavy-duty vehicles, hydrogen-powered technologies were identified to be the most promising due the fuel's high energy density and superior payload capacity, which are needed to meet these vehicles' high energy requirements. Given that hydrogen is still early-stage, the associated storage, transportation, and fueling infrastructure is not yet built out, making uptake a challenge for the City. This infrastructure development will largely depend on market forces and external support, highlighting the need for collaboration with industry partners and other stakeholders.

While hydrogen ICE vehicles that are fueled entirely by hydrogen have yet to hit the market, co-combustion retrofits that leverage both hydrogen and diesel for power are an available technology that can provide emission reductions, support hydrogen infrastructure development, and provide the City with experience using hydrogen as a transportation fuel.

- **Electric vehicles (EVs) –** These vehicles have achieved a high Technology Readiness Level (TRL) making them commercially viable options for meeting the City's light-duty fleet requirements. EVs offer a strong solution for decarbonizing municipal transportation, as they align seamlessly with employee mobility patterns and leverage mature energy-efficient powertrain technology. One key advantage of EVs is that the charging infrastructure they require can be implemented and controlled by the City itself. However, there may be some initial range anxiety among employees, which can be addressed through targeted education programs and the strategic expansion of charging infrastructure throughout the city. While EVs are ideal for light-duty applications, such as pickup trucks and smaller vehicles, heavier-duty options remain limited due to their significant power requirements, which can be incompatible with battery power. Companies like Volvo and Daimler AG are making strides in developing heavy-duty electric trucks and buses, but widespread adoption is limited. Hence, the City may need to consider other alternatives for its heavy-duty fleet until more options become available.
- **Hybrid range extenders (HRE) -** These vehicles are emerging as a promising solution for mid-sized trucks, with ongoing development and potential for future market availability. This application should not require additional infrastructure and can be used as a stop-gap measure to achieve fuel economy and lower emission benefits, while maintaining flexibility to operate on longer routes without range limitations.
- **Renewable diesel –** This fuel is being considered as a viable option for emissions reduction that does not require any additional infrastructure or technology, though it comes at a higher cost than conventional diesel. However, the lifecycle emissions for renewable diesel from the City's current supplier represent only an estimated 20% reduction in emissions due to large transportation distances. Securing a new supplier closer to the City can represent a better opportunity for emissions reduction but should be considered holistically with the new supplier's cost.

Alternative Technologies: Comparison

A review of fleet replacement technologies revealed the following potentially viable options summarized in the below table:

TABLE 11 ALTERNATIVE TECHNOLOGIES: COMPARISON

Technology	Hybrid Range Extender	EVs	FCEV	H_2-ICE	Co-Combustion
Definition	Combines an electric powertrain with a gasoline engine acting as a generator.	Powered by electric motors using electricity stored in batteries.	Use hydrogen to power an electric motor through a chemical reaction in a fuel cell, emitting only water vapour and warm air.	A modified version of the traditional gasoline-powered internal combustion engine that uses hydrogen as fuel.	Retrofits can be added to allow vehicles to use traditional fuel and hydrogen fuel simultaneously or individually.
Emissions	Emissions are dependent on the type of fuel consumed during actual use, which varies. Emissions are mostly driven by the ICE engine backup, which usually	Zero tailpipe. Lifecycle emissions are driven by the source of electricity used to charge the vehicle, which may	Zero tailpipe. Lifecycle emissions are driven by the source of electricity used to charge the vehicle, which may	Zero tailpipe. Lifecycle emissions are driven by the source of electricity used to charge the vehicle, which may	Emissions are dependent on the type of fuel consumed during actual use, which varies. Emissions are also driven by the

Technology	Hybrid Range Extender	EVs	FCEV	H_2-ICE	Co-Combustion
	uses unleaded gasoline. Emissions can be higher if the electricity source is not zero-emissions.	not be zero-emissions.	not be zero-emissions.	not be zero-emissions.	power source used to generate hydrogen, which may not be zero-emissions.
Technology	Extended Range EV	Lithium-ion battery	Fuel cell + electric motor	Modified ICE	Retrofit ICE
Fuel flexibility	Electricity + Gas (Unleaded)	Electricity only	Hydrogen only	Hydrogen only	Hydrogen + Diesel
Maintenance	Similar to traditional ICE	Lower than ICE (fewer moving parts)	Lower than ICE (fewer moving parts)	Higher than traditional ICE (expected)	Higher than traditional ICE (expected)
Capital Expenditure	Moderate to High	Moderate to High	High	Moderate	Low to moderate
Operating Expenditure	Low to Moderate	Low to moderate	Low to moderate	Moderate	Moderate
Cold weather performance	Reduced Range	Reduced Range	May face challenges	Good	Good
Refueling time	Similar to conventional	80% in 30 minutes (Level 3)	5-15 minutes	5-15 minutes	Similar to conventional
Vehicle range	Comparable to conventional	Less than conventional	Less than conventional	Comparable to conventional	Comparable to conventional
Infrastructure needs	Electric charging needs	Electric charging stations	Hydrogen stations	Hydrogen stations	Hydrogen stations

Fuel Options: Comparison

A review of fleet fuel options identified the following potentially viable options, summarized in the table below. Each of these fuels plays a significant role in the current energy ecosystem, influencing not only the environmental footprint of fleet operations but also the economic viability of vehicle technology choices.

TABLE 12 FUEL OPTIONS: COMPARISON

Fuel Option	Unleaded Gasoline	Conventional Diesel	Renewable Diesel	Hydrogen	Electricity
Definition	Petroleum-derived fuel used in internal combustion engines	Conventional diesel is a type of fuel derived from crude oil, used primarily in diesel engines	Alternative to conventional diesel fuel derived from fats and oils like canola or soybean instead of crude oil, compatible with existing diesel engines	An energy carrier that can power vehicles through direct combustion or through an electric motor	Electricity as a fuel used in electric motor vehicle whose propulsion is powered fully or mostly by electricity

Emissions	Unleaded gasoline engines produce carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOCs).	Diesel engines emit CO_2, NOx, particulate matter (PM), and hydrocarbons. While diesel engines are more fuel-efficient, they can produce higher levels of NOx and PM.	See slide 'Renewable Diesel - Leading Practice Review'	See slides 'Hydrogen Municipal Fleet Considerations (1-4)'	Zero tailpipe. However, emissions are driven by the source of electricity used to charge the vehicle, which may not be zero-emissions.
Maintenance	Regular oil changes, fuel filter replacements, and spark plug inspections	Oil changes, fuel filter replacements, and monitoring of the fuel injection system	Similar to diesel	Less moving parts but overall higher maintenance cost than ICE	~30% lower than ICE (fewer moving parts)
Cost ($/100km)	$10-15	$10-15	$13-19	$100-120	$1-4
Cold weather performance	Risk of poor performance (starting)	Risk of poor performance (fuel gelling)	Risk of poor performance (fuel gelling)	Hydrogen embrittlement, combustion abnormalities, and high-pressure pump requirements	Reduced Range

3.1.3 Leading Practice Review

Having identified the fuel alternatives at a high level, we now conduct an in-depth leading practice review to highlight the risks and opportunities associated with each fuel type identified in Table 13.

TABLE 13 LEADING PRACTICE REVIEW OF RENEWABLE DIESEL

Dimension	Risks	Opportunities
Emissions	**Tailpipe GHG emissions** from the combustion of renewable diesel are only slightly lower than conventional diesel, limiting local GHG emissions reductions in Kelowna. **Supplier location and feedstock** create significant variability around potential lifecycle emissions reductions. The City's current supplier, Suncor, ships renewable diesel to the City from southeast Asia. Based on transport emissions and the soy feedstock Suncor uses, it is estimated that lifecycle emissions reductions are approximately 20% relative to conventional diesel. At 8.9g CO_2e/MJ, soy as a feedstock has a relatively low- to mid-range emissions intensity/MJ relative to other feedstocks like canola (19.3 gCO_2e/MJ), carinata (15.2 gCO_2e/MJ) and corn oil (1.7 gCO_2e/MJ).	On a lifecycle basis, renewable diesel presents opportunities for real emissions reductions of up to 85%, enabling decarbonization. **Local air emissions:** Renewable diesel significantly reduces non-GHG tailpipe pollutants compared to fossil fuel diesel: • Particulate matter (PM): Reduced by 34-40% • Nitrogen oxides (NOx): Reduced by 10% • Hydrocarbons and carbon monoxide: Reduced by over 20%

Resource Availability	**Resource availability:** The use of agricultural products such as canola for fuel production raises questions about the diversion of resources from food to fuel – particularly in Kelowna, which is known for its fertile land and agricultural output.	**Feedstock alternatives**: Non-food sources such as used cooking oil or animal fats can also be used as feedstock, however, the overall supply of these sources is limited.
Performance	**Cold-weather performance:** It is understood that the City has faced challenges with the cold-weather performance of the renewable diesel sourced from its current supplier, Suncor, though this may not be an issue with other suppliers.	**Engine and infrastructure compatibility:** Renewable diesel meets the conventional petroleum ASTM D975 specification allowing it to be used in existing diesel engines and diesel fueling, transport, and storage infrastructure. Renewable diesel is fully interchangeable with diesel (i.e., 'drop-in' fuel) or be blended in any ratio without performance degradation.
Costs	**Higher than conventional diesel:** Renewable diesel is more expensive than conventional diesel and is currently being sourced by Kelowna at a premium of $0.25.	**Future cost-competitiveness:** It's expected that renewable diesel is likely to become cost competitive with conventional diesel over time under future carbon pricing scenarios.

Leading Practice Review: Hydrogen

A summary of hydrogen risks and opportunities are provided in **Table 14**.

TABLE 14 LEADING PRACTICE REVIEW OF HYDROGEN

Dimension	Risks	Opportunities
Emissions	**Nitrogen oxide emissions:** Hydrogen ICE engines are typically associated with increased production and emission of nitrogen oxides (NOx) due to the high temperatures required for hydrogen combustion. A preliminary study by UBC in partnership with Hydra Energy of co-combustion engines found that the truck's emission control systems can handle the increased NOx emissions with no net increase in NOx output to the environment. However, the technology is still early-stage and NOx emissions from hydrogen ICE vehicles in practice need to be monitored and better understood over time.	**Emissions reductions from co-combustion:** A study conducted by UBC in partnership with Hydra Energy found that co-combustion engines found that hydrogen replaced 25% of the truck's diesel consumption and resulted in approximately the same amount (~25% decrease) in CO2 emissions. **Emission reductions from hydrogen ICE:** Hydrogen ICE vehicles can offer significant GHG reductions compared to conventional diesel engines. The extent of this reduction largely depends on the hydrogen production method. Using B.C. clean electricity allows production to be relatively low-emissions, though the grid is not net-zero.
Resource Availability	**Hydrogen supply:** Securing a reliable supply of hydrogen and hydrogen vehicles may be challenging due to increasing demand and limited supply. These resources may be prioritized for other sectors, potentially delaying the City's access to these critical components.	**Early-stage adoption:** As an early-stage adopter, Kelowna may be able to secure a reliable hydrogen supply at a lower cost.
Costs	**Higher cost:** Hydrogen is much more expensive than any other fuel on a per-km basis, making marginal abatement costs very high.	**Funding Opportunities:** Hydrogen fueled vehicles could be supported by public funding opportunities to support further integration of these vehicles into Kelowna's fleet.

External	**Public Perception:** The potential for hydrogen as a viable fuel source in Kelowna depends significantly on public perception and acceptance. The severe climate change and safety consequences of hydrogen leakage may deter public support for hydrogen-fueled fleets and limit future market adoption.	Several hydrogen projects are ongoing in BC, pointing towards market development: Green Hydrogen Production Projects: Quantum Technology is developing a green hydrogen production plant on Vancouver Island, and the Steward Hydrogen Project in Stewart, B.C., focuses on producing green hydrogen for the transportation sector. CP Rail's Hydrogen Pilot Project: CP Rail is retrofitting locomotives with hydrogen fuel cell technology and producing hydrogen using small electrolysers. H2 Gateway Project: This project will establish 20 refueling stations and three hydrogen production facilities, enabling the decarbonization of heavy-duty transportation.
Feasibility	• **Infrastructure limitations:** Hydrogen production, storage, distribution, and fueling infrastructure is limited in Kelowna and requires development. Due to the low density and high flammability of hydrogen, it requires specialized transportation and storage, making such infrastructure development complex and expensive. Other challenges related to developing hydrogen infrastructure include permitting complexities and significant electrical upgrades needed for operational stations. Notably, these infrastructure deficiencies are widening as hydrogen demand increases rapidly. • **Specific Storage Requirements:** Hydrogen gas is typically stored at either 350 bar or 700 bar, with vehicle's on-board storage usually at 350 bars. The City currently only has one, limited 700 bar sources at its HTEC facility, which is incompatible with on-board storage requirements. There is also no local production at the facility, it only includes storage. The City will require reliable access to 350 bar hydrogen production and storage in the long-term as hydrogen uptake increases. • **Technological Maturity:** While H2-ICE is promising, it is still in the development phase and is not yet commercially available. There may be technical challenges that need to be addressed before it can be widely adopted, which can reasonably be expected to result in delays in market release. Due to its early stage, there is also significant uncertainty around the timing of the technology availability, cost, and viability for adoption.	

Leading Practice Review: Electric Vehicles

A summary of electric vehicle risks and opportunities are provided in Table 15

TABLE 15 LEADING PRACTICE REVIEW – ELECTRIC VEHICLES

Topic	Risks	Opportunities
Emissions	N/A	**BC's Clean Grid:** The environmental benefits of EVs are dependent on the sources of electricity used to charge them. With 98% of BC's electricity coming from clean or renewable sources, EVs charged in BC produce minimal GHG emissions during operation. As BC continues to invest in clean energy technologies and diversify its renewable energy mix, the grid is likely to become even lower emissions. This trend supports the increasing adoption of EVs by ensuring that their environmental benefits are realized.
Resource Availability	**Battery Disposal and Recycling:** The environmental impact of battery production and disposal is a concern. As EV adoption increases, the need for effective recycling and disposal methods for used batteries will become more pressing.	**Existing Battery Recycling Options in Kelowna:** Kelowna currently has several battery recycling facilities such as The Battery Doctors, ABC Recycling Kelowna, Interstate All Batter Center, and Canadian Energy Kelowna, amongst others.

Costs	**Higher upfront investment:** EVs remain more expensive at initial purchase prices than their conventional counterparts.	**Total Cost of Ownership:** Despite higher initial purchase prices, electric light-duty vehicles often have a lower total cost of ownership compared to their gasoline counterparts due to reduced fuel and maintenance expenses.
Feasibility	**Infrastructure Updates:** The City and FortisBC may need to invest in upgrading electrical systems in municipal facilities to support an increased number of EVs in its fleet. **Charging Time:** While charging times are decreasing, they can still be longer than refueling a gasoline vehicle.	**Technological Advancements:** Continuous improvements in battery technology are leading to longer ranges and shorter charging times for EVs.

Whether and how the City should employ renewable diesel, hydrogen, or electric vehicles must be considered alongside utilization, vehicle requirements, technology availability, etc. These considerations are built into the NPV, MAC, and other metrics that enable direct comparisons of alternative technology initiatives and should therefore drive decision-making at the City. Please see results of the Scenario Analysis for these metrics.

Selecting H2-Fueled Alternatives: FCEVs vs. Hydrogen ICE

A review of the two technologies fueled entirely by hydrogen, FCEVs and hydrogen ICE, was conducted to identify the most appropriate option for the City's applicability and cost requirements.

Applicability

- FCEVs are efficient at lower loads but struggle with high-power, heavy-duty applications such as dump trucks or snowplows. These are critical components of Kelowna's fleet.
- H_2ICE vehicles, on the other hand, excel in heavy-duty and transient operations due to their robust engine design and ability to handle high loads without additional hybrid systems. Medium-duty vehicles could benefit from H_2ICE technology where BEV range or payload capacity is insufficient.

* Note that for lighter vehicles like cars and SUVs, BEVs are deemed a better fit due to their higher efficiency and well-developed charging infrastructure.

Costs

- **Vehicle Costs:** FCEVs generally have higher upfront costs due to expensive fuel cell stacks and hydrogen storage systems. H_2ICE vehicles leverage existing ICE technology with modifications for hydrogen combustion, resulting in lower capital costs.
- **Maintenance Costs:** H_2ICE vehicles have maintenance requirements similar to traditional ICE vehicles, which Kelowna's fleet maintenance teams are already equipped to handle. FCEVs require specialized maintenance for fuel cells and related systems, potentially increasing operational costs.
- **Infrastructure Costs:** Both FCEVs and H_2ICE vehicles require hydrogen refuelling infrastructure. However, H_2ICE refuelling can integrate more easily into existing depot-based fuelling setups without extensive changes.

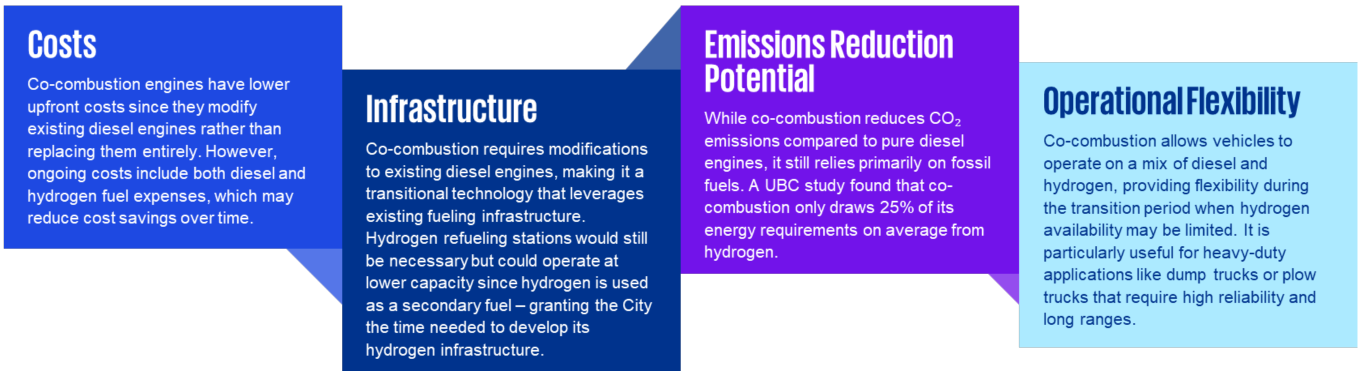
Overall, hydrogen ICE vehicles align better with the City's vehicle requirements at a lower cost and are thus chosen as the preferred alternative low-carbon technology for heavy and medium-duty applications in the long-term.

Having identified that Hydrogen ICE vehicles are more aligned to the City's requirements, it is important to consider short-term solutions, as these Hydrogen ICE vehicles are not yet available on the market.

H2-Fueled Alternatives: Co-Combustion as a Short-Term Solution

The figure below illustrates the benefits of hydrogen co-combustion

FIGURE 17 HYDROGEN CO-COMBUSTION BENEFITS



Hydrogen co-combustion offers a gradual transition towards hydrogen due to its lower upfront costs and compatibility with existing diesel engines. It provides immediate GHG reductions while leveraging current infrastructure. Kelowna could adopt a phased approach—starting with co-combustion in the short term while gradually transitioning to hydrogen ICE vehicles as hydrogen fuel availability and infrastructure improve.

3.2 Low-Carbon Model Alternatives Summary

Lower-carbon models were identified for each vehicle class with consideration for vehicle requirements and market availability. The following table outlines the rationale for the selection of the models used as replacements for each vehicle class.

TABLE 16 RATIONALE FOR THE SELECTION OF THE MODELS

Vehicle Class	Identified Models for Replacement	Rationale
Cars	• Kona EV • Nissan Leaf SV EV • Toyota Prius Plug-in Hybrid Electric Vehicle (PHEV)	• Kona EVs and Leaf SV EVs are the makes/models already in use by the City. The fleet also currently includes the Ford Focus EV, however it has been discontinued and therefore is not proposed as an option for model replacement. • In certain cases, City staff respondents noted specific requirements for long-distance, out-of-town travel where charging opportunities may be limited; here, the Toyota Prius PHEV is suggested for model replacement.

Vehicle Class	Identified Models for Replacement	Rationale
Vans	• Ford E-Transit • Ford F150 EV (with a canopy)	• The Ford E-Transit is one of the most commercially available EV vans that meets the larger load and space requirements of full-size van. • While some mid-size vans could have been downsized to a smaller EV such as the Chrysler Pacifica Hybrid or Volkswagen ID Buzz, the City noted a preference for Ford vehicles where possible due to existing contracts and/or trained maintenance labour. • Where City staff noted requirements for larger size and/or a canopy, the Ford F150 EV with a canopy was recommended as the replacement option for some, but not all midsize vans.
SUVs	• Subaru Soltera	• The Subaru Solterra is recommended as the electric SUV to align with the City's operational needs and preferences. By focusing on a brand like Subaru, the City can ensure consistency in service management and parts availability, similar to the strategy the City employs with Ford. • The Ford F-150 EV is the recommended replacement for 0.5-to-1-ton trucks, due to its commercial availability and alignment with City staff requirements. The F-150 EV is also the recommended replacement option for F250 and F350 models that could be downsized based on their requirements. However, the direct replacement option for F250 and F350 models are hybrid range extenders.
Light Duty Trucks Replacement A[2]	• Ford F-150 EV • Hybrid Range Extender	• The Ford F-150 EV is the recommended replacement for 0.5-to-1-ton trucks, due to its commercial availability and alignment with City staff requirements. The F-150 EV is also the recommended replacement option for F250 and F350 models that could be downsized based on their requirements. However, the direct replacement option for F250 and F350 models are hybrid range extenders.
Light Duty Trucks Replacement B[2]	• B 6.7 hydrogen internal combustion engine (H2 ICE)	• Once available, the B6.7 H2 ICE is recommended based on vehicle size and requirement compatibility for F250s-F350s.
Single Axle Trucks Replacement A[2]	• Hybrid Range Extender • Co-Combustion • Conventional internal combustion engine (ICE)	• Hybrid range extenders are replacements for F-series trucks due to the engine compatibility and power requirement alignment. • Co-combustion is piloted for one single-axle truck as it was deemed the only vehicle viable for this technology based on its size and fuel consumption. • In some instances, vehicles are due for replacement and a lower-emissions alternative is not available, so the baseline option (conventional ICE) is used as a replacement.
Single Axle Trucks Replacement B2	• B6.7 hydrogen internal combustion engine (H2 ICE) • X15 hydrogen internal combustion engine (H2 ICE) • Conventional ICE	• Once available, X15 H2 ICE and B6.7 H2 ICE are recommended based on vehicle size and requirement compatibility. • Due to their lower cost point and alignment with the City's higher-duty applications, H2 ICE vehicles were identified as the most viable technological solution that meets the requirements of this vehicle class.

Vehicle Class	Identified Models for Replacement	Rationale
Tandem Axle Trucks Replacement A2	• Conventional ICE	• Co-combustion is piloted for three tandem trucks to assess the viability of the technology for the City. In this case, vehicles with high fuel use are prioritized. It is assumed that the technology is proven successful during the pilot and is then rolled out based on attrition for a total of 12 co-combustion vehicles (one in single axle trucks, the remainder tandem axle), with continued prioritization of vehicles with high fuel use. High fuel use is defined as 2400 L/year. • In some instances, vehicles are due for replacement and a lower-emissions alternative is not available, so the baseline option (conventional ICE) is used as a replacement.
Tandem Axle Trucks Replacement B2	• X15 H2 ICE	• Once online in 2029, X15 H2 ICE vehicles recommended. These are the expected market-leading low-carbon alternatives that meet the requirements and specifications of the vehicle class. • Due to their lower cost point and alignment with the City's higher-duty applications, H2 ICE vehicles were identified as the most viable technological solution that meets the requirements of this vehicle class.
Utility Vehicles	• N/A	• As yet, there are no viable low-carbon alternatives on the market that meet the specific requirements for these vehicles.
Medium Duty Equipment	• N/A	• As yet, there are no viable low-carbon alternatives on the market that meet the specific requirements for these vehicles.
Heavy Duty Equipment	• N/A	• As yet, there are no viable low-carbon alternatives on the market that meet the specific requirements for these vehicles.

Note: [1] Vehicle models that are being replaced with the same model at attrition are not included above, as they are considered a BAU case.

[2] Two sets of replacements are recommended for single axle and tandem axle trucks due to H_2 ICE models becoming available on the market in 2029 and 2033 for X15 and B6.7 vehicles, respectively. Hybrid range extenders are expected to come online in 2029.

3.2.1 Scenario Analysis

Scenario Analysis Overview

The City of Kelowna is looking to lower the emissions from its fleet by replacing its current fleet with newer, low-emissions technologies. The technologies considered for each vehicle class are noted in the section above. The scenario analysis is the cumulative result of all previous analyses, including attrition, right-sizing for model and type of vehicle, technology and model applicability, and pilots. The aggressive and moderate scenarios are presented as scenarios 1 and 2 below.

Analysis suggests that replacement options are limited – generally only one alternative technology is available at a given point in time, and many technologies in the analysis are not yet on the market. This led to the development of two scenarios that differ only on **a temporal basis (i.e., *when* the purchase is made, but not *what*** is being purchased**).** Therefore, the two scenarios have similar cost and emissions reductions in the aggregate but different implications for these factors over time.

FIGURE 18 TWO SCENARIOS

SCENARIO 1	***SCENARIO 2***
Based on a strategy of adopting new technologies as soon as they become available without retiring existing assets before the end of their useful life. • 2029 X15 H_2 ICE availability • 2033 B6.7 H_2 ICE availability	Based on an assumed delay in the release of new technologies to market, resulting in extending the duration of temporary alternatives like co-combustion and hybrid range extenders. • 2033 X15 H_2 ICE availability • 2037 B6.7 H_2 ICE availability

The following table outlines the timing of replacement technology for different vehicles classes for the assessment of two strategic scenarios looking out to 2050. While Scenario 1 optimizes replacement with alternative technologies as soon as the vehicle is ready for replacement and the technology is expected to be available, Scenario 2 considers that the release of H_2 ICE engines will be delayed. The scenario analyses assume that the co-combustion pilot is successful and is thus rolled out to the wider fleet.

TABLE 17 TIMING OF REPLACEMENT TECHNOLOGY

<table>
<tr><th rowspan="2">Vehicle Class</th><th colspan="4">Scenario 1</th><th colspan="4">Scenario 2</th></tr>
<tr><th>2025-2027</th><th>2027-2029</th><th>2029-2033</th><th>2033-2050</th><th>2025-2027</th><th>2027-2029</th><th>2029-2032</th><th>2033-2050</th></tr>
<tr><td>Cars</td><td colspan="4">Replace with EVs based on attrition</td><td colspan="4">Replace with EVs based on attrition</td></tr>
<tr><td>SUVs</td><td colspan="4">Replace with EVs based on attrition</td><td colspan="4">Replace with EVs based on attrition</td></tr>
<tr><td>Vans</td><td colspan="4">Replace with EVs based on attrition</td><td colspan="4">Replace with EVs based on attrition</td></tr>
<tr><td>Light Duty Trucks (LDTs) (F150-F350)</td><td colspan="2">F150: Replace with EVs</td><td>F150: Replace with EVs
F250-350: Range extenders or downsize to F150 EV</td><td>F150: Replace with EVs
F250-350: X6.7 H_2 ICE as needed</td><td colspan="2">F150: Replace with EVs</td><td>F150: Replace with EVs
F250-350: Range extenders or downsize to F150 EV</td><td>F150: Replace with EVs
F250-350: X6.7 H_2 ICE as needed</td></tr>
<tr><td>Single Axle Trucks</td><td>Pilot Co-combustion for one vehicle.
Other vehicles requiring replacement to be replaced with conventional ICE.</td><td>Retrofit with co-combustion to a maximum of 12 vehicles between classes
Other vehicles requiring replacement to be replaced with conventional ICE.</td><td>Range extenders</td><td>X6.7 H_2 ICE</td><td>Pilot Co-combustion – 1 vehicle for 1 year
Other vehicles requiring replacement to be replaced with conventional ICE.</td><td>Retrofit with co-combustion to a maximum of 12 vehicles between classes
Other vehicles requiring replacement to be replaced with conventional ICE.</td><td>Range extenders</td><td>X6.7 H_2 ICE</td></tr>
</table>

Vehicle Class	Scenario 1				Scenario 2			
	2025-2027	2027-2029	2029-2033	2033-2050	2025-2027	2027-2029	2029-2032	2033-2050
Tandem Axle Truck	Pilot Co-combustion 3 vehicles. Other vehicles requiring replacement to be replaced with conventional ICE.	Retrofit with co-combustion to a maximum of 12 vehicles Other vehicles requiring replacement to be replaced with conventional ICE.	X15 H_2 ICE		Pilot Co-combustion – 3 vehicles for 1 year Other vehicles requiring replacement to be replaced with conventional ICE.	Retrofit with co-combustion to a maximum of 12 vehicles Other vehicles requiring replacement to be replaced with conventional ICE.	X15 H_2 ICE	

Scenario 1: Overall Emissions Reductions and CAPEX

With the technologies modelled, the City is able to achieve 69% emission reductions for its fleet in 10 years. It falls short of the City's targeted 40% reduction by 2030, achieving only a 38% reduction by 2030. While the City is able to achieve a 95% reduction of GHG emissions by 2050, it is not able to achieve their stated goal of net-zero by 2050 from a fleet perspective due to emissions from electricity consumption from the provincial grid, which is not net-zero.

Over BAU, emissions can be reduced by:

- 69% in 2035 (1,040 tCO_2e),
- 87% in 2040 (1,317 tCO_2e), and
- 95% in 2050 (1,463 tCO_2e)

Total additional CAPEX needed (undiscounted):

- Incremental CAPEX until 2035: $11,598,524
- Incremental CAPEX for project life: $77,308,140

FIGURE 19 CITY OF KELOWNA'S BAU VS SCENARIO 1 EMISSIONS REDUCTIONS (2025-2050)

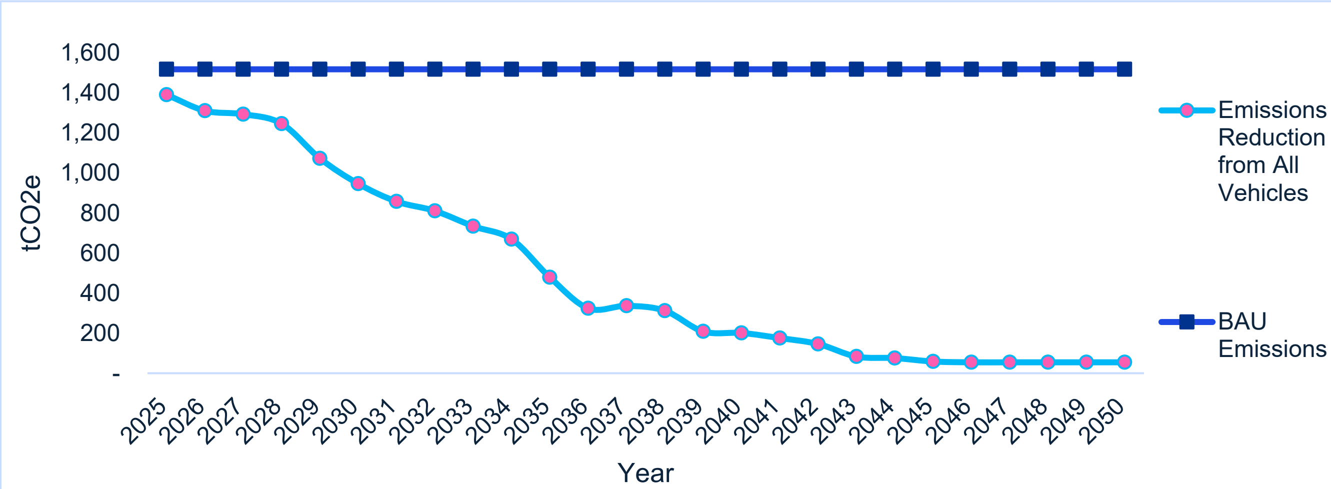


TABLE 18 SCENARIO 1 FINANCIAL AND EMISSIONS METRICS

Initiatives	Net Present Value (NPV)	Cumulative emission reductions (tCO2e)	Incremental CAPEX Spend (Negative is savings)	Incremental OPEX Spend (Negative is savings)	Total undiscounted CAPEX	MAC **(per tCO2e)**	ROI
Cars							
Hybrid EV Replacement	$2,228	511	$604,543	($328,488)	($4)	54%	Hybrid EV Replacement
Unleaded EV Replacement	$113,496	136	$62,648	($96,945)	($837)	155%	Unleaded EV Replacement
Unleaded Hybrid Replacement	($28,223)	10	$35,557	$ -	$2,706	0%	Unleaded Hybrid Replacement
LDT							
Unleaded to HRE	$2,032,455	844	($2,162,195)	$396,194	($2,408)	18%	Unleaded to HRE
Unleaded to EV	$805,870	6995	$3,982,137	($2,924,455)	($115)	73%	Unleaded to EV
Diesel to HRE	$108,991	41	($124,177)	$21,661	($2,627)	17%	Diesel to HRE
Diesel to EV	($47,667)	87	$83,466	($26,337)	$550	32%	Diesel to EV
Unleaded to B6.7 H2 ICE	($14,274,312)	3994	$11,458,389	$463,902	$3,574	-4%	Unleaded to B6.7 H2 ICE
Diesel to B6.7 H2 ICE	($842,849)	170	$682,462	$23,217	$4,965	-3%	Diesel to B6.7 H2 ICE
Single Axle							

Initiatives	Net Present Value (NPV)	Cumulative emission reductions (tCO2e)	Incremental CAPEX Spend (Negative is savings)	Incremental OPEX Spend (Negative is savings)	Total undiscounted CAPEX	MAC **(per tCO2e)**	ROI
Diesel to B6.7 H2 ICE	($63,774)	269	$149,169	$36,619	$237	-25%	Diesel to B6.7 H2 ICE
Unleaded to HRE	$1,751,722	724	($1,505,813)	$153,110	($2,420)	10%	Unleaded to HRE
Diesel to HRE	$346,445	48	($371,012)	$38,532	($7,283)	10%	Diesel to HRE
Diesel to Co-Combustion	($139,688)	46	$129,318	$32,965	$3,039	-25%	Diesel to Co-Combustion
Diesel to B6.7 H2 ICE	($3,406,978)	819	$3,574,610	$197,867	$4,159	-6%	Diesel to B6.7 H2 ICE
Diesel to X15 H2 ICE	($717,086)	251	$782,863	$46,657	$2,860	-6%	Diesel to X15 H2 ICE
Unleaded to B6.7 H2 ICE	($1,275,993)	1055	$1,783,342	$131,873	$1,209	-7%	Unleaded to B6.7 H2 ICE
SUV							
Hybrid EV Replacement	$29,285	24	$6,879	($23,514)	($1,231)	342%	Hybrid EV Replacement
Unleaded EV Replacement	$56,912	249	$222,396	($137,665)	($228)	62%	Unleaded EV Replacement
Tandem Axle							Tandem Axle
Diesel to Co Combustion	($126,156)	906	($1,204,233)	$596,096	$139	50%	Diesel to Co Combustion
Diesel to X15 H2 ICE	($17,216,969)	7545	$9,771,164	$1,309,674	$2,282	-13%	Diesel to X15 H2 ICE
Vans							
Unleaded EV Replacement	($790,583)	647	$1,759,001	($599,333)	$1,222	34%	Unleaded EV Replacement

- MAC is calculated by taking NPV and dividing it by the cumulative reduction in emissions
- A negative MAC indicates that the City is experiencing net cost savings for every tonne of GHG emissions reduced, even after accounting for capital expenditure (CAPEX). These savings come from reduced operational costs, primarily in maintenance and fuel
- A negative OPEX indicates that the City is experiencing net cost savings
- ROI is calculated by taking the total incremental OPEX and dividing it by the total incremental CAPEX.

An in-depth analysis of these results by vehicle class is noted on the following pages.

Scenario 1 Financial and Emissions Metrics: Cars

- On a per-kilometer basis, the City's unleaded cars emit approximately 2.5 times more emissions than their hybrid counterparts. Therefore, the greatest reduction in emissions for cars can be achieved by transitioning unleaded vehicles to EVs on a per-vehicle basis. However, above, the cumulative emissions reductions are higher for hybrids because there are many more hybrids in the fleet than there are unleaded cars.
- The most cost-effective approach for emissions abatement is unleaded cars moving to EVs, largely due to the reduced fuel and maintenance (OPEX) costs.
- In general, moving to EVs represents a negative MAC, or very low positive MAC for the City, indicating savings or low costs for each tonne of emissions abated. Furthermore, the acquisition of these vehicles proves to be a strong investment, delivering a return on investment (ROI) ranging from ~50% to 150%.

Scenario 1 Financial and Emissions Metrics: SUVs and Vans

- There is only one alternative technology option for vans and SUVs – EVs. These represent a strong investment due to the expected reduction in fuel and maintenance costs.
- MAC for SUV EV transitions is negative, indicating savings, while the MAC for vans is positive, indicating cost. This is due to the significantly higher CAPEX differential between unleaded vans and their EV replacement, versus the CAPEX differential between hybrid or unleaded SUVs and their EV replacement. However, the initiative still has positive ROI, which indicates that the OPEX savings outweigh the CAPEX investment over time.

Scenario 1 Financial and Emissions: Unleaded to EV Comparison

The transition from Unleaded to EVs represents different MACs across the vehicle classes. EVs always represent maintenance (OPEX) savings, however, for vans, the NPV is negative as EV vans' CAPEX is much higher than their conventional counterparts. Conversely, differential between the conventional option and the EV option for the other vehicle classes is not much higher.

Scenario 1 Financial and Emissions Metrics: Light Duty Trucks

- Moving from Unleaded to EV versus Diesel to EV represents higher energy savings due to the higher cost of renewable diesel. This is also reflected in the MAC.
- Due to the assumption of higher OPEX and CAPEX for H2 ICE vehicles (i.e., CAPEX for H2 ICE is $130,000 more than the conventional alternative), the ROI for H2 ICE engines are negative and represent high costs per tonne abated.
- Transitioning to hybrid range extenders has a positive NPV and a negative MAC (in other words, results in savings) due to the relatively low CAPEX investment required for the hybrid range extenders (estimated at $21,000)
- Emissions abatement for diesel single axle trucks is tempered by the existing use of renewable diesel. However, the costs associated with renewable diesel are fully incorporated into these calculations and are reflected in the higher ROI of unleaded to hydrogen.
- The CAPEX and OPEX projections for range extender and hydrogen vehicles are subject to significant uncertainty. This is due to the anticipated market release of these technologies being four years away, even under optimistic timelines. Consequently, any financial analysis pertaining to these emerging vehicle types should be interpreted with caution.

Scenario 1 Financial and Emissions Metrics: Single Axle Trucks

- Due to the assumption of higher OPEX and CAPEX for H2 ICE vehicles, the ROI for H2 ICE engines are negative and represent high costs per tonne abated.
- The future cost of these vehicles, regardless of if they are low carbon, is projected to be significantly higher than current models. This increase in base vehicle cost negatively impacts the MAC, even though it's not directly related to emission reduction efforts. Consequently, the MAC calculations for hydrogen vehicles suggest that emission reduction efforts are less cost-effective than they truly are, as they include cost increases unrelated to emission reduction technologies.
- Transitioning to hybrid range extenders has a positive NPV and a negative MAC (in other words, results in savings) due to the relatively low CAPEX investment required for the hybrid range extenders (estimated at $21,000)
- Emissions abatement for diesel single axle trucks is tempered by the existing use of renewable diesel. However, the costs associated with renewable diesel are fully incorporated into these calculations.
- The CAPEX projections for single-axle hydrogen and range extender vehicles are subject to significant uncertainty. This is due to the anticipated market release of these technologies being four to eight years away, even under optimistic timelines. Consequently, any financial analysis pertaining to these emerging vehicle types should be interpreted with caution.

Scenario 1 Financial and Emissions Metrics: Tandem Axle Trucks

- Due to the assumption of higher OPEX and CAPEX for H2 ICE vehicles (i.e., CAPEX H2 ICE is $130,000 more than the conventional alternative), the ROI for H2 ICE engines are negative and represent high costs per tonne abated.
- The future cost of these vehicles, regardless of if they are low carbon, is projected to be significantly higher than current models. This increase in base vehicle cost negatively impacts the MAC, even though it's not directly related to emission reduction efforts. Consequently, the MAC calculations for hydrogen vehicles suggest that emission reduction efforts are less cost-effective than they truly are, as they include cost increases unrelated to emission reduction technologies.
- Emissions abatement for diesel tandem axle trucks is dampened due to the existing use of renewable diesel. However, the costs of using renewable diesel are incorporated into these calculations.
- The CAPEX and OPEX costs for tandem-axle hydrogen and co-combustion vehicles are highly uncertain – particularly for hydrogen ICE vehicles, which are not to be released for another four to eight years under a best-case scenario.

3.3 Scenario Comparison

Scenarios 1 and 2 compare the emissions reduction pathways and associated financial metrics between an "on-time" and "delayed" release of hydrogen internal combustion engine technologies. Given that these technologies are only considered alternatives for vehicles in the light-duty, single axle, and tandem axle trucks, the emissions pathways for only those vehicle classes are highlighted – those for cars, SUVs, and vans have not changed from scenario 1.

The key difference between the two scenarios is driven by the impact of a discount factor and cost increases; the model assumes a discount factor of 4.7% year on year (inflation is 5%), resulting in less favourable NPVs and

MACs for scenario 2 as there is a timeline delay in some technology purchase. However, the metrics does not consider other potential benefits of either scenario:

- **Scenario 1:** Cost savings achieved by being an early adopter of new technologies, such as grants access and securing favourable contracts with suppliers (or securing contracts altogether – supply may not be available in the future as demand increases).
- **Scenario 2:** Cost savings from waiting to implement these technologies, such as reduced costs and risks.

Ultimately, cumulative emissions reductions and non-discounted aggregate capital spending will be the same between scenarios; the advantages of pursuing either scenario should be carefully considered within the context of the City's emissions reduction strategy and approach.

Scenario 2: Overall Emissions Reductions and CAPEX

With the technologies modelled, the City can achieve 57% emission reductions for its fleet in 10 years. It falls short of the City's targeted 40% reduction by 2030, achieving only a 26% reduction by 2030. While the City can achieve a 95% reduction of GHG emissions by 2050, it is not able to achieve their stated goal of net-zero by 2050 from a fleet perspective due to emissions from electricity consumption from the provincial grid, which is not net-zero. Emission reductions are achieved slower than in Scenario 1 due to delayed timing of vehicle purchases.

Over BAU, emissions can be reduced by:

- 57% in 2035 (870 tCO2e),
- 95% in 2045 (1,447 tCO2e), and
- 95% in 2050 (1,447 tCO2e)

Total additional CAPEX needed (undiscounted):

- Incremental CAPEX until 2035: $7,491,556
- Incremental CAPEX for project life: $74,385,969

FIGURE 20 CITY OF KELOWNA BAU VS. SCENARIO 2 (DELAYED)

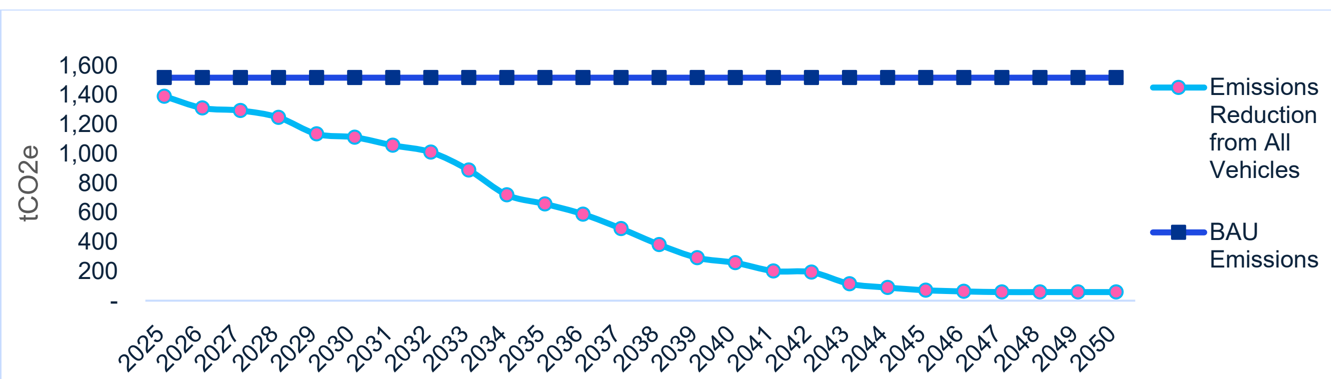


TABLE 19 SCENARIO 2 FINANCIAL AND EMISSIONS METRICS

Initiatives	Net Present Value (NPV)	Cumulative emission reductions (tCO2e)	Incremental CAPEX Spend (Negative is savings)	Incremental OPEX Spend (Negative is savings)	Total undiscounted CAPEX	MAC (per tCO2e)	ROI
LDT							
Unleaded to HRE	$ 2,032,455	839	$(2,162,195)	$ 396,194	$4,842,655	$(2,422)	18%
Unleaded to EV	$ 805,870	6,955	$ 3,982,137	$(2,924,455)	$27,939,460	$ (116)	73%
Diesel to HRE	$ 108,991	41	$ (124,177)	$ 21,661	$ 296,418	$(2,627)	17%
Diesel to EV	$ (47,667)	87	$ 83,466	$ (26,337)	$ 393,080	$ 550	32%
Unleaded to B6.7 H2 ICE	$(12,351,438)	3,331	$ 9,988,880	$ 394,059	$34,196,691	$ 3,708	-4%
Diesel to B6.7 H2 ICE	$ (533,061)	133	$ 411,032	$ 14,896	$ 1,399,003	$ 4,021	-4%
Single Axle							
Unleaded to HRE	$1,751,722	724	$(1,505,813)	$153,110	$2,563,492	$(2,420)	10%
Diesel to HRE	$346,445	48	$(371,012)	$38,532	$687,322	$(7,283)	10%
Diesel to Co-Combustion	$(139,688)	46	$129,318	$32,965	$552,385	$3,039	-25%
Diesel to B6.7 H2 ICE	$(3,448,393)	722	$3,593,542	$174,517	$14,627,379	$4,774	-5%
Diesel to X15 H2 ICE	$(717,086)	251	$782,863	$46,657	$2,618,579	$2,860	-6%
Unleaded to B6.7 H2 ICE	$(1,275,993)	1,055	$1,783,342	$131,873	$10,099,842	$1,209	-7%
Tandem Axle							
Diesel to Co Combustion	$(126,156)	906	$(1,204,233)	$596,096	$8,190,359	$139	50%
Diesel to X15 H2 ICE	$(6,172,843)	2,720	$3,485,928	$472,022	$17,156,145	$2,269	-14%

- MAC is calculated by taking NPV and dividing it by the cumulative reduction in emissions.
- A negative MAC indicates that the City is experiencing net cost savings for every tonne of GHG emissions reduced, even after accounting for capital expenditure (CAPEX). These savings come from reduced operational costs, primarily in maintenance and fuel.
- A negative OPEX indicates that the City is experiencing net cost savings.
- ROI is calculated by taking the total incremental OPEX and dividing it by the total incremental CAPEX.

3.4 Charging

3.4.1 Charging Analysis Introduction

This section provides guidance to the City of Kelowna regarding the future charging needs as the City transitions to electric vehicles. This analysis is intended to serve as a framework for the City's planning and decision-making processes. This guidance will help the City to strategically allocate resources, invest in necessary infrastructure, and prepare for the anticipated growth in EV adoption.

Charger Types

The "Charging Infrastructure Demand Analysis" establishes overall charging needs at the strategic level for the City of Kelowna based on future electric vehicles as determined by the "Sustainable Fleet Scenario Analysis". This analysis is further refined on a location by basis in following section seven "Charging Infrastructure Analysis by Location." This analysis is based on data provided by the City and assumptions agreed to by the City.

There are three main levels of electric vehicle chargers as outlined in the table below. Charging level is determined by power output and charging speed of the different types of charging equipment.

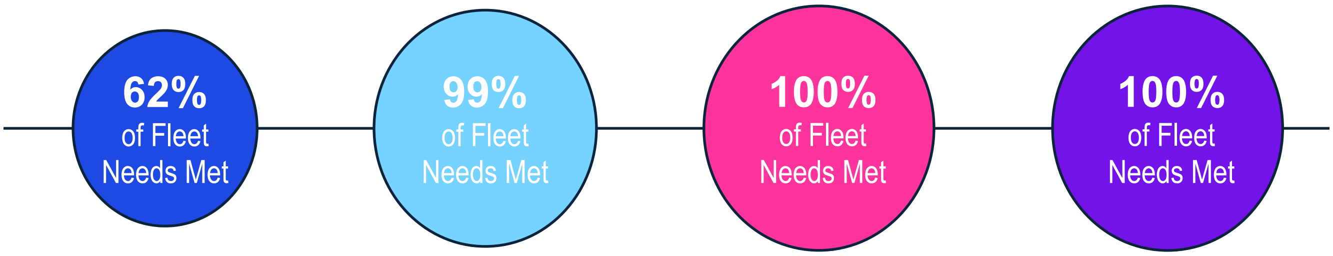
TABLE 20 LEVELS OF ELECTRIC VEHICLE CHARGERS

Charging Level	Power	Time to Charge	Typical Uses	Comments
Level 1: Wall outlet charging	1.4kW output Requires standard 120V/15A wall socket	Charges 4 - 11km/hour BEV: 12-20 hours	Home Emergency charging	Typical household outlet Typically used as a backup option when Level 2 or Level 3 charging is unavailable, or for vehicles with small batteries and low daily mileage requirements.
Level 2: AC charging	6.6 – 7.2kW output Requires 208V or 240V power input	Charges 30-40 km/ hour BEV: 2-8 hours	Home Businesses Common areas	Requires a 30A or 40A circuit Requires installation by a qualified electrician
Level 3: DC fast charging	25 to 350kW+ output Requires 3-phase high-power input	Charges 200-250 km/hour at 50kW Charges 8km/hour BEV: 1-4 hours	Business Opportunity charging Common areas	Requires installation of DC fast charger (DCFC) Note: The City currently has no Level 3 chargers installed and has no plans to install them.

3.4.2 Charging Analysis Summary

This section summarizes the results of the charging analysis.

FIGURE 21 CHARGING ANALYSIS SUMMARY



In this scenario, the fleet would require 234 dedicated Level one chargers.

This would yield a Total Daily range of ~18,000km (>the daily adjusted range of the fleet)

146 out of 234 vehicles of the fleets total daily range requirements would be met.

In this scenario, the fleet would require 54 Level one chargers and 86 Level two chargers.

This would yield in a total daily range provided by the chargers of ~26,000km.

Out of the 234 identified EV's, this configuration would serve 231 vehicles while providing a surplus of 72% over daily fleet range needs.

In this scenario, the fleet would require 126 Level one chargers and 88 Level two chargers.

This would yield in a total daily range provided by the chargers of ~52,000km. This configuration would serve all 234 vehicle needs

While providing a surplus of 245% over daily fleet needs.

In this scenario, the fleet would require 234 Level two chargers.

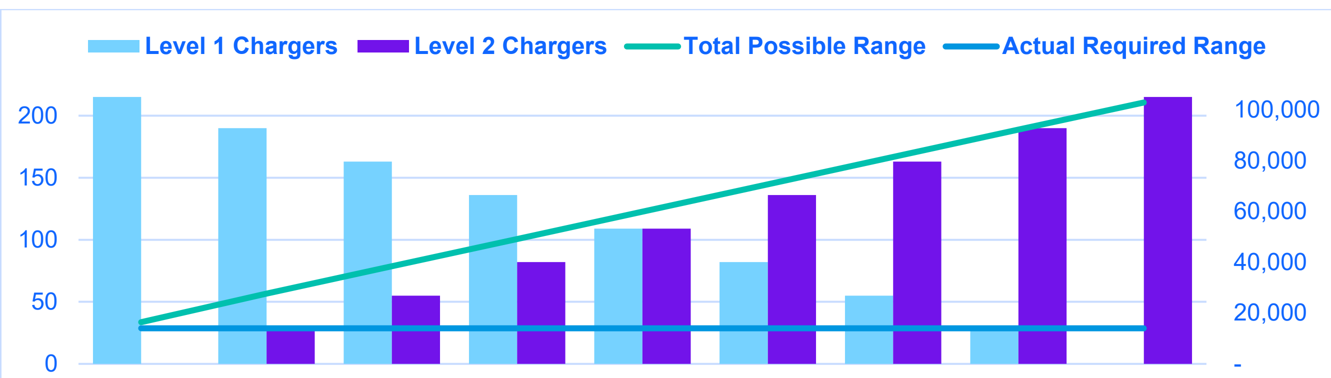
This serves the daily range requirement of all 234 vehicles and provides a daily range of ~110,000km, oversupplying the fleet by 642%.

This is a significant oversupply of charging infrastructure and not needed for the City.

Prioritized Charging Infrastructure

This section outlines the range of dedicated Level 1 and Level 2 chargers that can be configured without a daisy chain with dedicated chargers for each vehicle. This scenario does not assume optimized charging cycles and assumes one charger per vehicle.

FIGURE 22 RANGE OF DEDICATED CHARGERS



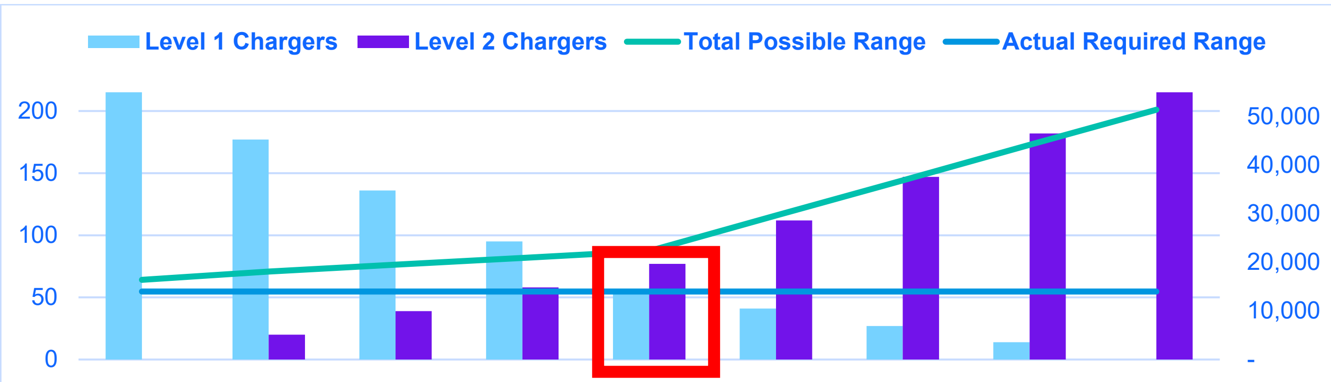
Prioritize Level 1

Implementing a 1:1 Level 1 to Vehicle ratio may serve the needs of a fleet as whole (overall daily fleet range), but it is important to note that when doing a vehicle specific analysis, only 62% of the fleets' needs are met. Refer to section seven “Charging Infrastructure Analysis by Location” for detailed information on charging requirements per department on the other hand, implementing a 1:1 ratio of Level 2 chargers, oversupplies the fleets needs by a significant margin and is therefore not recommended.

Daisy Chain Infrastructure

This section identifies the optimal number of Level 1 and Daisy chain Level 2 chargers to be configured. In this scenario, Level 1 vehicles get Level 1 charging through the chain; Level 2 vehicles get proportionate Level 2 charging based on number of vehicles in the chain. The analysis assumes approximately 1-3 vehicles per daisy chain charger.

FIGURE 23 OPTIMAL NUMBER OF CHARGERS TO BE CONFIGURED - BY LEVEL



Prioritize Level 1

In this scenario, 86 level 2 daisy chains complement 54 dedicated level 1 chargers. The daisy chain efficiently meets the needs of vehicles without dedicated chargers, offering flexibility and less charging planning while ensuring all fleet vehicles are charged efficiently. This scenario satisfies 99% of the individual vehicle needs, the remaining 1% of unmet charging needs could be met by installing one additional level 2 charger.

Prioritized Charging Configuration

This section discusses the findings for “Prioritized Charging Configuration” where a vehicle is allocated a dedicated Level 1 or 2 charger.

- The optimal mix of Level 1 and Level 2 chargers assuming conservative charging cycles and location specific factors such as number of vehicles is 126 Level 1 Chargers and 88 Level 2 Chargers (without daisy chains).
- In this scenario, the identified chargers provide a surplus of 245% fleet in terms of daily range but serve each vehicle appropriately based on their daily adjusted utilization.
- Under this scenario without the Daisy Chain technology, the city workers will need to organize charging effectively to optimize the use of chargers to ensure that “low priority” vehicles are charging the nights where high priority vehicles do not need to be charging.
- Additional charging can be achieved by allowing multiple vehicles to charge for shorter periods throughout the day, ensuring that each charger is utilized more efficiently.
- Organizing charging schedules can help tailor access to meet all the charging needs under this scenario. By implementing scheduled charging times or reservations, the City can prevent overcrowding and

ensure equitable access, prioritizing those who need longer charges while accommodating others who require quick top-ups. This approach maximizes the efficiency of existing charging infrastructure and additional chargers that may be added and could avoid the potential cost expenditure related to infrastructure of the Daisy Chain technology.

3.4.3 Charging Infrastructure – Summary

In conclusion, the City has two viable options for implementing its EV charging infrastructure strategy, both based on conservative assumptions:

Preferred Option: Daisy Chain Configuration - This involves installing **86 level 2** daisy chain chargers (with two to three charging ports) and 54 Level 1 chargers. This configuration reduces the need for workers to effectively organize charging, making it more efficient and less labor-intensive. Additionally, the Daisy Chain Configuration is potentially more cost-effective due to the lower number of chargers required and simpler installation.

Less Preferred Option: Prioritized Dedicated Charging - This involves installing **88 level 2** chargers and **126 level 1** chargers, which requires more intensive charging organization that must be undertaken by city workers. While this option offers ample coverage for the City's proposed EV fleet, it demands more labor and coordination, potentially increasing operational complexity and costs.

TABLE 21 VIABLE OPTIONS FOR IMPLEMENTING EV CHARGING INFRASTRUCTURE STRATEGY

Scenario:	Daisy Chain Configuration	Prioritized Dedicated Charging
Total level 1: Total level 2:	54 dedicated level 1s 88 level 2 daisy chains	126 dedicated level 1s 88 dedicated level 2s
Total Hours of Charging	3,510	3,510
Total Range Provided (km)	26,000	52,000
Charging Effectiveness KPI (km/hr)	7	15
% of Fleet Needs Met	99% (231 / 234 Vehicles)	100% (234 / 234 Vehicles)
% Surplus over Fleet Need	72% (~15,000 daily adjusted utilization)	245% (~15,000 daily adjusted utilization)

Both strategies ensure that vehicles can be reliably charged overnight without factoring in daytime charging. However, Daisy Chain Configuration is recommended due to its efficiency, reduced labor requirements, and potential cost savings.

3.4.4 Charging Analysis – Conclusion

Below is a summary of the results of the charging analysis per location.

TABLE 22 SUMMARY - CHARGING ANALYSIS PER LOCATION

Location	Units	Daily Adjusted Utilization (km)	Strategic Assessment	Justification	Max Daily Range offered (km)	BEV Recommendation (Max Chargers per Location)
Chapman Parkade	3	198	1-level 1, 1- level 2	Low-cost strategy	~500	N/A
City Hall	2	120	1-level 1 & 1-level 2	Maximize availability and redundancy	~600	6
Compost Facility	3	58	2-level 1 and 1-level 2	Prioritize redundancy and range	~700	1
Ellis St. Parking Lot	4	191	3-level 1 & 1 level 2	Charging port redundancy and capacity for additional vehicles	~700	N/A
Landfill	12	591	3-chain daisy configuration with load balancing, 8-level 1	Uninterrupted availability with above-required range	~2000	5
Library Parkade	10	1,183	5-level 1, 5-level 2	Meets all vehicles requirements and uninterrupted availability with above-required range	~3500	15
Memorial Parkade	17	1,495	3-dedicated level 2, 10-level 1	Redundancy, availability and range maximization	~3000	N/A
Parkinson Rec	4	87	4-level 1	Low cost strategy	~500	N/A
Police Services	3	260	1-dedicated level 2, 2-level 1	Range maximization	~700	N/A
Utilities Construction Yard	12	550	4-chain daisy configuration with load balancing with 4 dedicated level 1	Redundancy, availability and range maximization	~2500	6
Westside Gravel Pit	1	74	1-dedicated level 2 charger	Range maximization	~500	N/A
Windsor Road	17	559	5-chain daisy configuration with load balancing with 5 dedicated level 1	Redundancy, availability and range maximization	~3000	19
Parks Yard	55	5153	5-dedicated level 2, 10-daisy chain configuration, 7 dedicated level 1	Redundancy and fleet optimization	~7000	34
Public Works Yard	45	3311	5-dedicated level 2, 10-chain daisy configuration, 5 dedicated level 1	Redundancy and low cost strategy	~7000	28
Wastewater Treatment Facility	28	2010	5-dedicated level 2, 3- chain daisy configuration with load balancing, 8- dedicated level 1	Redundancy and fleet optimization	~4000	12
Firehall	17	1090	5 – chain daisy configuration with load balancing, 2 dedicated level 2, 3 dedicated level 1	Fleet optimization and redundancy	~4000	5

TABLE 23 – REQUIRED CHARGER INVENTORY

Total Level 1	Total Level 2	Total Level 2 (Daisy)	Total Chargers Required
~68	~32	~40	~140

Based on the results of the analysis – Parks Yard, Public Works Yard and Wastewater Treatment Facility require the greatest increase in level 2 chargers while other locations may suffice with level 1 chargers or a level 2 Charger with a daisy configuration. It is advised to install Level 2 chargers where possible due to increased efficiency of charging and greater optimization of the fleet.

3.4.5 Billing Best Practices

Given the current challenges with accessing and itemizing bills from charging data based on our Supply Analysis, some tailored billing best practices for the City to consider are outlined below.

TABLE 24 INTEGRATED BILLING PRACTICES

Practice	Description	Benefits
Implement Submetering	• Install submeters on chargers to track energy usage per department or vehicle.	• Enhanced Accountability: Departments/entities can be billed based on actual usage, promoting responsible energy consumption. • Detailed Reporting: Provides granular data for better budget planning and trend analysis. • Implementation: Work with Flo to integrate submetering capabilities into the existing infrastructure.
Automated Itemized Billing	• Utilize billing software that can automatically generate itemized invoices. • Providers: Evnity, Wevo Energy	• Transparency: Departments receive detailed bills, improving financial accountability. • Efficiency: Reduces manual processing and errors. • Implementation: Integrate billing software with Flo's monitoring system to automate the generation of itemized bills.
Direct Access to Geotab Data	• Establish a direct API connection to Geotab for real-time data access.	• Timely Decision-Making: Immediate access to data allows for quicker adjustments and strategic planning. • Operational Efficiency: Reduces dependency on third-party representatives and streamlines data retrieval. • Implementation: Collaborate with Geotab to set up an API that provides direct access to the necessary data.
Centralized Data Management Platform	• Implement a centralized platform that consolidates data from Flo and Geotab. • Providers: GreenFlux, Evnity.	• Unified View: Provides a comprehensive overview of all charging activities and energy consumption. • Strategic Insights: Facilitates better analysis and reporting, aiding in strategic planning and operational improvements. • Implementation: Choose a platform that can integrate with both Flo and Geotab, ensuring seamless data consolidation.

Practice	Description	Benefits
Regular Audits and Reviews	• Conduct regular audits of energy consumption and billing processes.	• Accuracy: Ensures billing accuracy and identifies any discrepancies. • Continuous Improvement: Provides insights for ongoing improvements in energy management and billing practices. • Implementation: Schedule periodic audits and reviews, involving relevant stakeholders to ensure thorough evaluations.

Level 1&2 charging in EVs can be effectively tracked using smart meters integrated into the charging stations. These smart meters measure the energy consumption of each charging session, providing precise data on electricity usage. This data can be processed by billing systems, which generate detailed reports and invoices based on the amount of energy consumed. By using smart meters, City of Kelowna can ensure accurate billing for EV charging, whether for personal or departmental use, and maintain transparency in energy usage.

By implementing these best practices, the City can improve its billing processes, enhance accountability, and make more informed decisions regarding its EV charging infrastructure.

City Staff Charging Personal Vehicles:

- **Usage Guidelines:** Implement clear guidelines outlining when and how staff can use city-installed chargers for personal vehicles, whether for work or non-work-related purposes.
- **Billing System:** Use a billing system that tracks usage and charges staff for personal vehicle charging to ensure fair use and cost recovery.
- **Education Programs:** Provide education programs to inform staff about the policies and encourage responsible usage.

B2B Charging Between Departments:

- **Interdepartmental Agreements:** Establish agreements between departments to define usage, billing, and payment processes for shared chargers.
- **Centralized Billing:** Use centralized billing software to capture and allocate costs accurately across departments.
- **Usage Tracking:** Implement tracking systems to monitor usage and ensure transparency in billing.

3.5 Maintenance

3.5.1 Introduction

This section contrasts the current state of Kelowna's fleet maintenance facilities and the necessary adaptations to accommodate the growing presence of alternative fuel vehicles.

As the automotive industry evolves, the transition from ICE vehicles to EVs and hydrogen fueled vehicles presents both challenges and opportunities for fleet maintenance. Current maintenance facilities are primarily designed for ICE vehicles, lacking the capacity for EV-specific repairs and charging infrastructure.

To effectively manage the shift towards a low carbon fleet, it is essential to implement best practices that align with future needs including:

- Building and delivering comprehensive training programs for maintenance staff allowing for continuous upskilling of technicians to handle the complexities of EV and hydrogen technologies,
- Integrating advanced telematics systems,
- Establishing of safety protocols tailored to high-voltage and hydrogen systems,
- Expanding existing facility to meet basic facility requirements,
- Developing dedicated maintenance bays for EVs and hydrogen vehicles, equipped with the necessary tools and safety measures.

This strategic approach will not only enhance the operational capabilities of the fleet ensuring a smooth transition and operational efficiency, but also contribute to the reduction of GHG missions, aligning with provincial safety standards and environmental goals.

3.5.2 Maintenance: Current State and Future Needs

This section provides a summary contrasting the current state and future needs for fleet maintenance at the City.

TABLE 25 MAINTENANCE - CURRENT STATE AND FUTURE STATE

Dimension	Current State	Future Needs
Age	• The current maintenance building is over 50 years old with limited expansions or improvement. • Current facility does not meet space requirement of modern larger-sized vehicles.	• A fit-for-purpose maintenance facility allows for the incorporation of latest green automotive technologies and infrastructure to support EVs and other low carbon alternatives ensuring that the City is equipped to handle the evolving demands of fleet maintenance.
Space	• There is limited space across all facilities leading to outdoor storage of tools and equipment (resulting in exposure to weather and vandalism), outdated infrastructure, and insufficient office and support spaces. • Existing maintenance facilities are designed for ICE vehicles and lack the capacity for EV-specific repairs or charging infrastructure.	• Expanded facilities to accommodate EV charging stations, battery storage areas, and high-voltage repair zones. • Dedicated bays for EVs and hydrogen fuel cell vehicles, with safety measures to handle high-voltage systems and hydrogen storage.
Safety	• Safety protocols focus on ICE vehicles, with limited provisions for high voltage systems, battery fires and hydrogen hazards.	• Training for technicians on handling high-voltage systems and hydrogen safety. • Implementation of fire suppression systems specific to battery fires. • Enhanced safety zones for charging equipment and hydrogen refuelling.

Requirements: Electric Vehicles

Electric vehicles have specific maintenance requirements considering training safety protocols, facility design, and related tools.

TABLE 26 REQUIREMENTS - ELECTRIC VEHICLES

Maintenance focus areas for EVs	• More frequent tire pressure monitoring and rotation for EVs due to their heavier weight • Cooling system maintenance to abate battery fire hazard • Software updates for vehicle control systems • Electrical connector inspection • Battery health monitoring and maintenance • Routine brake system inspection and lubrication
Technician training	• Thorough training on EV systems, including battery management, EV cooling systems, thermal management systems, motor control, high voltage safety & diagnostics and repair, and charging infrastructure • Understanding of manufacturer-specific maintenance protocols for different EV models
Safety protocols	• Handling high voltage systems, including de-energization and isolation techniques • Fire suppression systems for lithium-ion battery fires • Designated storage areas for damaged batteries • Emergency response plan for electrical incidents • Personal Protective Equipment (PPE) requirements
Facility design considerations	• EV maintenance workspace with proper ventilation • Clear signage for high voltage areas • Adequate lighting for working on electrical components • Designated charging stations with appropriate power capacity • Specialized storage areas for storing and handling EV batteries
Specialized tools and equipment	• Diagnostic for battery health and performance. • High voltage safety equipment for electrical shock. • Dedicated lifting systems suitable for EV chassis design • Battery removal and handling tools • Insulated hand tools • Thermal imaging cameras

Requirements: Hydrogen Vehicles

Hydrogen vehicles have specific maintenance requirements considering training safety protocols, facility design, and related tools.

TABLE 27 REQUIREMENTS - HYDROGEN VEHICLES

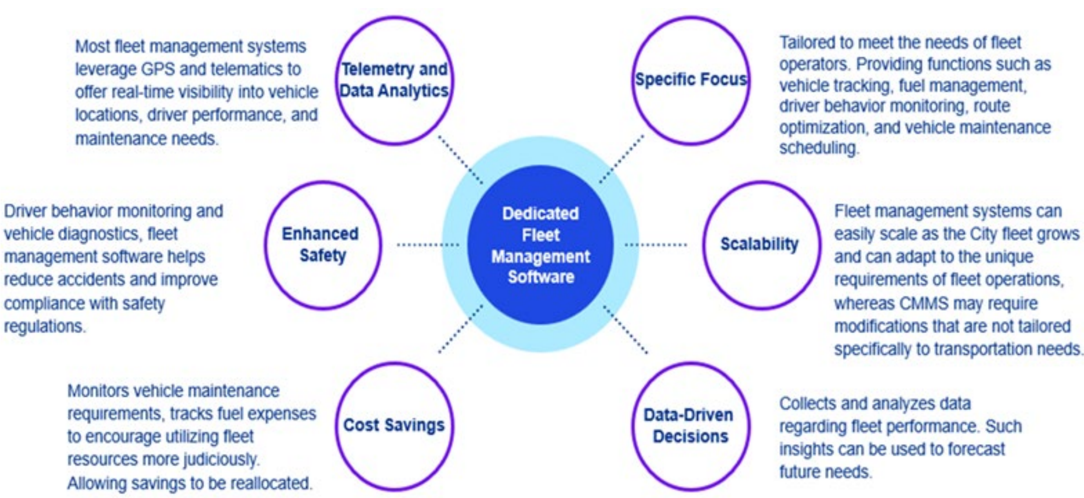
Pressure Equipment Safety Regulation	This regulation outlines the requirements for the construction and maintenance of pressure systems. Including: • Certification of pressure equipment • Regular inspections and maintenance protocols • Proper training for personnel involved in operation and maintenance
Electrical Safety Regulation (ESR)	This regulation mandates standards that ensure electrical installations do not pose risks of faults or hazards. Including: • Professional qualifications for those performing electrical work • Adherence to the Canadian Electrical Code • Routine inspections to verify compliance with electrical safety standards

British Columbia Fire Code (BCFC)	This regulation mandates fire prevention and suppression measures in facilities utilizing pressure fuel systems. Including: • Installation of appropriate fire suppression systems such as sprinklers or chemical agents • Fire safety plans that detail emergency preparedness and response measures • Accessibility and clarity of fire exits in a facility
Gas Safety Regulation (GSR)	This regulation specifically addresses safety for the installation and upkeep of gas appliances and systems. Including: • Systems are installed by qualified professionals • Adequate maintenance schedules are established and adhered to • Emergency shut-off systems are in place
Environmental Protection Measures	Environmental regulations also encompass the management of spills and potential contaminations, particularly for systems handling fuels such as hydrogen. Including: • Protocols for immediate response to spills or leaks • Regular assessments of environmental impact • Containment measures to prevent pollution

Requirements: Information Technology

The City needs a dedicated Fleet Management System-FMS that meets the diverse needs of Internal Combustion Engines, Electric Vehicles, Hydrogen Retrofits, Hydrogen Internal Combustion Engines, Hydrogen Fuel Cell Electric Vehicles, Hybrid Vehicles, and Hybrid Range Extenders. General Computerized Maintenance Management Systems do not provide all the key inputs to streamline effective decision making. Below is an illustration of the range of values that City stands to derive from the deployment of a dedicated FMS.

FIGURE 24 REQUIREMENTS- INFORMATION TECHNOLOGY



Requirements - Personnel, Technicians, Skills

TABLE 28 REQUIREMENTS - PERSONNEL, TECHNICIANS, SKILLS

Technology	H_2-ICE	Co-Combustion	EVs	Renewable Diesel
Best Practices	Regularly inspect high-pressure hydrogen	Technicians should be skilled in calibrating fuel systems to	Routine Battery Maintenance	Conduct regular inspections of engines

Technology	H_2-ICE	Co-Combustion	EVs	Renewable Diesel
	storage tanks and fuel systems for leaks or wear Use of materials resistant to hydrogen embrittlement in engine components	achieve optimal H2-diesel blend Ability to Monitor injector performance to ensure proper fuel mixing and analyze effects of different hydrogen-diesel ratios on engine performance	Monitoring of Thermal Management Systems Leverage Advanced Diagnostic Equipment Data-Driven Optimization	running on renewable diesel to ensure compatibility with fuel properties and OEM engine specification Knowledge of emissions systems and regulations, peculiar to renewable diesel
Key Skills and Roles for Fleet Personnel	Engine technicians Safety specialists	Engine technicians Fuel specialist	High-voltage technicians Fleet managers with knowledge of EVs	Engine technicians with expertise in advanced diagnostics, fuel injectors etc.
Training Requirements	Certification in hydrogen handling Training on thermal pressure relief devices Certification in pressure fuel repair and inspection Regular upskilling programs on H2-ICE vehicle technologies	Training on dual-fuel system calibration and emissions control Courses on High Voltage Safety, High Pressure systems and general maintenance & repair of dual-fuel vehicles Certification in pressure fuel repair and inspection	EV-specific certifications (e.g. EVSC, Automotive Service Excellence EV (ASE)) Regular upskilling programs for ICE technicians transitioning to EV maintenance roles	Minimal retraining required as renewable diesel is mostly compatible with ICE engines Training on emissions systems and regulations, with focus on renewable diesel
Safety Training	Leak detection protocols using IoT-enabled sensors Emergency response for invisible hydrogen flames	Emergency protocols for managing both diesel and hydrogen leaks	High-voltage safety protocols for battery handling Fire suppression techniques specific to lithium-ion battery fires	Emergency protocols for diesel management

Future Proofing for Vehicle Maintenance Facility

A. Number of Technicians with Specializations

For future state, where the City's fleet will be transitioning to the following categories:

Table 29 Requirements – Personnel future proofing

Category	Count	Comment	Category	Count	Comment
EV Car	32	Electric	Tandem Axle Trucks	17	X15 H2 ICE
EV Van	31	Electric	Utility Vehicle	9	EV replacement
EV SUV	12	Electric	Heavy Duty Equipment	68	Electric replacement
EV LDT	106	Electric	Medium Duty Equipment	12	Electric replacement
Hybrid Range Extender	51	LDT	Light Duty Equipment	69	Electric replacement
Single Axle Trucks	21	B6.7 H2 ICE	Other City Vehicles	50-100	Out of scope but used by the City

Based on the foregoing, the city would need approximately 18-22 technicians. Specializations should include:

TABLE 3031 REQUIREMENTS – SPECIALIZATION

Technology	Estimated Need	Comment
EV Technicians	5-6	Requires special training and certification
ICE Technicians	6-8	Including Apprentice and heavy duty mechanics
Hydrogen Vehicle Technicians	3-4	Requires special training and certification
General Technicians	4-5	Including Servicepersons (2)
Aggregate	18-21	Result in 1800 – 2520 VEUs – more than double the City's current VEU needs. Will address staff shortage and improve KPIs

B. Number of Bays

Given the variety and number of vehicles in the future state, the City should aim for 20-25 bays to ensure efficient maintenance and minimize downtime.

C. Type of Equipment and Counts

Each bay should be equipped with the necessary tools and equipment specific to the vehicle types they will service. For example:

- EV Bays: Charging stations, diagnostic tools for electric systems, insulated tools.
- ICE Bays: Standard diagnostic tools, lifts, oil change equipment.
- Hydrogen Vehicle Bays: Hydrogen fueling stations, specialized diagnostic tools for hydrogen systems.

D. Standard Bay vs Technician: The standard ratio is typically 2 bays per tech.

TABLE 32 REQUIREMENTS – STANDARD BAY VS. TECHNICIAN

Ratios	Estimate	Comment
Technician/Bay	2 bays per tech	• 2 bays to 1 technician for effective throughput and prevent overcrowding
Equipment/Bay	5-6 pieces of essential equipment	• In addition to Crane, Vehicle Lift, Diagnostic Tools, Air Compressor; Tool Storage. • Fluid Management Systems: Safety Equipment (e.g. Fire extinguishers, first aid kits, and personal protective equipment (PPE)
Equipment/ Technician	Technician should have access to 3-4 specialized tools	• Standard tools include, torque wrench, insulated tools, brake service tools, and specialized tools like, hydrogen leak detector

Breakdown: Below is a sample breakdown of what the recommended bays look like while considering different technologies, required equipment and sizes.

- **ICE Bays:** 8 Recommended
- **EV Bays:** 7 Recommended
- **H2 Vehicle Bays:** 6 Bays (Some of these can be used for alternative fuel vehicles like renewable diesel)

- **Others:** 4 Bays (these include 2 bays for welding & fabrication as well as bays for the Fire Department)

Requirements for maintenance pits is factored into bay sizes in line with fire safety standards.

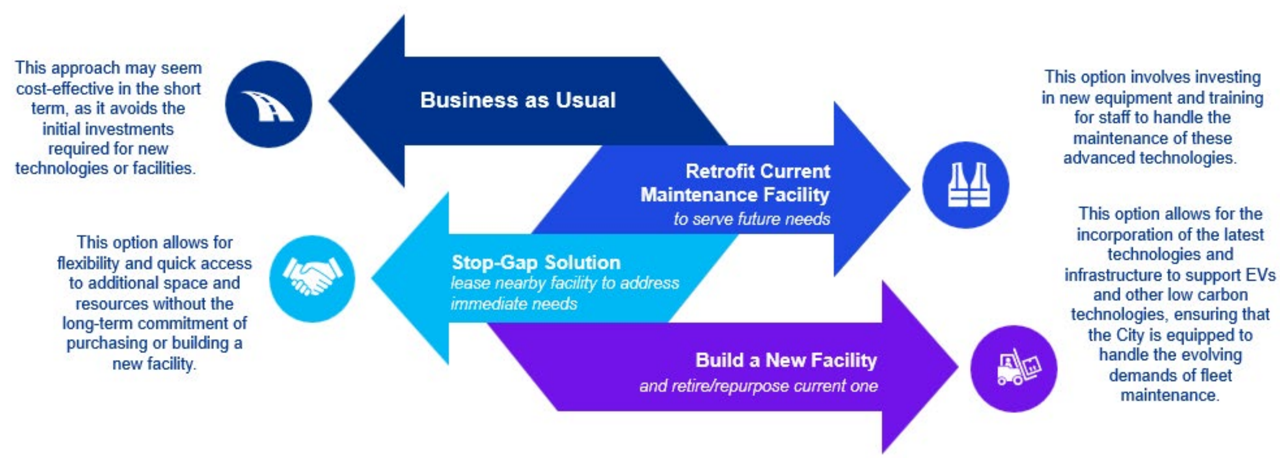
TABLE 33 REQUIREMENTS – BAY REQUIREMENTS

Bay No.	Size (feet)	Dedicated Vehicle Type	Floor Heights (feet)	Standard Equipment Requirement
1-8	Standard2 (45'L x 12'W X 14'H)	ICE	Minimum 14'	Overhead Crane, Standard diagnostic tools, lifts, oil change equipment
9-15	Standard-Extended (45'L x 12'W X 15'H)	EV	Minimum 15'	Overhead Crane, Charging stations, diagnostic tools for electric systems, insulated tools
16-21	Adaption of current size (50'L x 13'W X 19'H)	H2-Vehicle	Minimum 19'	Overhead Crane, Hydrogen fueling stations, specialized diagnostic tools for hydrogen systems
22-23 (Welding & Fabrication)	(50'L x 13'W X 19'H)		Minimum 19'	MIG Welder, TIG Welder, Plasma Cutter, Welding Table, Grinding and Cutting Tools (e.g. angle grinders, bench grinders, and cutting wheels for preparing and finishing welds), Safety Equipment etc.
24-25 (Miscellaneous e.g. Fire Department)	(50'L x 13'W X 19'H)		Minimum 19'	Fire & Standard Equipment

3.5.3 Options Analysis & Recommendation

Based on the foregoing, the following maintenance facility options have been identified:

FIGURE 25 MAINTENANCE FACILITY OPTIONS



Our analysis indicates that the current maintenance facility has exceeded its useful life, posing significant operational and safety risks. Retrofitting the facility with modern equipment to meet future demands is both operationally and financially impractical. Therefore, we recommend implementing a temporary solution while planning for a transition to a purpose-built maintenance facility.