FINAL
REPORT
August 2021

Sustainable Fleet Strategy

Framework and Action Plan Report

PREPARED FOR THE CITY OF BRAMPTON

PREPARED BY RICHMOND SUSTAINABILITY INITIATIVES | FLEET CHALLENGE

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Terms and Abbreviations

B10 – A blend of 10% biodiesel and 90% fossil diesel; in this report, B10 represents an annualized blend of B20 (used during summer months) and B5 (used during winter and shoulder months)
BAU – Business-as-usual
BEV – Battery-electric vehicle
BET – Battery-electric truck
CAC – Criteria air contaminants; a cause of ground level smog
CAFE – Corporate average fuel economy
Capex – Capital expense
City of Brampton – the Corporation of the City of Brampton; the community and geographic entity of Brampton
CIF – Cost inflation factor
CNG – Compressed natural gas
CO_2 or CO_2e – Carbon dioxide or carbon dioxide equivalent
Downtime – Period when a vehicle is unavailable for use during prime business hours
E85 – A blend of around 85% ethanol and 15% gasoline
EV – Electric vehicle
EVSE – Electric vehicle supply equipment
FAR™ – Fleet Analytics Review™ (Fleet Challenge Excel software tool)
GHG – Greenhouse gas (expressed in CO_2 equivalent tonnes)
GHG Intensity – A measure of GHGs produced relative to VKT or VMT (see below)
HD or HDV – Heavy-duty vehicle (Classes 7-8)
HEV – Hybrid-electric vehicle
ICE – Internal combustion engine
KPI – Key performance indicator
LCA – Lifecycle analysis
LD or LDV – Light-duty vehicle
LMHD – Light-, medium-, and heavy-duty vehicle
LPG – Liquified petroleum gas, more commonly referred to as propane
LTCP – Long-term capital planning
MD or MDV – Medium-duty vehicle
MHD or MHDV – Medium- and heavy-duty vehicle
MHEV – Mild hybrid-electric vehicle
MT – Metric tonne
NPV – Net present value
OEM – Original equipment manufacturer
Opex – Operating expense
PHEV – Plug-in hybrid electric vehicle
PM – Preventative maintenance
ROI – Return-on-investment
Solution – A technology, best management practice, or strategy to reduce fuel use and GHGs

Terms and Abbreviations (cont'd.)

TCO – Total cost of ownership

Uptime – Period when a vehicle is available for use during prime business hours (opposite of downtime)

Vehicle availability – See "Uptime"

VKT or VMT – Vehicle kilometres/miles travelled

WACC – Weighted average cost of capital

ZEV – Zero-emission vehicle

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Foreword

The Sustainable Fleet Strategy: Framework and Action Plan Report, has been prepared for the City of Brampton by Richmond Sustainability Initiatives (RSI) of Toronto, Ontario and its project team Fleet Challenge (FC), collectively referred to as RSI-FC. We have included this foreword because we feel it is important for readers of this report to first have a full understanding of the situation and context.

The report is based on our team's detailed data analysis of one-year of historical data for **625 City of Brampton fleet vehicles** as submitted by the City. In-scope vehicles for this report include the Corporate Fleet (light-duty, medium-duty, and heavy-duty vehicles, totalling 422 owned units and 35 rental units), Fire & Emergency Services Fleet (light-duty and medium-duty vehicles, and fire engines, totalling 107 owned units), and the non-revenue Transit Fleet (light-duty and medium-duty vehicles, totalling 18 owned units and 43 rental units).

The RSI-FC team has made considerable effort to make the Sustainable Fleet Strategy as meaningful and relevant as possible to the City of Brampton, in line with its GHG emissions reduction target of 50% by 2040 compared to 2016 levels and 80% reduction by 2050. In preparing Part One: Background Review and Analysis Report of the Sustainable Fleet Strategy, our team analyzed and evaluated baseline fleet results and proposed opportunities for fuel-use and GHG reduction that make economic sense and are reasonably attainable in the short- to long-terms. In Part Two: Framework and Action Plan Report, we modelled these solutions and the results of scenario analysis are presented for the City's consideration.

Our analysis has been completed using a specialized software tool that was developed by RSI-FC, which is referred to as the Fleet Analytics Review™ (FAR). Fuel-reduction solutions were analyzed using FAR, designed to efficiently estimate the cost-benefit and GHG emissions-reduction potential of many best management practices (BMPs) and low-carbon fuels that have been proven to be beneficial to commercial and municipal fleets. As well, a transition to battery-electric vehicles (BEVs) was modeled and evaluated over the next 15 years. The Framework and Action Plan Report provides a viable roadmap and a number of options for consideration by the City – solutions that can be implemented immediately and through to 2035.

We have made every effort to ensure that the business assumptions employed in our analysis are as accurate as possible and based on our many years of experience working with commercial and municipal fleets. All estimates are based on published studies, research, and real data. Sources are noted throughout the document.

Fossil fuel use reduction translates directly to greenhouse gas reduction[1] (hereafter referred to as GHG reduction, carbon reduction, or CO_2 reduction); therefore, all references to fuel savings include the consequential GHG impacts (i.e., increase or decrease).

[1] The terms greenhouse gas, GHG, carbon, CO_2e, and CO_2 are synonymous for the purposes of this report.

Cautious Approach

All solutions explored in this report represent what our team considers to be possible, each with its own set of potentials. However, there are many variations that would modify capital expenses, operating expenses, and GHG emissions projections over time (e.g., switching from fossil fuels to alternate/renewable fuels earlier/later than modelled, phasing in battery-electric vehicles earlier/later than modelled or for segments of the fleet as opposed to fleet-wide implementation, etc.). Therefore, actual fuel/GHG reduction is tied to the *degree of successful achievement* in implementing each of the solutions and the timing of their implementation.

Challenges to Green Fleet Planning

Regardless of which fuel-switching options recommended in our report are ultimately selected by the City of Brampton, the reality is that each will require some degree of extra effort and some will require additional cost to implement. For example, although flex-fuel units are capable of using E85 ethanol (85% ethanol and 15% gasoline), finding sources for this fuel or attending different retail commercial fuel stations may bring new operational challenges that must be resolved. Other examples are the effort and cost of installing level 2 electric vehicle charging stations and/or direct current (DC) fast-charging stations, or the significant expense of compressed natural gas (CNG) or propane (LPG) refuellers.

Emissions Calculation Methods

Internationally, there are two standard reporting methods for vehicle GHG emissions modelling: (1) tailpipe combustion, and (2) fuel lifecycle (sometimes referred to as fuel cycle or well-to-wheel). Modelling of fuel lifecycle GHG emissions of motor fuels is used to assess the overall GHG impacts of the fuel, including each stage of its production and use, in addition to the fuel actually used to power a vehicle. Modelling of tailpipe emissions includes just the actual emissions produced by the vehicle itself through combustion. Lifecycle GHG emissions are, therefore, usually greater than tailpipe emissions.

While lifecycle emissions have been established for most fuel types, lifecycle emissions are often difficult to quantify for best management practices and also for electric vehicles because of the different mixes of electricity sources in different jurisdictions and at different times of day (i.e., fossil-fuel based, nuclear, and renewables). For this reason, to assess the potential GHG reduction on an "apples-to-apples" basis for each proposed solution, we employ the tailpipe combustion method. Although not providing a complete well-to-wheel picture of GHG emissions, the results of our modelling employing the tailpipe combustion method gives a clear indication as to which solutions offer the greatest GHG reduction potential. Using this method, battery-electric vehicles (BEVs) emit zero tailpipe emissions.

For renewable fuels (i.e., biodiesel and ethanol), we use "net vehicle operation" emissions factors, which account for both the change in airborne carbon that occurred due to the combustion process. This approach considers the sequestration of carbon through growing of biomass and the re-release of carbon through vehicle combustion; the result is a more complete picture of airborne carbon and significantly lowered overall operative emissions for higher renewable fuel blends.

Of Further Consideration

In Part One of the Sustainable Fleet Strategy, we calculated the City of Brampton's fleet baseline and determined optimized economic lifecycles for different vehicle categories based on Brampton's fleet data. In Part Two, we modelled go-forward scenarios from baseline to 2035 to provide a roadmap for implementation of fuel-reduction interventions/solutions. The interventions/solutions encompass three groups:

- Group One: Lifecycle optimization and best management practices (BMPs);
- Group Two: Low-carbon fuel switching; and
- Group Three: Transition to battery-electric vehicles (BEVs).

We expect that the City of Brampton may wish to evaluate unique combinations of these solutions based on practicality, availability of models, corporate budgets, vehicle conditions, etc. For this purpose, the FAR software tool will be provided to the City for its own internal use post-project. The tool will be useful for efficiently evaluating any number of fuel-saving solutions under consideration.

As a backdrop to the objectives of the Sustainable Fleet Strategy, our goal is to stimulate the City of Brampton's interest in continuing to move its fleet towards a low-carbon future. We have made every effort to ensure our analysis is as accurate as possible, but at the time of actual implementation the business assumptions we have employed may have shifted. Therefore, we strongly urge the City to complete thorough cost-benefit analyses at any time in the future when considering implementing the recommended interventions/strategies we have outlined. Furthermore, we suggest that a slow-start, cautious approach be taken, which would include pilot testing new technologies in a small control group over at least four seasons of operation, carefully monitoring their performance and assessing the effectiveness of the solutions prior to any plans for wide-scale implementation.

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Executive Summary

Low-carbon transportation is essential to both short-term GHG and fuel-use reduction and long-term decarbonization of the economy. In 2020, the transportation sector accounted for about 25% of greenhouse gas (GHG) emissions in Canada, second only to the oil and gas sector[2]. In Brampton, more than half of the City's 2016 corporate GHG emissions were generated from mobile sources[3]. Municipalities like Brampton can play a key role in cutting emissions by transitioning their fleets to low-carbon and/or electric vehicles, while saving fuel and maintenance costs.

In November 2020, following a formal, competitive Request for Proposal (RFP) process, the City of Brampton engaged Richmond Sustainability Initiatives – Fleet Challenge (RSI-FC) of Toronto, Ontario, to develop a Sustainable Fleet Strategy for select fleet assets of Fleet Services (Corporate Fleet), Fire & Emergency Services, and Brampton Transit.

Through the development and implementation of a Sustainable Fleet Strategy, the City aims to realize:

- Reduced GHG and air pollutant emissions;
- Improved fuel efficiency and reduced fuel cost;
- An optimized and right-sized fleet;
- Enhanced operation efficiency and service excellence;
- Improved lifecycle asset management;
- Demonstrated leadership in environmental sustainability; and
- Increased opportunities for external funding.

About Richmond Sustainability Initiatives

Since 2005, RSI-FC has collaborated with fleet managers, technology providers, subject matter experts, and auto manufacturers to find viable solutions, technologies, and best management practices for reducing operating costs and vehicle emissions. From the beginning, we have remained a self-supporting and independently funded program without commercial biases or influences, providing fleet review and consulting services to dozens of leading private and public sector fleets in Canada and the United States.

About Fleet Analytics Review™

For the development of the Sustainable Fleet Strategy, RSI-FC employed our innovative, leading-edge data-modelling techniques and our proprietary software, Fleet Analytics Review™ (FAR). FAR

[2] Source: https://climateactiontracker.org/countries/canada/
[3] Source: https://geohub.brampton.ca/pages/finance-ghg-emissions

is a software tool designed and developed by our company specifically for complex green fleet planning. FAR enables our team to develop short- to long-term green fleet plans and strategies by calculating GHG emissions reductions and return-on-investment (ROI) for various best practices and technologies – all driven by actual historical data. In turn, this allows us to evaluate the business case of each solution and provide meaningful recommendations for long-term capital planning (LTCP).

Context

In June 2019, Brampton City Council declared a climate emergency[4], joining the Government of Canada and more than 400 Canadian municipalities that have done the same. According to corporate GHG emissions data, more than half of Brampton's 2016 corporate GHG emissions were generated from mobile sources, including the City's vehicle fleet and equipment[5]. This highlights the importance of implementing green fleet strategies to achieve the City's GHG emission reduction goal of 50% by 2040 compared to 2016 levels. The Sustainable Fleet Strategy can play a key role in providing recommendations and potential pathways for achieving "deep decarbonization" of the City's fleet.

Vision, Goals, and Objectives

The vision for the Sustainable Fleet Strategy: Framework and Action Plan Report is for the City of Brampton to steadily transition towards a green fleet and continue to be a leading municipal fleet in operational excellence and environmental sustainability. With this vision in mind, the goal is to provide an ambitious, yet feasible, roadmap for the City to achieve its GHG emissions reduction target (50% reduction from 2016 levels by 2040, and 80% by 2050). To guide Brampton in achieving this goal, we have thoroughly analyzed the City's in-scope fleet data and we have identified and assessed operational improvements and new technologies to reduce GHG emissions from vehicles.

The primary objectives of the Framework and Action Plan Report were to:

(1) Data-model all potential fuel-reduction solutions and estimate their impacts (reductions of Operating expenses, Capital expenses, and GHG emissions) relative to the baseline.

(2) Create a battery-electric vehicle (BEV) transition plan and estimate the cost impacts and GHG-reduction potential relative to the baseline over a 15-year budget cycle.

(3) Estimate additional capital required for electric vehicle supply equipment (EVSE) over a 15-year budget cycle, and recommend solutions for offsetting these charging infrastructure costs through government funding, reduced operating budgets, and fleet reserve.

[4] Source: https://www.brampton.ca/EN/residents/GrowGreen/Pages/Community-Energy-and-Emissions-Reduction-Plan.aspx
[5] Source: https://geohub.brampton.ca/pages/finance-ghg-emissions

(4) Create a sustainable fleet action plan to improve the sustainability performance of the City's fleet including short-term (1-2 years), mid-term (3-5 years), and long-term (5-10+ years) .

Overview of Analysis

In Part One, our team completed baseline analysis and a lifecycle analysis (LCA) study of select vehicle categories in the City of Brampton's fleet to determine optimal economic lifecycles for specific vehicle types. Using RSI's Fleet Analytics Review™ (FAR) software, we then balanced year-over-year capital budgets over a 15-year budget horizon using optimized economic lifecycles and by considering return-on-investment (ROI) for units due for replacement.

In Part Two, our team systematically assessed the impacts of various fuel-reduction solutions on the City's fleet operations and capital budgeting. From this analysis, we developed recommendations for the Sustainable Fleet Strategy. The analysis in the Framework and Action Plan Report included:

- The development of 10 data models to evaluate the impacts (Operating expenses, Capital expenses, and GHG reductions) of proposed go-forward fuel-reduction solutions relative to the baseline over a 15-year budget cycle, which resulted in a long-term capital planning (LTCP) outlook.

- Estimations for electric vehicle supply equipment (EVSE) requirements to model the cost of a charging infrastructure over a 15-year budget cycle, in consideration of the specific needs of Brampton's fleets.

- A review of low-carbon fleet options and recommendations for a structured, phased-in transition to battery-electric vehicles (BEVs) with consideration of LTCP.

- An overview of purchasing versus leasing versus renting fleet assets and discounted cashflow analysis (DCA) for the rental units in the Transit (non-revenue) fleet.

In this report we have made recommendations that have potential for the City of Brampton to relatively quickly, yet cost-consciously, transition away from fossil fuels, optimize the use of capital towards BEV replacements and charging infrastructure, and ultimately achieve deep GHG reductions while maintaining stability in capital budget planning and service delivery.

Go-Forward Fuel-Reduction Solutions

RSI-FC completed extensive research into known, credible, proven, and potentially viable fuel-reduction solutions for the City of Brampton, that could be implemented currently or in the near future. The solutions we modelled were categorized into three groups (see below). For every solution in each of the three groups, we assessed the impacts relative to the baseline:

- Group One: Best management practices (BMPs) or "house-in-order" strategies;
- Group Two: Fuel-switching or "messy-middle" solutions – interim, present-day strategies including renewable fuels (E85 ethanol and B10 annualized biodiesel) and alternate fuels (compressed natural gas (CNG) and liquified petroleum gas (LPG)); and
- Group Three: Hybrid-electric and battery-electric vehicles (HEVs and BEVs, respectively).

RSI-FC's proprietary FAR software was used to evaluate these options through applying a stepwise modelling approach. That is, in Part One our team modelled optimized lifecycles and balanced capital budgets by considering return-on-investment (ROI) for units due for replacement over a 15-year budget cycle. In Part Two, our team modelled go-forward fuel-reduction solutions, starting with best management practices (BMPs) as we believe it is crucial to first "get the house in order" before implementing external solutions (i.e., fuel-switching or battery-electric). We included all viable BMPs in our modelling before assessing fuel-switching options for appropriate units as well as battery-electric transition for units due for replacement over the 15-year window.

The recommendations we provide herein are based on analysis of the Brampton fleet's historical data to forecast long-term impacts (the "past predicts the future"). They are pragmatic and fiscally-prudent, based on research, data-driven analysis, and sound economic principles and practices.

Preparing for a Battery-Electric Vehicle Future

Significant among our recommendations in the Sustainable Fleet Strategy is a temporary pause on replacing Brampton's end-of-lifecycle internal combustion engine (ICE) vehicles (when appropriate) until equivalent battery-electric vehicle (BEV) models become available in the market.

Vehicle investments are long-term; units purchased today will remain in service for up to a decade or longer. ICE vehicles will quickly become outdated as BEVs rapidly take over. Globally, numerous jurisdictions have already legislated the end of the ICE – some as soon as 2030. On January 28, 2021, General Motors pledged to cease building gasoline and diesel cars, vans, and SUVs by 2035. Even more recently, on June 29, 2021, the Canadian government announced a mandatory target for all new light-duty cars and passenger trucks sales to be zero-emission by 2035, accelerating Canada's previous goal of 100 percent sales by 2040[6].

ICE vehicles purchased today for a fleet with a current-day value in the millions of dollars may be nearly worthless when ICEs become obsolete.

[6] Source: https://www.canada.ca/en/transport-canada/news/2021/06/building-a-green-economy-government-of-canada-to-require-100-of-car-and-passenger-truck-sales-be-zero-emission-by-2035-in-canada.html

BEVs have a fraction of the moving parts of an ICE vehicle, cost far less to maintain, offer better performance, and can have a much lower total cost of ownership (TCO). Concurrently, BEV prices are coming down; it is believed that BEVs may reach price-parity with ICEs as soon as 2025. For these reasons, if the condition of currently-owned Brampton fleet ICE vehicles will allow, we suggest prolonging their lifecycles until BEV replacements are available.

Today, only light-duty (cars, SUVs), transit buses, and a handful of medium- and heavy-duty (MHD) truck BEV models are available. However, by 2022 the types of vehicles that comprise a major portion of the Brampton fleet, including pickup trucks, will be available as BEVs. And by 2024, BEV MHD truck offerings will be more plentiful. The time is now to **begin preparing for the transition to BEVs** by investing in electric vehicle supply equipment (EVSE) while awaiting suitable BEVs to become readily available. Importantly, existing electrical capacity at facilities may require significant upgrades to power charging stations for multiple vehicles – a potential challenge that should be addressed as early as possible.

Summary of Results

RSI-FC data-modelled nine fleet-wide low-carbon solutions (scenarios) for the City of Brampton, for which we calculated the potential impacts of each relative to the 2019 baseline, and categorized them into three groups: best management practices (BMPs), fuel switching, and battery-electric vehicle (BEV) phase-in. We modelled one additional hybrid-electric scenario for the Fire & EMS sub-fleet. Further details and sub-fleet scenario results, as well as a cost analysis for electric vehicle charging infrastructure (EVSE), are provided in *Section 3.0*.

These “what-if” scenarios assessed the potential outcomes if each of the 10 low-carbon solutions being modelled were in place for the same types of vehicles, the same number of vehicles, travelling the same number of kilometres as in baseline year, 2019. All scenarios are based on lifecycle analysis (LCA) and balanced capital budgets from Part One, for which our team modelled optimized economic lifecycles and balanced capital budgets by considering return-on-investment (ROI) for units due for replacement over a 15-year budget cycle.

Our modelling estimated operating and capital costs as well as GHG emissions reductions over subsequent fiscal years (2021-2035) relative to baseline year, 2019. In *Table 1* (below), results are summarized and include average annual Capital expenses (Capex) over a 15-year budget cycle, average annual Operating expense (Opex) changes over a 15-year budget cycle relative to the 2019 baseline, and annual tailpipe GHG reduction by 2035 relative to the 2019 baseline. For the purpose of data-modelling, the baseline fleet data provided by the City was for 2019 but we treated 2020 as the baseline year, presuming 2019 data was a reasonable proxy for 2020; therefore, all scenarios are data-modelled from 2021 onwards.

Group One scenarios summarize the potential impacts of short-term fleet-wide implementation of viable BMPs through to 2035 relative to the 2019 baseline. These best practices are relatively low-cost, high-impact "house-in-order" solutions that we recommend as first steps in any GHG-reduction strategy.

Group Two scenarios summarize the potential impacts of short-term fleet-wide fuel switches (for appropriate units) through to 2035 relative to the 2019 baseline. **Each fuel-switching solution has been modelled independently and builds on (i.e., includes) the benefits of *all* Group One solutions.** We refer to fuel switches as "messy-middle" solutions – the ones that are achievable right now with a degree of effort and cost – which fleets can employ for reducing their environmental impacts while awaiting more BEV models to become available.

The purpose of modelling all possible fuel switches is for completeness; although we are aware that the City's fleet management may not want to further explore particular fuel-switching options, we believe that it is important to have modelling data for comparative analysis with other GHG reduction solutions – to holistically assess all viable options.

The Group Three scenario summarizes the cumulative impacts of a fleet-wide, multi-year (immediate to 2035) phase-in of battery-electric vehicles (BEVs) as units become due for replacement. **Like Group Two, the results for Group Three build on (i.e., include) the benefits of *all* Group One solutions**; however, the majority of tailpipe emissions reductions by the end of the budget period are due to replacing internal combustion engine (ICE) vehicles with BEVs.

The recommended BEV transition plan provided in this Sustainable Fleet Strategy (in addition to all BMPs), if fully implemented in the timeline proposed, has the potential to reduce the City of Brampton's fleet tailpipe GHG emissions by **86% by 2035**. Our recommendations in this report are pragmatic and fiscally-prudent, based on research, data-driven analysis, and sound economic principles and practices.

Table 1: Summary of fleet-wide results of scenario analysis over the period 2021-2035 relative to the 2019 baseline.

Group	FAR Scenario Description	Implementation Timing[7]	Average Annual Vehicle Replacement Capex[8] ($ millions)	Average Annual Opex[9][10] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction[11] Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
One	Enhanced specs: light-weighting, LRR[12] (all units)	Short-term	7.4	+217	230	6%
	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	7.4	+205	812	21%
	Route planning/optimization & trip reduction (all units)	Short-term	7.4	+203	637	16%
	All BMPs (all solutions above, for all units)	Short-term	7.4	+227	1,372	35%
Two[13]	Fuel switch: E85 (all possible flex-fuel units)	Short-term	7.4	-128	2,137	54%
	Fuel switch: B10 (annualized blend – all diesel on-road units)	Short-term	7.4	-119	1,512	38%
	Fuel switch: CNG (all applicable units)	Short-term	7.4	-361	1,810	46%
	Fuel switch: LPG (all applicable units)	Short-term	7.4	-349	1,578	40%
Three[14]	BEV phase-in: cars & SUVs starting immediately, pickups & vans starting in 2022, vans, and medium- and heavy-duty (MHD) trucks starting in 2024; includes Fire & EMS light-duty (LD) phase-in only	Immediate - 2035	7.9	+315	3,376	86%

[7] For data-modelling purposes, "short-term" means that a fleet-wide implementation of the solution (for appropriate units) is modelled one-year period following the baseline – for the same types of vehicles, the same number of vehicles, travelling the same number of kilometres as the baseline. The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.
[8] Average annual Capital expenses (Capex) for the entire modelling period (2021-2035), including compounding inflation for each year at current rate of inflation
[9] Average annual Operating expenses (Opex) for the entire modelling period (2021-2035) , including compounding inflation for each year at current rate of inflation
[10] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.
[11] Annual GHG reduction by the end of the modelling period (2035) relative to the 2019 baseline
[12] "LRR" refers to low rolling resistance tires
[13] Builds on benefits of all Group One solutions
[14] Builds on benefits of all Group One solutions. EVSE costs are treated separately in an additional analysis.

Summary of Recommendations

In *Table 2* (below), we summarize our recommendations for Brampton's Sustainable Fleet Strategy. Recommendations are a combination of: (1) potential opportunities for improvement of the City's best management practices (BMPs), or "house-in-order" solutions; (2) potential interim fuel-switching or "messy-middle" solutions; (3) go-forward actions in preparation for the transition to battery-electric vehicles (BEVs); and (4) purchase versus lease versus rent considerations. The majority of the BMP recommendations are key findings from Part One of the Strategy: Baseline Review and Analysis.

Table 2: Summary of recommendations for Brampton's Sustainable Fleet Strategy

Area/ Topic	Recommendation(s)	Fleet Services	Fire and Emergency Services	Transit	Implementation Timing[15]	Cost $ = low $$ = medium $$$ = high
Best Management Practices	(1) Follow a historical data-driven lifecycle cost assessment, which is completed by modelling repair, maintenance, fuel, and cost of capital over a vehicle's entire lifecycle, to determine the optimal replacement age of vehicles (such as by using RSI-FC's lifecycle analysis software).	x	x	x	Short- to medium-term	$
	(2) Employ a total cost of ownership (TCO) approach to optimize the use of capital. Procurement should consider TCO in its competitive bidding proposal structures instead of the lowest-compliant bid approach.	x		x	Short-term	$

[15] Short-term = 2021-2022; medium-term = 2023-2025; long-term = 2026-2035

(3) Ensure the size of vehicles needed is based on their use case; when appropriate, select a smaller vehicle sized appropriately for the task at hand (rightsizing). This would require user group buy-in when outlining what is needed to perform job duties.	x		x	Short-term	$
(4) Decommission under-utilized units to reduce the overall number of fleet vehicles (downsizing).	x	x	x	Short-term	$
(5) Allocate auction proceeds into a reserve fund to ensure there is a direct benefit from the sale of used vehicles and that vehicle replacement needs are met.	x	x	x	Short-term	$
(6) Consider a chargeback system for all user groups. Assigning vehicles costs to user groups are known to deliver tremendous cost-savings.	x		x	Short- to medium-term	$
(7) Ensure job suitability of vehicles is appropriate before proceeding with light-weighting enhancements.	x	x	x	Short- to medium-term	$
(8) Implement fuel-efficient driver training.		x	x	Short-term	$
(9) Develop a fuel-efficient driver incentive program in which drivers	x	x	x	Short-term	$

	are incentivized to improve behaviours or reduce their travel through approaches such as card stamping and prize draws.					
	(10) Encourage virtual meetings (post Covid-19 pandemic) and staff carpooling, when possible, to reduce fleet vehicle emissions.	x	x	x	Short-term	$
Fuel Switching – E85 Ethanol	(1) With significant GHG reduction potential, consider E85 for factory flex-fuel units during the transition to battery electric vehicles (BEVs).	x		x	Short- to medium-term	$
	(2) Consider a pilot project with several units switched to E85 to determine the fuel-efficiency loss and cost-effectiveness; if successful, consider switching other appropriate units – particularly those with several years of useful life remaining.	x		x	Short- to medium-term	$
Fuel-Switching – Compressed Natural Gas (CNG)	(1) Consider CNG only as an optional, secondary GHG reduction solution for medium- and heavy-duty vehicles (MHDVs), as a commitment to CNG may not be a prudent choice for the long-term due to high fuelling infrastructure costs.	x			Short- to medium-term	$$$
Battery-Electric Vehicle Phase-In	(1) Conduct a temporary pause on purchasing new internal combustion engine (ICE) vehicles (when appropriate) for the short term –	x	x	x	Short- to medium-term	$

	one year for pickups, three years for medium- and heavy-duty vehicles MHDVs) – while awaiting battery-electric vehicle (BEV) counterparts to become available. The exception is for light-duty (LD) passenger BEVs which are currently available with sufficient range, such as the Kia Soul and the Chevrolet Bolt.					
	(2) Through a lens of achieving and exceeding deep GHG-reduction goals, allocate the majority of fleet capital spending on BEVs (for appropriate vehicle categories as BEV models become available).	x	x	x	Short- to long-term	$$$
	(3) Strictly through a lens of fiscal planning, prioritize replacement of ICE units with BEVs *only if they would deliver ROI* – typically ones that have relatively high annual mileage.	x	x	x	Short- to long-term	$$
	(4) Conduct a pilot project for several BEVs when they become available (e.g., pickups) to track range capabilities and cost savings and assess the units' performance for all seasons and varying weather conditions.	x	x	x	Short- to medium-term	$$

	(5) Assuming the pilot project is successful, acquire BEVs in bulk to replace units that would provide the greatest ROI.	x	x	x	Medium- to long-term	$$$
	(6) Closely monitor the acquisition costs for BEVs and re-evaluate the business case (cost-benefit) for individual units as prices come down.	x	x	x	Short- to long-term	$
	(7) Provide high-voltage training for technicians and closely monitor the launch of new BEV training programs.	x	x	x	Short- to long-term	$
Electric Vehicle Supply Equipment	(1) Allocate capital towards charging infrastructure required for the transition to BEVs for all vehicle categories. Much of the additional capital costs associated with electric vehicle supply equipment (EVSE) may be offset through lower capital spending during the pause recommended for purchasing internal combustion engine (ICE) pickups and medium- and heavy-duty vehicles (MHDVs).	x	x	x	Short- to long-term	$$$
	(2) Continue to pursue funding from NRCan's Zero Emission Vehicle Infrastructure Program (ZEVIP).	x	x	x	Short- to long-term	$

	(3) Assess existing electrical capacity at facilities to determine whether substantial upgrades to power charging stations for multiple vehicles are required.	x	x	x	Short- to mid-term	$$
	(4) Explore supplying power to each garage on two separate feeds from the grid to reduce the risk of local failure taking power away from the whole site.	x	x	x	Short- to long-term	$$
Collaboration/Partnership Approaches	(1) Engage in internal partnerships within and across departments or fleets, such as multi-departmental funding applications for charging infrastructure, or sharing of BEV pilot program results to determine vehicles requirements and specifications (e.g., real-world range, real-world charging needs) ahead of large purchasing decisions involving many units.	x	x	x	Short- to long-term	$
	(2) Engage in external partnerships with the Region of Peel and/or other municipalities/regions in the Greater Toronto and Hamilton Area (GTHA) for potential collaborations, such as joint specification writing and/or joint tenders and sharing of BEV pilot program results through working groups.	x	x	x	Short- to long-term	$

	(3) Leverage the knowledge gained on BEV transition (e.g., procurement of vehicles and charging infrastructure) through organizational memberships such as the Clean Air Partnership or the Municipal Equipment and Operations Association of Ontario (MEOA) and apply any lessons learned to make informed decisions.	x	x	x	Short- to long-term	$
Risk/Change Management Approaches	(1) Share knowledge and educational strategies with internal and/or external partners. This could entail communicating the business case for BEVs and dispelling myths about BEVs, such as potential negative and/or false perceptions on battery safety, battery life, battery end-of-life, and vehicle performance.	x	x	x	Short- to long-term	$
	(2) Develop BEV educational and outreach materials for employees and operators summarizing the reasons and benefits of transitioning to BEVs.	x	x	x	Short- to medium-term	$
	(3) Invite frontline employees to take BEV test drives to familiarize them with fully-electric vehicles and charging, as well as to give them first-hand experience of improved	x	x	x	Short- to medium-term	$

	performance (e.g., instant torque, little noise, regenerative breaking).					
	(4) Provide operators with a BEV orientation before releasing new models into the fleet to enable them to become familiar with the different driving experience (e.g., instant torque, little noise, regenerative breaking), as well as to alleviate/eliminate any apprehension or uncertainties.	x	x	x	Short- to long-term	$
	(5) Conduct a pilot project for several BEVs as they become available (e.g., pickups) to track range capabilities and cost savings and assess the units' performance for all seasons (one year) in varying weather conditions.	x	x	x	Short- to medium-term	$$
Monitoring & Reporting Progress	(1) Include fuel consumption (L/100 km), or corporate average fuel economy (CAFE), as a key performance indicator (KPI), or as part of benchmark and monitoring reports, to set goals and measure progress towards targets for improved fuel efficiency and reduced GHG emissions. To implement this, user groups would need to have more influence in purchase decisions (based on fuel	x		x	Short-term	$

		economy and emissions, as well as total cost of ownership).					
	(2)	Include GHG intensity (kg CO_2e/km) as a KPI, or as part of benchmark and monitoring reports. This indicator would allow the City to measure its success in reducing GHG emissions while taking into account the potential growth of its fleet due to a growing population.	x	x	x	Short-term	$
	(3)	Include area ratio (no. of units/km^2) and/or population ratio (population/no. of units) as a KPI, or as part of benchmark and monitoring reports, to assess the relative size of the City's fleet proportional to its geographic size and population.	x		x	Short-term	$
	(4)	Use RSI-FC's electric vehicle supply equipment (EVSE) costing outlook, which is based on future demand for battery-electric vehicles (BEVs) in the City's fleets, as a benchmark for monitoring and tracking the uptake of BEVs as well as the progression in the installation of charging infrastructure.	x	x	x	Short- to long-term	$
Purchase, Lease or Rent	(1)	If the City considers leasing as an alternative to purchasing or renting,	x		x	Short- to long-term	$

Fleet Challenge
Driving Change

	first issue an RFP or RFQ to determine these costs with absolute clarity. Then, with certainty around these key assumptions, lease versus buy discount cashflow (DCF) analysis should be recalculated.				
	(2) Carefully prepare bid specifications for a vehicle leasing RFP/Q so that *all* cradle-to-grave leasing costs, including all service charges and fees, can be identified and evaluated.	x	x	Short- to long-term	$
	(3) In RFP/Qs, consider adding a requirement that potential lease vendors must state their beginning-to-end, total-cost-of-leasing projections, including all fees and surcharges over the entire lease term in their proposals.	x	x	Short- to long-term	$
	(4) To ensure consistent bid responses, include in the RFP/Qs a standard response format, such as a fillable .pdf template, for bidders to list their charges, rates, additional fees, and surcharges in a common way that competing bidders' responses can be compared like-for-like.	x	x	Short- to long-term	$
	(5) Require vendor proposals to include their proposed fixed or floating	x	x	Short- to long-term	$

		interest rate; if the latter, the percentage of the profit "adder" (markup) for the lessor that will be applied must be stated.				
	(6)	Require vendor proposals to guarantee that all conceivable service charges and other fees that may be applied over the leased vehicle's entire cradle-to-grave lifecycle have been stated.	x	x	Short- to long-term	$

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Section 1.0: Introduction and Background

Climate change is a critical and urgent global issue. The United Nations defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods[16]." The term includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer[17].

Greenhouse gases (GHGs) produced by human activity is the largest contributor to climate change. GHGs are gaseous compounds (such as carbon dioxide) that absorb infrared radiation, trap heat in the atmosphere, increasing global temperature and thus contributing to the greenhouse effect[18]. While there are several GHGs[19] to consider, when calculating emissions the most commonly used measure is carbon dioxide equivalent (CO_2e)[20]. This combines the effects of all the major GHGs into a single, comparable measure.

Over the past several decades, scientific evidence of climate change, also referred to as global warming due to the increasing temperatures of the global climate system, has been vast and unequivocal. Thus, the Paris Agreement (the Agreement, the Accord) was established with a goal of keeping global warming below two (2) degrees Celsius compared with preindustrial times. The Agreement entered into force on November 4th 2016. Canada is a signatory and as so has established aggressive carbon-reduction targets and plans.

In addition to climate change, emissions from engine exhausts also contribute to ground-level air pollution and human health risk. Criteria air contaminants (CACs) contribute to smog, poor air quality, and acidic rain. CACs include several gases, particulate matters and volatile organic compounds[21]. In scientific studies, CACs have been linked to increased risks of respiratory and cardiovascular diseases as well as certain cancers. The World Health Organization reports that in 2012 around seven million people died as a result of air pollution exposure; one in eight of total global deaths were linked to air pollution[22]. According to the American Medical Association, globally, an estimated 3.3

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[16] Source: United Nations Framework Convention on Climate Change 1992: https://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/conveng.pdf
[17] Source: EPA. https://www3.epa.gov/climatechange/glossary.html
[18] Source: https://www.merriam-webster.com/dictionary/greenhouse%20gas
[19] GHGs include, but are not limited to carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), nitrogen trifluoride (NF_3), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs).
[20] "Carbon dioxide equivalent is a measure used to compare the emissions from various greenhouse gases based upon their global warming potential. For example, the global warming potential for methane over 100 years is 21. This means that emissions of one million metric tonnes of methane is equivalent to emissions of 21 million metric tonnes of carbon dioxide." Source: https://stats.oecd.org/glossary/detail.asp?ID=285
[21] CACs include Total Particulate Matter (TPM), Particulate Matter with a diameter less than 10 microns (PM10), Particulate Matter with a diameter less than 2.5 microns (PM2.5), Carbon Monoxide (CO), Nitrogen Oxides (NOx), Sulphur Oxides (SOx), Volatile Organic Compounds (VOC), and Ammonia (NH3).
[22] Source: http://www.who.int/mediacentre/news/releases/2014/air-pollution/en/

million annual premature deaths (5.86% of global mortality) are attributable to outdoor air pollution[23], although ambient air pollution has been regulated under national laws in many countries.

Socially responsible institutional (e.g., municipal), commercial, and industrial fleets can play an important role in reducing GHG emissions and air pollution.

Fleet Sector Impact

Low-carbon transportation is essential to both short-term GHG and fuel-use reduction and long-term decarbonization of the economy. In 2020, the transportation sector accounted for about 25% of greenhouse gas (GHG) emissions in Canada, second only to the oil and gas sector[24]. In Brampton, more than half of the City's 2016 corporate GHG emissions were generated from mobile sources[25]. Moreover, fleet emissions represent a steadily increasing portion of the City of Brampton's GHG emissions. Municipalities can play a key role in cutting emissions by transitioning their fleets to low-carbon and/or electric vehicles, while saving fuel and maintenance costs.

The transition to battery-electric vehicles (BEVs) of all classes will be a game-changer as these vehicles take up more of the market in the next several years, both in terms of operational cost savings and the deep GHG emission reductions required to curb the most severe impacts of climate change. Significant and growing commitments to integrating BEVs into fleet operations will be a driving force in the transition to BEVs[26]. Moreover, continued improvements in range capability and charging infrastructure will accelerate the electrification of fleets.

About Richmond Sustainability Initiatives

Since 2005, Richmond Sustainability Initiatives – Fleet Challenge (RSI-FC) has collaborated with fleet managers, technology providers, subject matter experts, and auto manufacturers to find viable solutions, technologies, and best management practices for reducing operating costs and vehicle emissions. From the beginning, we have remained a self-supporting and independently funded program without commercial biases or influences, providing fleet review, strategies and management consulting services to dozens of leading private and public sector fleets in Canada and the United States.

Through the combination of our experience and the use of our Fleet Analytics Review™ (FAR) software tool, we are delivering an advanced Sustainable Fleet Strategy for the City of Brampton that is realistic and achievable.

[23] Source: https://jamanetwork.com/journals/jama/article-abstract/2667043
[24] Source: https://climateactiontracker.org/countries/canada/
[25] Source: https://geohub.brampton.ca/pages/finance-ghg-emissions
[26] Source: ChargePoint. Trends & Prediction in Fleet Electrification [pdf]. June 2020.

Background

The City of Brampton operates three major sub-fleets – Fleet Services (Corporate Fleet), Fire & Emergency Services, and Brampton Transit – which serve the City's population of 593,638[27] residents, as of the 2016 Census, as well as the City's businesses.

In June 2020, the City declared a climate emergency, joining the Government of Canada and more than 400 Canadian municipalities that have done the same. According to corporate GHG emissions data, more than half of Brampton's 2016 corporate GHG emissions were generated from mobile sources, including the City's vehicle fleet and equipment[28], highlighting the importance of implementing green fleet strategies to achieve the City's GHG emission reduction goal of 50% by 2040 compared to 2016 levels. The Sustainable Fleet Strategy can play a key role in providing recommendations and potential pathways for achieving "deep decarbonization" of the City's fleet.

Green Fleet Accomplishments

In 2020, the City of Brampton received an American Public Works Association (APWA) Leading Fleets Award. Although the City did not make the Leading Fleets Top 50 list, it was recognized as one of 50 Notable Fleets for municipalities across North America. Furthermore, the City's fleet was one of only five Canadian municipal fleets to be recognized in either category.

In 2009, the City of Brampton received an E3 Fleet Review. E3 is a national program managed by Richmond Sustainability Initiatives (RSI) involving an assessment of the sustainability performance of both private and public sector fleets across North America. Brampton fleet management's goal is to become E3 gold certified in the near future. Moreover, the Sustainable Fleet Strategy will assist the City in achieving its goals of further greening its fleet, including transitioning to battery-electric vehicles (BEVs).

Vision, Goals, and Objectives

The vision for the Sustainable Fleet Strategy: Framework and Action Plan Report is for the City of Brampton to steadily transition towards a green fleet and continue to be a leading municipal fleet in operational excellence and environmental sustainability. With this vision in mind, the goal is to provide an ambitious, yet feasible, roadmap for the City to achieve its GHG emissions reduction target (50% reduction from 2016 levels by 2040, and 80% by 2050). To guide Brampton in achieving this goal, we have thoroughly analyzed the City's in-scope fleet data and have identified and assessed operational improvements and new technologies to reduce GHG emissions from vehicles.

[27] Census Profile, Canada 2016 Census. Statistics Canada.
[28] Source: https://geohub.brampton.ca/pages/finance-ghg-emissions

The primary objectives of the Framework and Action Plan Report were to:

(1) Data-model all potential fuel-reduction solutions and estimate their impacts (reductions of Operating expenses, Capital expenses, and GHG emissions) relative to the baseline.

(2) Create a battery-electric vehicle (BEV) transition plan and estimate the cost impacts and GHG-reduction potential relative to the baseline over a 15-year budget cycle.

(3) Estimate additional capital required for electric vehicle supply equipment (EVSE) over a 15-year budget cycle, and recommend solutions for offsetting these charging infrastructure costs through government funding, reduced operating budgets, and fleet reserve.

(4) Create a sustainable fleet action plan to improve the sustainability performance of the City's fleet including short-term (1-2 years), mid-term (3-5 years), and long-term (5-10+ years).

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Section 2.0: Approach and Methodology

RSI-FC maintains that fuel-reduction plans must be sustainable – both environmentally and financially. For this reason, RSI-FC's approach to developing our recommendations for Brampton's sustainable fuel-reduction strategy is based on data modelling of the current situation and completing research on a number of go-forward solutions.

To achieve optimal efficiency in completing this type of analysis, our team developed Fleet Analytics Review™ (FAR), a software tool designed specifically for complex green fleet planning and evaluation of short- to long-term fuel-reduction strategies, both in terms of cost savings and GHG reductions.

About Fleet Analytics Review™

Fleet Analytics Review™ (FAR) is a user-friendly, interactive decision support tool. FAR was designed to aid our team and fleet managers in developing short- to long-term green fleet plans by calculating the impacts of vehicle replacement and fuel-reduction solutions on operating costs, cost of capital, and GHG emissions. Moreover, it is used for long-term capital planning (LTCP) through an approach that works to balance, or smoothen, annual capital budgets and avoid cost spikes if possible. For a detailed FAR description, please see *Appendix A*.

Fuel-reduction solutions are analyzed using FAR, designed to efficiently estimate the cost-benefit and GHG emissions-reduction potential of many best management practices (BMPs), low-carbon fuels, and current or emerging technologies that have been proven to be beneficial to commercial and municipal fleets. The tool is used to evaluate these options in the context of the existing fleet being reviewed. That is, after optimizing lifecycles and implementing "house-in-order" strategies, fuel-saving options are modelled for units due for replacement to determine if they can deliver operating cost savings over subsequent fiscal years and, if so, the potential GHG emissions reductions.

FAR will be licensed in perpetuity to the City of Brampton for its internal use post-project. The FAR model is dynamic, and users can easily run future scenarios (such as assessing different vehicle types, fuels, or engine/drivetrain combinations) to see how such decisions impact operating expenses – ahead of their implementation, thereby heading off potentially costly errors.

Go-Forward Fuel-Reduction Solutions

Currently available fuel-reduction solutions can generally be grouped into three categories – (1) best management practices (BMPs); (2) fuel switching; and (3) hybrid-electric and battery-electric vehicles (HEVs and BEVs, respectively) – as described below. Details on all fuel-reduction solutions researched by RSI-FC can be found in *Appendix B*.

1) **Best Management Practices.** FAR calculates the cost-benefit and GHG reduction, unit-by-unit and fleet-wide, of BMPs or "house-in-order" strategies including operational improvements such as fuel-efficient driver training, route planning, etc., as well as vehicle specifications enhancements such as improved aerodynamics, reduced rolling resistance, light-weighting, and others.

2) **Fuel Switching.** FAR calculates the cost-benefit and GHG reduction, unit-by-unit and fleet-wide, of switching vehicle fuels from fossil-based (e.g., diesel) to alternate ones that are still fossil-based but cleaner burning (e.g., natural gas) or to renewable fuels (e.g., biodiesel).

3) **Hybrid-Electric and Battery-Electric Vehicles.** FAR calculates the cost-benefit and GHG reduction, unit-by-unit and fleet-wide, of switching to either hybrid-electric vehicles (HEVs), plug-in hybrid-electric vehicles (PHEVs), or battery-electric vehicles (BEVs). Transitioning to BEVs is the ultimate GHG reduction strategy for a fleet. In our analysis, we model tailpipe emissions reduction; switching to battery-electric reduces fuel consumption by 100% applying this method. However, in terms of life cycle GHG emissions, BEVs are "fuelled" by electricity needed to charge the battery(ies), which can indirectly use fossil fuel depending on the source of electricity.

Fuel-reduction solutions will have variable rates of success. For example, if a highway trucking fleet opts for aerodynamics packages on their trucks it may takes years to phase them in fully, so full fuel-savings results will accrue over a period of time. Similar logic applies to best practices based on human behaviour. With driver training, for instance, given that humans all have different rates of learning and information retention, bad driving habits may creep back in over time (or conversely, drivers may improve over time).

Similarly, regarding fuel switching, fuel-reduction potential will also be dependent on a multitude of factors, including driver training and habits, climates of operation, and maintenance cycles. For switching to BEVs, which can be regarded as a fuel switch with the source of "fuel" being the electrical power grid, tailpipe emissions are zero and thus there is no range of fuel-reduction potential at the source (i.e., 100% reduction is achieved at the tailpipe). However, the amount of electricity that is needed to power these units will depend on the same aforementioned factors, influencing operation costs and GHG emissions depending on the source of electricity.

Steps to Producing Brampton's Sustainable Fleet Strategy

RSI-FC employs a multi-step approach in low-carbon, green fleet planning. In Part One of the Sustainable Fleet Strategy: Background Review and Analysis Report, the steps included:

1) **Baseline Analysis.** At the outset, it is crucial to confidently know the current fleet baseline in terms of several key performance metrics ranging from cost, service levels (such as utilization and availability rates), and GHG emissions. For this step, we complete a FAR baseline analysis.

   For Brampton, we received baseline data of the in-scope fleet from City staff. The dataset provided to our team included a list of units, makes/models/years, asset values and ages, asset descriptions, fuel types, fuel costs, repair costs, and maintenance costs for a one-year review period (2019). We loaded this input data into FAR and completed baseline analysis.

2) **Business-as-Usual Review**. Most fleets have in place standard, business-as-usual (BAU) protocol/policies regarding vehicle replacement, capital budgeting, and fleet modernization planning. Fleet management generally employs pre-determined vehicle replacement guidelines (such as vehicles that will be replaced every "x" years or "y"-thousand kilometres travelled).

   Using FAR, RSI-FC analyzed the long-term outcomes of Brampton's current-day BAU vehicle replacement practices in terms of impacts on annual capital budgets, operating costs, and the GHG emissions.

3) **Lifecycle Analysis.** With RSI-FC's proprietary lifecycle analysis (LCA) software tool, our team inputs a fleet's historical data to calculate the optimal economic lifecycles for each vehicle category in the fleet.

   For Brampton, we completed LCA for vehicle categories consisting of multiple units to determine optimal economic lifecycles based on the City's average operating data.

4) **Data-Modelling Optimized Lifecycles.** With a fleet's optimal economic lifecycles calculated via LCA modelling, we input these vehicle replacement cycles into FAR to data-model the outcomes in terms of long-term capital budgets.

   For Brampton, we modeled a 15-year capital budget plan and go-forward operating cost and GHG emission impacts based on optimal economic lifecycles.

5) **Business Case Optimization.** For many of our client's fleets, once optimized lifecycles have been modelled in FAR it becomes very apparent that some vehicles deliver better return-on-

investment (ROI) than others. One reason is that some vehicles that are due for replacement based on the client's current replacement practices may have had lighter usage than other similar age units. For vehicles in better condition, service life can be extended to optimize the total cost of ownership (TCO). Lower ROI would result if a vehicle, still in good condition, was replaced prematurely; value will be lost.

For Brampton, the approach used by RSI-FC's data analysts was to *defer* replacement of some vehicles to the ensuing capital budget years to ensure full value is received from each unit. Fleet managers everywhere must make tough vehicle replace-or-retain decisions like this each year to optimize and stretch the use of available capital. Using RSI-FC's ROI-based approach to deferrals, year-over-year long term capital budgets can be better balanced. Ideally, this step should be completed by Fleet staff based on vehicle condition assessments and to balance go-forward annual capital budgets. Without any knowledge of vehicle condition, for this step our team deferred any units which, based on the data provided, were shown to have lower operating costs (including cost of capital) than if replaced. This step allowed us to balance Brampton's long-term capital budgets based on optimal ROI.

In Part Two of the Sustainable Fleet Strategy: Framework and Action Plan Report, our team continued from Step (5) in Part One and completed the following steps:

6) **"House-in-Order" Actions.** Before making commitments to fuel-switching or low-carbon technologies, we think it is essential to first get a fleet's "house in order" to save fuel and reduce GHG emissions. By this, we are referring to best management practices (BMPs) that should first be put in place, including:

    - **Enhanced Vehicle Specifications**. Low rolling resistance (LRR) tires and/or auto-inflation systems, aerodynamic vehicles, light-weighting, idle-reduction technologies, etc.

    - **Transportation Demand Management (TDM).** Trip reduction/avoidance and route planning/optimization

    - **Driver Training and Motivation.** Managing driver behaviours with eco-training and idle-reduction policies

    - **Fleet Downsizing.** Reducing the total number of low-utilization vehicles by undertaking a review to determine if some vehicles can be eliminated through early decommissioning

    - **Right-Sizing.** Specifying the correctly-sized vehicles for the job at hand

For Brampton, our team data-modelled several BMP solutions applicable to Brampton's fleet, which we termed Group One scenarios. We further divided this group into the following three scenarios:

- **Enhanced Specifications:** Low rolling resistance (LRR) tires and light-weighting
- **TDM**: route planning/optimization and trip reduction
- **Driver Behaviours**: eco-training and anti-idling policy/technologies (already in use at Fleet Services)

As data analysts without on-ground knowledge of vehicle needs, it is challenging to quantitatively model fleet downsizing and vehicle right-sizing; fleet managers best understand the usage patterns and demands of their specific vehicles. For this reason, for the City of Brampton we elected to provide qualitative recommendations for downsizing and right-sizing – based on our experience working with nearly 200 municipal and commercial fleets.

7) **"Messy-Middle" Solutions.** BEVs are undisputedly the optimal solution to GHG reduction and, for higher annual-mileage units, cost savings. However, today, only a limited number of BEV types are available. Battery-electric trucks (BETs) are coming, but in the meantime, many municipalities are seeking to get started with reducing their fleet GHGs right away. For these fleets, including the City of Brampton, an intermediate answer may be fuel-switching – transitioning away from fossil gasoline and diesel to alternate, lower-carbon fuels like propane (liquified petroleum gas, or LPG) and compressed natural gas (CNG), or renewable fuels like E85 ethanol and biodiesel (the latter of which is already being used at Fleet Services and Transit).

For Brampton, our team data-modelled all fuel-switching scenarios applicable to Brampton's fleet, which we termed Group Two scenarios and include:

- **Compressed Natural Gas (CNG)** for all applicable units of all classes
- **Liquified Petroleum Gas (LPG)** for all applicable units of all classes
- **Biodiesel B10** (annualized blend) for all diesel on-road units (B5 already in use at Fleet Services; B4/5 (winter) and up to B20 (summer) already in use at Transit)
- **Ethanol E85** for all possible flex-fuel units

The purpose of modelling all possible fuel switches is for completeness; although we are aware that the City's fleet management may not wish to further explore fuel-switching options, we believe that it is important to have modelling data for comparative analysis with other GHG reduction solutions – to holistically assess all viable options.

8) **Battery-Electric Vehicle Phase-in Planning.** Although there are numerous advantages of BEVs, few, if any fleets would – or could – replace all their internal combustion engine (ICE) units immediately with BEVs given capital budgets constraints and the fact that BEV offerings are quite limited at this time. This means that BEVs must be phased-in over many years. For this reason, we data-model the gradual impacts of fleet BEV adaptation on a 15-year phased-in basis.

   RSI-FC believes that phasing-in of BEVs should occur based on optimized lifecycles and balanced long-term budgets through business case optimization (see Step 5). In other words, the first units to be replaced with BEVs should be those that have been assessed as the optimal candidate vehicles that will deliver the best ROI. These are typically units with higher utilization and fuel consumption.

   For Brampton, after completing LCA and business case optimization for like-for-like vehicle replacements, our team then used FAR to model replacement of units at the end of their lifecycles from ICE to BEV in sync with fiscal years for which the type/categories of BEVs are expected to become available. LCA-optimized lifecycles are recommended by our team as a way to extend the lifecycles, wherever possible, of current-day ICE (gas and diesel) fleet vehicles while awaiting BEV replacements to become available.

   Given that some units do not show ROI when replaced with a BEV, our modelling is strictly a BEV phase-in over 15 fiscal years in accordance with the expected availability of BEV types until eventually, by the end of the period, all units with anticipated battery-electric options in the market are replaced. Our team reasoned that this approach is most appropriate given the objective of green fleet planning is to provide a roadmap for deep GHG emissions reduction, despite some lower mileage units being unlikely to deliver ROI if replaced with a BEV based on our modelling.

Methodology for Calculating Fleet GHG Emissions

As explained in the *Foreword* of this report, there are two standard reporting methods for vehicle GHG emissions modelling: (1) tailpipe combustion, and (2) fuel lifecycle (sometimes referred to as fuel cycle or well-to-wheel). Modelling of fuel lifecycle GHG emissions of motor fuels is used to assess the overall GHG impacts of the fuel, including each stage of its production and use, in addition to the fuel actually used to power a vehicle. Modelling of tailpipe emissions includes just the actual emissions produced by the vehicle itself through combustion. Lifecycle GHG emissions are, therefore, usually greater than tailpipe emissions.

While lifecycle emissions have been established for most fuel types, lifecycle emissions are often difficult to quantify for best management practices and also for electric vehicles because of the different mixes of electricity sources in different jurisdictions and at different times of day (i.e., fossil-fuel based, nuclear, and renewables). For this reason, to assess the potential GHG reduction on an "apples-to-apples" basis for each proposed solution, we have employed the tailpipe combustion method for the City of Brampton. Although not providing a complete well-to-wheel picture of GHG emissions, the results of our modelling employing the tailpipe combustion method gives a clear indication as to which solutions offer the greatest GHG reduction potential. Using this method, battery-electric vehicles (BEVs) emit zero tailpipe emissions.

RSI-FC has employed the most recent combustion (tailpipe) emission factors[29] associated with fossil fuels and alternate/renewable fuels as per GHGenius[30] Version 5.01a. Importantly, we have compared equivalent work or energy for the various fuels investigated to provide a realistic estimation of GHG emissions reductions. Without comparing fuels on an energy-equivalent basis, it often (erroneously) appears that alternate/renewable fuels lead to a greater reduction than the actual, on-ground reality. The following considerations must be taken into account for alternate/renewable fuels:

- For compressed natural gas (CNG), to compare energy on an apples-to-apples basis, account for the amount of natural gas (in kilograms) required to obtain the same energy content as a litre of diesel, also known as the diesel-litre equivalent (DLE), or a litre of gasoline. Based on the same work performed, a CNG vehicle has tailpipe emissions about 20-30% less than a comparable diesel or gasoline vehicle. In our FAR analysis, RSI-FC accounts for energy equivalency between diesel/gasoline and CNG.

- Propane (liquified petroleum gas, or LPG) has a significant GHG emissions reduction potential when compared to the same volume of gasoline; however, it contains much less energy than gasoline per unit volume. Based on the same work performed, the tailpipe emissions reduction for a propane-powered vehicle is actually around 9.5% when compared to a gasoline-powered vehicle. In our FAR analysis, RSI-FC accounts for the reduction in fuel-efficiency for propane.

- For renewable fuels (i.e., biodiesel and ethanol), there is a distinct difference between strictly tailpipe emissions and what is termed "net vehicle operation" emissions. RSI-FC uses net vehicle operation emissions factors, which account for the change in airborne carbon that occurs due to the combustion process. This approach considers both the sequestration of carbon through growing of biomass and the re-release of carbon through vehicle combustion; the result is a more complete picture of airborne carbon and significantly lowered overall operative emissions for higher renewable fuel blends.

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[29] Source: GHGenius V 5.01a, Natural Resources Canada.
https://www.nrcan.gc.ca/energy/efficiency/transportation/7597

[30] GHGenius is a spreadsheet model that calculates the amount of greenhouse gases generated from the time a fuel is extracted or grown to the time that it is converted in a motive energy vehicle to produce power. Whether the fuel is burned in an internal combustion engine or transformed in a fuel cell, GHGenius identifies the amount of greenhouse gases generated by a wide variety of fuels and technologies, the amount of energy used and provided, and the cost effectiveness of the entire lifecycle.

- For biodiesel, fuel economy and cold weather performance need to be considered as well. Our recommendation is to use B5 in the winter and shoulder months to avoid gelling and B20 in the summer; in our modelling we estimate an annualized blend of B10. The energy content of pure biodiesel (B100) is close to 8% lower than pure diesel[31]. Taking into account this energy loss, using blends ranging from B5 to B20, the latter of which may be restricted to summer due to gelling in cold weather, requires slightly more fuel than pure diesel and lowers tailpipe GHG emissions by an estimated 10 percent as a whole. In our FAR analysis, RSI-FC accounts for the small but measurable reduction in fuel-efficiency for biodiesel blends.

- For ethanol fuel blends, although tailpipe GHG emissions are significantly less on a per liter basis, actual tailpipe GHG savings are reduced because a much greater volume of ethanol is required to achieve the same work. Taking into account this energy loss, using E85 requires significantly more (about 42%) fuel than pure gasoline. In our FAR analysis, RSI-FC accounts for the reduction in fuel-efficiency for E85. After accounting for the increase in volume to achieve the same work, using "net vehicle operation" emissions factors still results in an overall operative GHG emissions reduction of over 80% (i.e., the carbon that is sequestered through the biomass growth nearly completely offsets carbon output from combustion).

For ongoing fleet GHG emissions calculations at the City of Brampton, the tailpipe combustion method (currently employed by RSI-FC) and the fuel lifecycle emissions method are both defendable options. While the lifecycle method is more holistic and complete, the tailpipe emissions is a straightforward method that gives a clear indication as to which solutions offer the greatest GHG reduction potential. Whichever method is chosen, it is critical to consider energy equivalency as noted above for alternate/renewable fuels. If the fuel lifecycle emissions method is chosen, it is critical to include the source of electricity for charging BEVs. The combustion emissions factors and energy factors used for the Sustainable Fleet Strategy can be found in the Fleet Analytics Review™ (FAR) software tool, which will be licensed in perpetuity to the City of Brampton for its internal use post-project.

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[31] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.

Section 3.0: Low-Carbon Fleet Planning

The primary objective of the Sustainable Fleet Strategy was to analyze the City of Brampton's in-scope fleet data and identify and assess GHG reduction opportunities – including operational improvements and new technologies – and their associated costs/cost savings for Fleet Services, Transit (non-revenue units), and Fire & EMS.

In Part One: Baseline Review and Analysis Report, RSI-FC prepared the baseline from data provided by the City for the review period (2019), including capital expenses (Capex), operating expenses (Opex), and fuel consumption for all units. From the baseline, we modelled a 15-year budget cycle (to 2035) for business-as-usual (BAU) vehicle retention practices, optimized economic lifecycles through lifecycle analysis (LCA), and balanced Capex using optimized economic lifecycles by only replacing due units when they would deliver return-on-investment (ROI).

In Part Two: Framework and Action Plan, we modelled a number of fuel-reduction scenarios categorized into three groups: best management practices (BMPs), fuel switching, and battery-electric vehicle (BEV) phase-in. More details on all solutions that have been researched by RSI-FC, including the ones presented to the City, can be found in *Appendix B*.

The emphasis of our roadmap to 2035 is on BEV phase-in, as this is the most effective long-term GHG reduction strategy for a fleet as battery-electric technology continues to advance. Although lower mileage units are unlikely to deliver ROI if replaced with a BEV based on our modelling, our team reasoned that this approach was most appropriate given the objective of this report is to assist the City of Brampton to achieve deep GHG emissions reduction. Additionally, our team has estimated the costs of electric vehicle supply equipment (EVSE) over the same (15-year) time horizon based on the current size and mileage of Brampton's fleet.

Low-Carbon Fleet Analytics Review™ Scenarios

After optimizing economic lifecycles and performing long-term capital budget balancing (components of Part One), we performed a number of scenario analyses to assess the potential impacts of an array of fuel-reduction solutions. For each scenario, Fleet Analytics Review™ (FAR) calculated annual GHG emissions, operating costs, and capital requirements, and provided a long-term capital planning (LTCP) outlook from the baseline (2019 as a proxy for 2020) to 2035.

The scenarios have been categorized into three groups – best management practices (BMPs), fuel switching, and battery-electric vehicle (BEV) phase-in – and the potential impacts are presented relative to the baseline. We modelled one additional hybrid-electric scenario for the Fire & EMS sub-fleet.

For the purpose of data-modelling, the baseline fleet data provided by the City was for 2019; however, we treated 2020 as the baseline year using 2019 data as a proxy for 2020. These "what-if" scenarios assess the potential outcomes if each of the low-carbon solutions were in place for the same vehicles, the same number of vehicles, travelling the same number of kilometres as in 2019. The FAR scenarios are described below:

Completed in Part One: Baseline Review and Analysis

- FAR #1 is the baseline for the 2019 review period, which serves as a proxy for 2020, and is based on current vehicle lifecycles.
- In FAR #2, we assessed the potential impacts (annual GHG emissions, operating costs, and capital required) of optimized vehicle replacement practices based on our lifecycle analysis (LCA) study of Brampton's select vehicle categories.
- In FAR #3, using optimized economic lifecycles from FAR #2, we performed long-term capital budget balancing by modelling replacement of only those units which were shown to provide return-on-investment (ROI).

Completed in Part Two: Framework and Action Plan

- Starting from FAR #3, in FAR #4-6 we assessed the potential impacts of several best management practices (BMPs) for the existing fleets that we believe should be addressed at the outset, prior to any more costly upgrades or replacements. The cumulative impacts of implementing all of these BMPs, or "house-in-order" strategies, are modelled in FAR #7.
- Starting from FAR #7 (assuming all "house-in-order" strategies are fully implemented), in FAR #8-11 we data-modelled several "messy-middle" scenarios involving switching appropriate units to alternate and renewable fuels. The fuels we modelled are proven and mature green fleet, low-carbon solutions that may be possible today while awaiting the commercial availability of suitable battery-electric vehicles (BEVs).

  For Fire & EMS, due to potential supply challenges and given the fleet currently uses retail fuelling stations, the availability and reliability of ethanol poses a risk/concern to the emergency response nature of the operations. Therefore, **for modelling purposes only**, our team assessed the potential impacts of switching Fire & EMS to E85, should management ever deem the risk to be manageable.

  Transit currently uses biodiesel blends up to B20 are used for all diesel units, with the blend changing throughout the year (B20 in summer, B4-5 in winter). Fleet Services currently uses B5 year-round for all diesel units and is not interested in switching to higher blends due to issues with higher downtime and maintenance they experienced when using B20 in the past. For Fire & EMS, the availability of biodiesel outside of the response areas poses a risk/ reliability concern to the emergency response nature of the operations. Therefore, **for modelling purposes only**, our team assessed the impacts of switching Fleet Services and Fire & EMS diesel units to B10 (annualized) to holistically assess and compare all viable options.

- Starting from FAR #7, in FAR #12 we assessed the potential impacts of hybrid conversion for Class 3-5 Fire & EMS units only – those units that may not be suitable candidates for BEV replacement in coming years.

- Starting from FAR #7, in FAR #13 we assessed the potential impacts of a long-term phase-in of BEVs. We modelled the replacement of units due for replacement with BEVs in the light-duty (LD) category (cars, SUVs) starting immediately (2021), which are currently the only options available. We then modelled the replacement of pickups and vans starting in 2022, and medium- and heavy-duty (MHD) trucks beginning in 2024. Note that, for Fire & EMS, we modelled BEV replacement only for LD units. *Table 3* shows the expected timeline of BEV types and examples of original equipment manufacturers (OEMs) currently producing or expected to produce these vehicles.

Table 3: Expected timeline of BEV types and examples of OEMs

BEV Type	Expected Availability	Example OEMs
Car/SUV	Currently available	Chevrolet, Kia, Tesla
Pickup	2022	General Motors, Ford, Rivian, Lordstown, Tesla
Refuse Truck	Currently Available	BYD, Lion Electric, Mack, Volvo
Passenger Bus	Currently Available	Lion Electric
*Transit Bus	Currently Available	New Flyer, Nova Bus (City of Brampton currently has these buses)
Medium- and Heavy-Duty Truck	2024	Daimler, Lion Electric, Tesla, Workhorse

*Transit buses are out of scope for the Sustainable Fleet Strategy

FAR Scenario Comparative Analysis

A comparative analysis of the various FAR scenarios demonstrates the varying levels of effectiveness over the long-term – estimated through our modelling – for different fuel-reduction solutions/strategies that the City of Brampton can implement to reduce its fleet GHG emissions.

Table 4 (overleaf) summarizes fleet-wide results of the scenarios over the 15-year budget period modelled (2021-2035) in terms of average annual capital expenses (Capex) over a 15-year budget cycle, average annual Operating expense (Opex) changes over a 15-year budget cycle relative to the 2019 baseline, and annual tailpipe GHG reduction by 2035 relative to the 2019 baseline.

Figure 1 (overleaf) is a graphical representation of *Table 4,* but shows the *actual* Opex and GHG emissions as opposed to the reduction – a different depiction of the same results. It summarizes fleet-wide scenario results over the modelling period in terms of average annual Opex and GHG emissions by the year 2035 – providing a good visualization for which solutions/strategies are most effective in terms of both operating costs and environment.

Group One scenarios (indicated by pink rows, bars, dots) summarize the potential impacts of short-term, fleet-wide implementation of viable best management practices (BMPs) through to 2035 relative to the 2019 baseline. These best practices are relatively low-cost, high-impact "house-in-order" solutions that we recommend as prudent first steps in any GHG-reduction strategy.

Group Two scenarios (indicated by mustard rows, bars, dots) summarize the potential impacts of short-term, fleet-wide fuel switches (for appropriate units) through to 2035 relative to the 2019 baseline. **Each fuel-switching solution has been modelled independently and builds on (i.e., includes) the benefits of *all* Group One solutions.** We refer to fuel switches as "messy-middle" solutions – those that are achievable right now with a degree of effort and cost – which fleets can employ for reducing their environmental impacts while awaiting more BEV models to become available.

The purpose of modelling all possible fuel switches is for completeness; although we are aware that the City's fleet management may not wish to further explore fuel-switching options, we believe that it is important to have modelling data for comparative analysis with other GHG reduction solutions – to holistically assess all viable options.

The Group Three scenario (indicated by green row, bar, dot) summarizes the cumulative impacts of a fleet-wide, multi-year (immediate to 2035) phase-in of battery-electric vehicles (BEVs) as units become due for replacement. **Like Group Two, the results for Group Three build on (i.e., include) the benefits of *all* Group One solutions**; however, the majority of tailpipe emissions reductions by the end of the budget period are due to replacing internal combustion engine (ICE) vehicles with BEVs.

Table 4: Summary of fleet-wide results of scenario analysis over the period 2021-2035 relative to the 2019 baseline

Group	FAR Scenario Description	Implementation Timing[32]	Average Annual Vehicle Replacement Capex[33] ($ millions)	Average Annual Opex[34][35] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction[36] Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
One	Enhanced specs: light-weighting, LRR[37] (all units)	Short-term	7.4	+217	230	6%
	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	7.4	+205	812	21%
	Route planning/optimization & trip reduction (all units)	Short-term	7.4	+203	637	16%
	All BMPs (all solutions above, for all units)	Short-term	7.4	+227	1,372	35%
Two[38]	Fuel switch: E85 (all possible flex-fuel units)	Short-term	7.4	-128	2,137	54%
	Fuel switch: B10 (annualized blend – all diesel on-road units)	Short-term	7.4	-119	1,512	38%
	Fuel switch: CNG (all applicable units)	Short-term	7.4	-361	1,810	46%
	Fuel switch: LPG (all applicable units)	Short-term	7.4	-349	1,578	40%
Three[39]	BEV phase-in: cars & SUVs starting immediately, pickups & vans starting in 2022, vans, and medium- and heavy-duty (MHD) trucks starting in 2024; includes Fire & EMS light-duty (LD) phase-in only	Immediate - 2035	7.9	+315	3,376	86%

[32] For data-modelling purposes, "short-term" means that a fleet-wide implementation of the solution (for appropriate units) is modelled one-year period following the baseline – for the same types of vehicles, the same number of vehicles, travelling the same number of kilometres as the baseline. The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.

[33] Average annual Capital expenses (Capex) for the entire modelling period (2021-2035), including compounding inflation for each year at current rate of inflation

[34] Average annual Operating expenses (Opex) for the entire modelling period (2021-2035), including compounding inflation for each year at current rate of inflation

[35] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.

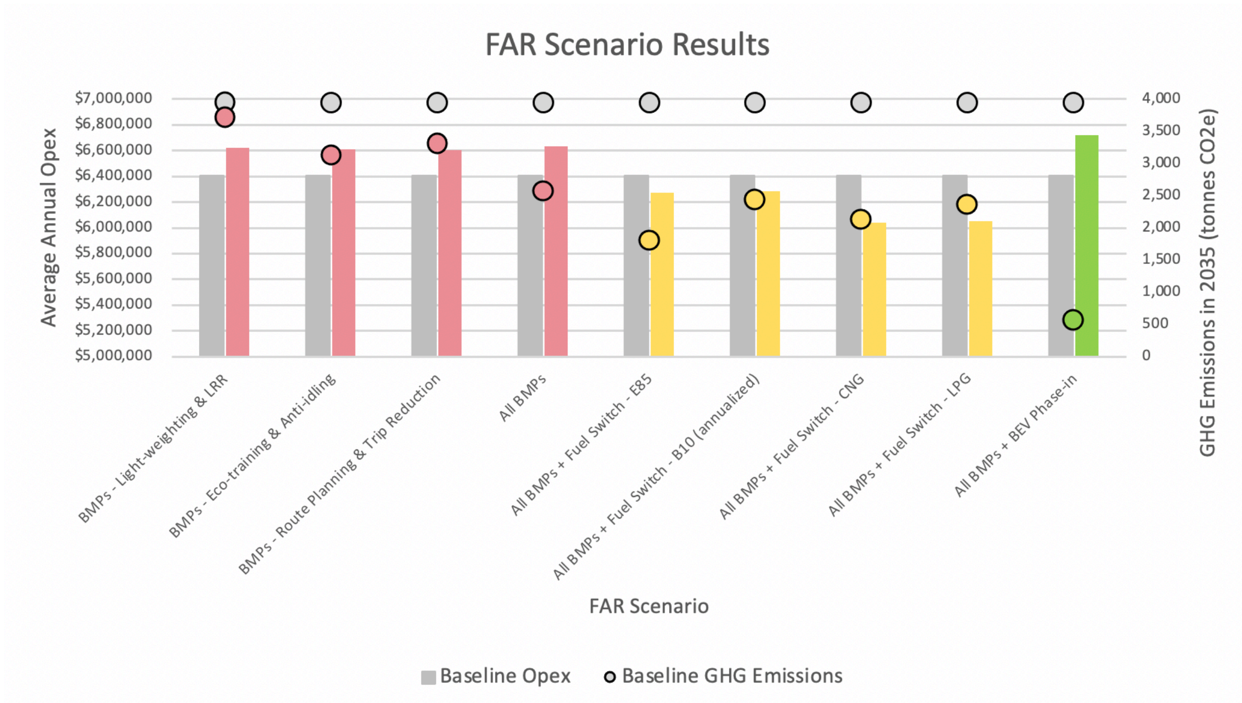
[36] Annual GHG reduction by the end of the modelling period (2035) relative to the 2019 baseline

[37] "LRR" refers to low rolling resistance tires

[38] Builds on benefits of all Group One solutions

[39] Builds on benefits of all Group One solutions. EVSE costs are treated separately in an additional analysis.

Figure 1: Summary of fleet-wide results of scenario analysis over the modelled period 2021-2035, in terms of Opex and GHG emissions. Bars represent Opex (primary axis) and dots represent GHG emissions (secondary axis).



When viewing *Table 4* and *Figure 1*, there are several important results revealed from our modelling, which include:

- Driver eco-training and anti-idling policy/technologies, if fully implemented fleet-wide, have the greatest GHG-reduction of all BMPs, based on our modelling.

- Switching all possible flex-fuel units to ethanol 85 (E85) has the greatest GHG-reduction potential of all fuel-switching options, based on our modelling. As there is limited availability of this fuel (sold outside of Ontario according to our research), finding a reliable supply of E85 may be a barrier; however, interim or "messy middle" solutions all have their challenges that can be overcome with effort and determination.

- Compressed natural gas (CNG), strictly based on our fleet-wide modelling, is shown as a cost-effective solution over the long-term.

  Although CNG conversion is a solution that can potentially deliver significant fuel cost savings, when breaking down modelling results for each in-scope fleet it was shown to be cost effective only for Fleet Services. This is due to the high cost of installing fast-fuelling systems; the larger size of the Fleet Services' fleet compared to the Transit (non-revenue units) and Fire & EMS fleets resulted in the high infrastructure costs being spread over a greater number units (as per our modelling) – demonstrating a viable business case.

However, given that medium- and heavy-duty vehicles (MHDVs) are moving away from the internal combustion engine toward battery-electric zero-emission units, a commitment to CNG does not appear to be a prudent choice for the long-term.

Moreover, although switching CNG results in substantial GHG emissions reductions, employing this solution alone will not achieve the goal of deep decarbonization of the Brampton fleet.

- **Transitioning to BEVs is the most effective long-term GHG-reduction solution for Brampton's fleets.** The slightly higher average annual Opex compared to the baseline, based on our modelling, has resulted because we have included the cost of capital as part of Opex; currently, the upfront costs of BEVs is greater than internal combustion engine (ICE) vehicles, and we have assumed this to be the case going forward.

  Note that we expect the cost of BEVs to come down with time but did not make this assumption based on speculation; rather, our FAR analysis uses current, real data as much as possible and limits assumptions.

Low-Carbon Fleet Strategies

The next critical piece of the Sustainable Fleet Strategy is to present relevant and actionable low-carbon fleet strategies for the City's consideration. To communicate this in a logical, step-by-step manner, we encapsulated the FAR scenario results as single long-term capital planning (LTCP) strategies – for the entire fleet and for each sub-fleet (*Tables 5-8*, overleaf) – which provide a roadmap for the City to achieving and exceeding its GHG emissions reduction target (50% reduction from 2016 levels by 2040).

For planning purposes, we have included:

(1) the overall impacts of short-term implementation of viable best management practices (BMPs, Group One solutions);

(2) the overall impacts of short-term implementation of fuel-switching options (Group Two solutions); and

(3) year-by-year impacts of battery-electric vehicle (BEV) phase-in (Group Three solution).

Together, the three groups of solutions form possible low-carbon fleet strategies from 2021-2035 for the City of Brampton's fleets, in terms of timing of implementation, estimated capital expenses (Capex) required, estimated changes in operating expenses (Opex) relative to the baseline year, and estimated tailpipe GHG emissions reductions.

BMPs (Group One solutions) are relatively low-cost, high-impact “house-in-order” solutions that we recommend as first steps in any GHG-reduction strategy.

Fuel switches (Group Two solutions) are modelled as **independent scenarios**, providing the City of Brampton with an array of “messy-middle” options that are achievable in the short-term with a degree of effort and cost while awaiting more BEV models to become available, but that **each one builds on *all* the benefits of Group One solutions**.

The purpose of modelling all possible fuel switches is for completeness; although we are aware that the City’s fleet management may not wish to further explore fuel-switching options, we believe that it is important to have modelling data for comparative analysis with other GHG reduction solutions – to holistically assess all viable options.

Like the fuel-switching scenarios, the BEV phase-in scenario (Group Three solution) **builds on *all* the benefits of Group One solutions**.

Results from Part One of the Sustainable Fleet Strategy (current lifecycles, optimized economic lifecycles, and balanced Capex using optimized economic lifecycles) are included for reference purposes in *Tables 5-8* (overleaf).

Note that large vehicle replacement Capex spikes in FAR models 1 (current lifecycles) and 2 (optimized economic lifecycles) are due to the large number of vehicles that had exceeded their planned replacement age at the time of our review. In FAR 3, our analysts balanced the replacement of units based on optimized economic lifecycles and return-on-investment (ROI) to spread the capital over the budget period.

All Fleets

Table 5: Fleet-wide low-carbon fleet plan

Group	FAR #	FAR Scenario Description	Implementation Timing[40]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[41] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
-	1	Current lifecycles	2021	28.2	-820	27	1%
	2	Optimized lifecycles	2021	25.5	-640	20	0.5%
	3	Balanced Capex using optimized lifecycles	2021	7.5	-330	5	0.1%
One[42]	4	Enhanced specs: light-weighting, LRR (all units)	Short-term	7.4	+217	230	6%
	5	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	7.4	+205	812	21%
	6	Route planning/optimization & trip reduction (all units)	Short-term	7.4	+203	637	16%
	7	All BMPs (all solutions above, for all units)	Short-term	7.4	+227	1,372	35%
Two[43]	8	Fuel switch: E85 (all possible flex-fuel units)	Short-term	7.4	-128	2,137	54%
	9	Fuel switch: B10 (annualized blend – all diesel on-road units)	Short-term	7.4	-119	1,512	38%
	10	Fuel switch: CNG (all applicable units)	Short-term	7.4	-361	1,810	46%
	11	Fuel switch: LPG (all applicable units)	Short-term	7.4	-349	1,578	40%
Three[44]	13	BEV phase-in: cars & SUVs	2021	6.0	+30	1,339	34%
		BEV phase-in: cars, SUVs, pickups, vans	2022	5.0	-352	1,658	42%
		BEV phase-in: cars, SUVs, pickups, vans	2023	6.2	-68	2,000	51%

[40] The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.
[41] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.
[42] Builds on FAR #3
[43] Builds on FAR #7 (all benefits of Group One solutions)
[44] Builds on FAR #7 (all benefits of Group One solutions). EVSE costs are treated separately in an additional analysis.

Group	FAR #	FAR Scenario Description	Implementation Timing[40]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[41] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2024	12.0	-331	2,290	58%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2025	9.5	+155	2,487	63%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2026	9.6	+368	2,748	70%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2027	4.3	+307	2,893	73%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2028	7.4	+491	3,012	76%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2029	6.6	+546	3,178	81%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2030	5.9	+478	3,311	84%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2031	11.8	+479	3,361	85%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2032	10.3	+622	3,375	86%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2033	9.2	+815	3,376	86%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2034	6.2	+522	3,376	86%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2035	8.3	+664	3,376	86%

Fleet Services

Table 6: Fleet Services low-carbon fleet plan

Group	FAR #	FAR Scenario Description	Implementation Timing[45]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[46] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
-	1	Current lifecycles	2021	10.3	-789	21	0.8%
	2	Optimized lifecycles	2021	7.7	-607	14	0.5%
	3	Balanced Capex using optimized lifecycles	2021	1.8	-228	2	0.1%
One[47]	4	Enhanced specs: light-weighting, LRR (all units)	Short-term	3.4	-63	160	6%
	5[48]	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	3.4	-71	565	21%
	6	Route planning/optimization & trip reduction (all units)	Short-term	3.4	-72	444	16%
	7	All BMPs (all solutions above, for all units)	Short-term	3.4	-54	955	35%
Two[49]	8	Fuel switch: E85 (all possible flex-fuel units)	Short-term	3.4	-302	1,489	54%
	9	Fuel switch: B10 (annualized blend – all diesel on-road units)	Short-term	3.4	-295	1,052	38%
	10	Fuel switch: CNG (all applicable units)	Short-term	3.4	-390	1,270	46%
	11	Fuel switch: LPG (all applicable units)	Short-term	3.4	-476	1,105	40%
Three[50]	13	BEV phase-in: cars & SUVs	2021	0.3	+96	936	34%
		BEV phase-in: cars, SUVs, pickups, vans	2022	3.6	-249	1,214	44%

[45] The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.
[46] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.
[47] Builds on FAR #3
[48] These solutions have already been implemented at Fleet Services; therefore, most of these benefits have likely been achieved and are only shown for modelling purposes.
[49] Builds on FAR #7 (all benefits of Group One solutions)
[50] Builds on FAR #7 (all benefits of Group One solutions). EVSE costs are treated separately in an additional analysis.

Group	FAR #	FAR Scenario Description	Implementation Timing[45]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[46] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
		BEV phase-in: cars, SUVs, pickups, vans	2023	3.8	+1	1,430	52%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2024	5.2	-318	1,701	62%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2025	4.3	+2	1,892	69%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2026	4.3	+75	2,147	78%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2027	3.6	+13	2,259	82%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2028	3.7	+157	2,358	86%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2029	5.1	+132	2,488	91%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2030	4.4	+89	2,621	96%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2031	3.6	+115	2,669	97%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2032	3.2	+160	2,682	98%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2033	3.0	+276	2,683	98%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2034	3.4	+17	2,683	98%
		BEV phase-in: cars, SUVs, pickups, vans, Class 3 to 8 trucks	2035	3.8	+174	2,683	98%

Fire & EMS

Table 7: Fire & EMS low-carbon fleet plan

Group	FAR #	FAR Scenario Description	Implementation Timing[51]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[52] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
-	1	Current lifecycles	2021	17.5	-0.25	5	0.6%
	2	Optimized lifecycles	2021	17.5	-0.25	5	0.6%
	3	Balanced Capex using optimized lifecycles	2021	5.7	-77	2	0.3%
One[53]	4	Enhanced specs: light-weighting, LRR (all units)	Short-term	3.9	+294	48	6%
	5	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	3.9	+295	161	21%
	6	Route planning/optimization & trip reduction (all units)	Short-term	3.9	+295	127	16%
	7	All BMPs (all solutions above, for all units)	Short-term	3.9	+303	271	35%
Two[54]	8	Fuel switch: E85 (all possible flex-fuel units)	Short-term	3.9	+265	353	46%
	9	Fuel switch: B10 (annualized blend – all diesel on-road units)	Short-term	3.9	+216	307	40%
	10	Fuel switch: CNG (all applicable units)	Short-term	3.9	+456	368	47%
	11	Fuel switch: LPG (all applicable units)	Short-term	3.9	+216	314	41%
-	12	Hybrid conversion (Class 3-5 Fire & EMS units only)	Short-term	3.9	+299	274	35%
Three[55]	13	BEV phase-in: cars & SUVs only	2021	5.7	-66	261	34%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2022	1.0	-70	273	35%

[51] The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.
[52] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.
[53] Builds on FAR #3
[54] Builds on FAR #7 (all benefits of Group One solutions)
[55] Builds on FAR #7 (all benefits of Group One solutions). EVSE costs are treated separately in an additional analysis.

Group	FAR #	FAR Scenario Description	Implementation Timing[51]	Annual Vehicle Replacement Capex ($ millions)	Annual Opex[52] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
		BEV phase-in: cars, SUVs, LD vans & pickups only	2023	2.1	-45	331	43%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2024	6.5	+1	341	44%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2025	5.2	+164	348	45%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2026	5.3	+304	354	46%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2027	0.4	+321	367	47%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2028	3.3	+354	386	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2029	1.1	+437	386	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2030	1.2	+435	387	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2031	8.2	+377	388	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2032	7.0	+481	389	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2033	5.8	+564	390	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2034	2.6	+520	390	50%
		BEV phase-in: cars, SUVs, LD vans & pickups only	2035	4.4	+505	390	50%

Transit

Table 8: Transit (non-revenue units) low-carbon fleet plan

Group	FAR #	FAR Scenario Description	Implementation Timing[56]	Annual Vehicle Replacement Capex ($ thousands)	Annual Opex[57] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
-	1	Current lifecycles	2021	410	-26	0.8	0.2%
	2	Optimized lifecycles	2021	340	-28	0.8	0.2%
	3	Balanced Capex using optimized lifecycles	2021	56	-24	0.2	0.1%
One[58]	4	Enhanced specs: light-weighting, LRR (all units)	Short-term	162	+14	22	5%
	5	Driver behaviours: eco-training & anti-idling policy/technologies (all units)	Short-term	162	+11	85	20%
	6	Route planning/optimization & trip reduction (all units)	Short-term	162	+11	66	16%
	7	All BMPs (all solutions above, for all units)	Short-term	162	+6	146	34%
Two[59]	8	Fuel switch: E85 (all possible flex-fuel units)	Short-term	162	-75	295	70%
	10	Fuel switch: CNG (all applicable units)	Short-term	162	+307	173	41%
	11	Fuel switch: LPG (all applicable units)	Short-term	162	+25	159	37%
Three[60]	13	BEV phase-in: cars & SUVs (owned units only)	2021	0	+15	142	34%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2022	357	-16	171	40%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2023	320	-7	238	56%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2024	200	+1	247	58%

[56] The 2019 baseline was used as a proxy for 2020; therefore, 2021 is the first year modelled after the baseline.
[57] For data-modelling purposes, Opex includes the annual cost of capital for any vehicle upgrades/conversions and fuelling infrastructure, spread over the budget cycle for the selected units. The fast-fuelling system cost assumptions were $1.68M for CNG and $68k for LPG; these capital costs were shared for every 50 CNG/LPG units. For BEV charging infrastructure, additional capital costs were estimated separately using an EVSE costing tool.
[58] Builds on FAR #3
[59] Builds on FAR #7 (all benefits of Group One solutions)
[60] Builds on FAR #7 (all benefits of Group One solutions). EVSE costs are treated separately in an additional analysis.

Group	FAR #	FAR Scenario Description	Implementation Timing[56]	Annual Vehicle Replacement Capex ($ thousands)	Annual Opex[57] Impacts Over 2019 Baseline ($ thousands)	Annual Tailpipe GHG Reduction Over 2019 Baseline (tonnes CO_2e)	Annual Tailpipe GHG Reduction Percentage Over 2019 Baseline
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2025	0	+4	247	58%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2026	0	+5	247	58%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2027	310	-12	267	63%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2028	346	-5	267	63%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2029	391	-7	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2030	345	-28	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2031	0	+3	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2032	61	-2	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2033	375	-7	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2034	142	+2	304	71%
		BEV phase-in: cars, SUVs, LD pickups (owned units only)	2035	93	+3	304	71%

Electric Vehicle Supply Equipment Planning

RSI-FC maintains the position that electric vehicle supply equipment (EVSE) should not be treated as a direct corporate vehicle capital expense, but rather as a facilities/properties capital expense. With this in mind, we have developed an EVSE costing outlook for the City of Brampton, separate from Fleet Analytics Review™ (FAR), to provide long-term capital planning (LTCP) for the City's charging infrastructure needs, based on a number of estimations described in this section.

EVSE & Asset Management

RSI-FC maintains that EVSE should be a capital asset paid for, owned, and managed from the budget of the corporate facilities/properties department. Therefore, the capital cost of charging equipment should not be directly posted to fleet vehicles; rather, EVSE is an asset (an attribute/enhancement) that increases the market value of the facility/property where fleet vehicles are parked. Moreover, EVSE costs should be a capital expense for the facility's corporate "owner" (usually this is a facilities/properties department), not the vehicle's corporate "owner" (which is usually a fleet department). This is different than in the non-corporate world where the battery-electric vehicle (BEV) owner is often the same owner as the property owner, such as is the case for personal cars and homes.

Today, there is a lot of focus on asset management best practices for corporations, including the public sector. It is a contemporary asset management best practice that property-related costs, including capital and operating expenses, should be expense items managed by the responsibility centre that manages the asset, in this case the corporate facilities/properties department. The facilities/properties department can then apportion and transfer these costs to their internal users of each property, such as a fleet department.

In a "full cost recovery" business model as we espouse, the facilities/properties department must recover sufficient revenue to fully offset the costs of owning and managing the property, including the installation, use, and maintenance of EVSE.

Regarding the electricity needed to charge BEVs, we have included the cost of electricity as a "fuel" cost under operating expenses in FAR. However, the same asset management principles can be applied. Usually the local power provider bills the facilities/properties department for all electricity used by each property. In an ideal full cost recovery business model, the facilities/properties department would transfer the power costs to its user departments for the amount used in each period. The EVSE would meter the amount of electricity used by each BEV – just like the amount of gas or diesel used by each internal combustion engine (ICE) is tracked vehicle today with fuel pump meters.

EVSE Costing Outlook

RSI-FC developed an EVSE costing outlook for the City of Brampton based on charging infrastructure needs over a 15-year time horizon – to align with the long-term capital planning (LTCP) for battery-electric vehicle (BEV) phase-in. Please see *Table 9* (overleaf) for details and a description of our methods and estimations below for Brampton's owned units.

Our team determined level 2 (L2) and level 3 (L3) charging needs for the City's owned units (Transit rental charging requirements described later). After discussion with Fleet managers, it was agreed that two L3 chargers will be required at each of Fleet Services' major locations – Williams Parkway, Sandalwood Parkway, and Flower City Community Campus (FCCC).

To determine the number of BEVs that can share one L2 charger, we employed the following method based on vehicle mileage and current battery range capabilities:

- The average annual mileage for all in-scope Brampton fleet vehicles (based on the 2019 baseline) is about 10,000 km. Dividing by about 250 work days/year (excluding weekends and holidays) gives an average daily driving distance of 40km.

- If we assume a typical minimum (winter) BEV range of 200km for most BEVs currently on the market, then one BEV would be able to last about four work days from full charge to about 50 km (25%) remaining – the point at which charging becomes necessary to avoid range anxiety.

- Given the approximations arrived at above, one BEV would need L2 charging about every four work days. Therefore, the same charger can be used for multiple BEVs on a rotating basis – ideally four BEVs. Realistically, if multiple BEVs need to charge at the same time, or if a vehicle operator forgets to plug in their vehicle overnight, we can safely assume that two L2 chargers would be needed for every four BEVs – or **one L2 charger for every two BEVs**.

To determine the total number of L2 chargers required to serve the entire Brampton fleet (once transitioned to BEVs) – excluding heavy-duty (HD) fire trucks – we made the following estimations:

- The number of BEVs added on a phased-in basis to Brampton's fleets exceeds the number of possible BEV replacements by around 2031; this means that the cost of any additional chargers past this point will essentially be redundant because BEVs will be replaced with other BEVs.

- Given this reality, we estimated (based on the current total fleet size) about **600 possible BEV replacements for owned units** (which excludes HD fire trucks but includes the possibility of some rentals being replaced with owned BEVs) by 2031. Therefore, when the number of L2 chargers purchased reaches 300, the EVSE requirements are considered complete.

- A fleet should not be keeping up with the demand for EVSE based on the number of new BEVs added to their fleet; they should be *outpacing* demand to allow for a smooth transition. Therefore, we have estimated the number of L2 chargers required for purchase to outpace demand, and also to make use of the temporary pause in purchasing BEV medium- and heavy-duty (MHD) vehicles in 2022 and 2023 as per our recommendations – to maximize the use of capital and "front load" the investment in EVSE.

Our team included the cost of 20 L2 chargers currently being installed at the Fire Campus, which has been partially funded by NRCan's Zero Emission Vehicle Infrastructure Program (ZEVIP, see next section). The net cost of each L2 charger ($7,500), after NRCan funding, from the installation at the Fire Campus has been used as a benchmark for all remaining L2 chargers, with 2% inflation added to the cost of L2 chargers year-over-year. We used similar reasoning for the estimated net cost of L3 chargers to the City ($60,000), assuming the City would provide 60% of the cost of a $100,000 L3 charger (the remaining 40% externally funded).

Importantly, existing electrical capacity at facilities may require substantial upgrades to power charging stations for multiple vehicles, which may significantly add to the estimated costs presented in our analysis.

Given that all fuelling for current Transit rentals is done on site, we have included Transit rental charging requirements as an add-on to our EVSE analysis (not included in *Table 9*, overleaf) in the event that all Transit rentals are eventually switched to battery-electric – a very reasonable expectation. We made the same cost estimations as for owned units (based on current subsidies) but with different mileage and charging considerations based on manager input, including:

(1) Expected mileage to average 4,000 km per month per unit;
(2) Rental vehicles used 365 days of the year; and
(3) Only four hours of reliable charging time (midnight to 4am).

To determine the total number of L2 chargers required to serve the Transit rentals (once transitioned to BEVs and based on the current rental fleet size of 40), we made the following estimations:

- Four hours of L2 charging would likely give light-duty BEVs a charge of approaching 100% (likely closer to 90%) if, taking the same assumptions described earlier, charging is started at about 50 km (25% battery life) remaining – the point at which charging becomes necessary to avoid range anxiety.

- Considering that each rental is expected to be driven about 132 km/day (based on 48,000 km/year with each unit driven 365 days/year), each rental would require one L2 charger based on the minimum (winter) range of 200 km, as described earlier. This means that **approximately 30 additional L2 chargers** (given that there was some "buffer" provided for owned units described earlier) are required.

- Taking the net cost of each L2 charger as $7,500 (described earlier), this equates to a total EVSE cost estimate of $225,000 for Transit rentals. *Note that power supply limitations at the existing two garages may make substantial upgrades necessary, which may significantly add to the estimated cost provided here. A qualified electrical professional should be consulted to assess the situation and make recommendations.*

Table 9: Fleet-wide EVSE long-term costing outlook for owned units

Year # of BEV Phase -in Plan	Year of BEV Phase -in	Location	Number of owned BEVs added to Brampton Fleets (per phase-in plan)	Cumulative Number of owned BEVs added to Brampton Fleets (per phase-in plan)	Number of BEVs Serviced by each L2 Charger	Number of L2 Chargers Required to Meet Demand	Number of L3 Chargers Required	Cumulative Number of L2 Chargers Required to Meet Demand	Estimated Number of L2 Chargers Required for Purchase (to outpace demand)	Estimated Cost per Charger (after grants & subsidies)	Total Cost of Chargers	Cumulative Cost of Chargers
1	2021	Williams Parkway	-		-	-	2	-	-	$60,000	$120,000	$120,000
	2021	Sandalwood Parkway	-		-	-	2	-	-	$60,000	$120,000	$240,000
	2021	Flower City Community Campus	-		-	-	2	-	-	$60,000	$120,000	$360,000
	2021	All Brampton Fleet Parking Sites	8	8	2	4	0	4	20	$7,500	$150,000	$510,000
2	2022	All Brampton Fleet Parking Sites	83	91	2	42	0	46	60	$7,650	$459,000	$969,000
3	2023	All Brampton Fleet Parking Sites	118	209	2	59	0	105	60	$7,803	$468,180	$1,437,180
4	2024	All Brampton Fleet Parking Sites	65	274	2	33	0	138	20	$7,959	$159,181	$1,596,361
5	2025	All Brampton Fleet Parking Sites	47	321	2	24	0	162	20	$8,118	$162,365	$1,758,726
6	2026	All Brampton Fleet Parking Sites	53	374	2	27	0	189	20	$8,281	$165,612	$1,924,338
7	2027	All Brampton Fleet Parking Sites	26	400	2	13	0	202	20	$8,446	$168,924	$2,093,263
8	2028	All Brampton Fleet Parking Sites	45	445	2	23	0	225	20	$8,615	$172,303	$2,265,565
9	2029	All Brampton Fleet Parking Sites	36	481	2	18	0	243	20	$8,787	$175,749	$2,441,314
10	2030	All Brampton Fleet Parking Sites	58	539	2	29	0	272	20	$8,963	$179,264	$2,620,578
11	2031	All Brampton Fleet Parking Sites	91	630	2	28	0	300	20	$9,142	$182,849	$2,803,427
12	2032	All Brampton Fleet Parking Sites	59	689	2	0	0	300	0	$9,325	$0	$2,803,427
13	2033	All Brampton Fleet Parking Sites	60	749	2	0	0	300	0	$9,512	$0	$2,803,427
14	2034	All Brampton Fleet Parking Sites	45	794	2	0	0	300	0	$9,702	$0	$2,803,427
15	2035	All Brampton Fleet Parking Sites	49	843	2	0	0	300	0	$9,896	$0	$2,803,427
TOTAL			*843*			*300*					*$2,803,427*	

NRCan's Zero Emission Vehicle Infrastructure Program

The Government of Canada is committed to helping accelerate the decarbonization and electrification of our transportation sector, and charging infrastructure is a key component to achieving this. Natural Resources Canada (NRCan) has pledged to invest $130 million from 2019-2024 to further expand the country's charging network, particularly level 2 and higher stations, through its Zero Emission Vehicle Infrastructure Program (ZEVIP).

The City of Brampton has already benefited from this program with the installation of 26 level 2 chargers at City-owned facilities (for public use) and 20 level 2 chargers at the Fire Campus currently in progress. There is potential for more support for the installation of 100 level 2 chargers at Fleet Services' three major locations – Williams Parkway Operations Centre (WPOC), Sandalwood Parkway (SW), and Flower City Community Campus (FCCC).

The funding is being delivered through cost-sharing contribution agreements for eligible projects, including:

- BEV charging infrastructure in parking areas intended for public use (e.g., service stations, restaurants, libraries, etc.);
- On-street charging infrastructure;
- Workplace charging infrastructure;
- On-road light-duty vehicle fleet (including municipal fleets);
- On-road medium- or heavy-duty vehicle fleets (including refuse trucks and public utility vehicles);
- Charging infrastructure for multi-unit residential buildings (MURBs); and
- Public transit charging infrastructure.

The window for Request for Proposals (RFPs) was open until June 22, 2021. NRCan is targeting having funding decisions by October 2021. NRCan's contribution through this program will be limited to 50% of total project costs up to a maximum of $5M per project. The maximum funding and approximate costs for each type of charging infrastructure is shown in *Table 10* (directly taken from NRCan's website[61] with costs and charging rates from the City of Toronto's Electric Vehicle Strategy Report[62]):

[61] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/zero-emission-vehicle-infrastructure-program/21876
[62] Source: https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf

Table 10: Specifications for NRCan's Zero Emission Vehicle Infrastructure Program, plus approximate total costs and charging rates

Type of Infrastructure	Output	Maximum NRCan Funding	Total Costs (Equipment + Installation)	Approximate Charge Rate Per Hour
AC Level 2 (208/240V) Connectors	3.3 kW - 19.2kW	Up to 50% of total project cost, to a maximum of $5,000 per connector*	$5,000 - $10,000	40 km
DC Fast Charger	20 kW - 49 kW	Up to 50% of total project cost, to a maximum of $15,000 per fast charger	-	-
DC Fast Charger	50 kW and above	Up to 50% of total project cost, to a maximum of $50,000 per fast charger (50 kW-99 kW) and $75,000 per fast charger (100 kW and above)	$50,000 - $200,000	300+km

* To calculate the funding for level 2 chargers, each connector can count as a unit towards the minimum of 20 chargers if each connector can charge a vehicle at the same time.

Synopsis of Low-Carbon Fleet Planning

RSI-FC is recommending a low-carbon fleet strategy for the City of Brampton that calls for a temporary pause on purchasing new internal combustion engine (ICE) vehicles (when appropriate) for the short term (one year for pickups, three years for medium- and heavy-duty vehicles (MHDVs)), while awaiting battery-electric vehicle (BEV) counterparts to become available. The exception, of course, is for light-duty (LD) passenger BEVs which are currently available with sufficient range, such as the Kia Soul and the Chevrolet Bolt.

Our position is that fleets should re-consider buying new fossil-fuelled units because ICE vehicles are quickly becoming an outdated and archaic technology, and there will soon be BEV replacement options. The purchase of new ICE vehicles now, whether gasoline or diesel, means that a fleet, like the City of Brampton's fleet, will commit to using new fossil-fuelled vehicles for approximately the next decade when zero tailpipe emissions BEVs, which are often more economical than their fossil-fuel counterparts, are just around the corner.

Compressed natural gas (CNG) conversion is a solution that can potentially deliver significant fuel cost savings and GHG reductions; however, the cost of installing a fast-fuelling system (well in excess of $1M CAD, $1.68M used in our modelling) is far greater than installing a direct current (DC) or level-3 (L3) fast charger for BEVs ($50-200k[63] CAD, $60k used in our modelling after grants/subsidies). Moreover, if BEVs come down in price over time, the business case will continue to improve and potentially more units would demonstrate a positive return-on-investment (ROI). Given that MHDVs are most likely moving away from the internal combustion engine toward battery-electric zero-emission units, fleet-wide commitment to CNG does not seem to be a prudent choice for the future.

If the City of Brampton decides to proceed with a plan that is similar to the one RSI-FC is recommending and pause purchasing new (otherwise fossil-fuelled) pickups (for one year) and MHDVs (for three years) when appropriate, we recommend, in the interim, to fully implement best management practices (BMPs) and also consider switching flex-fuel units to ethanol 85 (E85). Driver eco-training and anti-idling policy/technologies, if fully implemented fleet-wide, have the greatest GHG-reduction of all BMPs, based on our modelling. Switching all possible flex-fuel units to ethanol 85 (E85) has the greatest GHG-reduction potential of all fuel-switching options, based on our modelling. As there is limited availability of this fuel (sold outside of Ontario according to our research), finding a reliable supply of E85 may be a barrier; however, interim or “messy middle” solutions all have their challenges that can be overcome with effort and determination.

Moreover, in the interim we recommend that the City of Brampton allocate capital towards charging infrastructure required for the transition to BEVs for all vehicle categories. The additional capital costs associated with electric vehicle supply equipment (EVSE) can be offset through lower capital spending during this pause we are recommending for purchasing ICE vehicles.

Based on feedback from the City Fleet Managers as well as our approximations, RSI-FC is suggesting around $500,000 in capital spending on EVSE in the years 2021 (immediate), 2022, and 2023 – to keep up with future demand for BEV additions to the fleet, as well as to optimize the use of capital during a period of lower spending while awaiting battery-electric pickups and MHD vehicles to become available. During this period (2021-2023) of RSI-FC’s BEV phase-in plan, the capital expenses (Capex) on new vehicles purchased (all fleets combined) range from about $5-6M – about $2M lower each year than would typically be spent based on balanced Capex using optimized lifecycles (as determined in Part One of the Sustainable Fleet Strategy). Therefore, over the next three years (including the current fiscal year), based on our modelling and estimations it is possible for the City of Brampton to recover relatively higher upfront EVSE installations costs (about $1.5M in total) through significantly lower capital spending. Moreover, there is a potential to have a net savings of

[63] Source: https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf

several million dollars, which can then be used to offset higher Capex as MHD BEVs become available for purchase.

While GHG emissions decrease sharply over the next 15 years according to the BEV phase-in plan we have proposed, there is an overall increasing trend in operating expenses (Opex), which may be counterintuitive given the enormous fuel savings potential for BEVs. This occurs for two reasons: (1) we have included the cost of capital as part of Opex, which is currently greater for BEVs than ICE vehicles (due to higher vehicle prices) and we have assumed this to be the case going forward; and (2) we have included compound inflation in our analysis.

Fuel cost savings, for some units, are not great enough to offset the increased cost of capital due to relatively low mileage. Of course, the higher the kilometres travelled, the stronger the business case for BEVs becomes. There is a strong likelihood that the acquisition cost of BEVs will decline with time as both supply and demand increase, and as battery technology continues to improve. However, we did not want to make this assumption based on speculation; rather, our FAR analysis uses current, real data as much as possible and limits assumptions.

Although some units did not show return-on-investment (ROI) when replaced with a BEV due to increased cost of capital, we phased-in BEVs until eventually, by 2035, all units with anticipated battery-electric options in the market are replaced. Strictly through a lens of fiscal planning, our recommendation to the City of Brampton is to prioritize replacement of ICE units with BEVs *only if they would deliver ROI* – typically ones that have relatively high annual mileage.

In terms of Capex over the entire 15-year BEV phase-in plan, the average annual capital required is about $7.9M (for all fleets combined). This is reasonable considering that the current replacement capital needs for all fleets combined, from our baseline analysis in Part One of the Strategy, is about $74M. Estimating an average lifecycle to be 10 years (fleet-wide) based on optimized lifecycles, the annual capital required is, roughly, on pace with the rate of depreciation ($74M divided by $7.9/year is roughly equal to 9.4 years) given that we are including compound inflation in our modelling.

Section 4.0 Recommendations, Risks, and Considerations

Here, we provide our recommendations for the three groups of fuel-reduction solutions (best management practices, fuel switching, and BEV phase-in), electric vehicle supply equipment (EVSE), partnerships and change management, and monitoring and reporting progress. We also state the risks and concerns for fuel-switching options, based on manager feedback, the direction of the market (i.e., towards BEVs), and overall cost and GHG impacts. More details on all solutions that have been researched by RSI-FC, including the ones presented to the City, can be found in *Appendix B*.

Recommendations are based on our experience of working with nearly 200 municipal and commercial fleets, as well as the Best Management Practices Review (BMPR) and stakeholder input from our Green Fleet Survey (Part One of the Strategy). Moreover, our recommendations include approaches for creating a culture of receptiveness to change and innovation – in the context of BEV transition – through collaboration/partnerships and risk/change management.

Best Management Practices

(1) For all fleets, follow a historical data-driven lifecycle cost assessment, which is completed by modelling repair, maintenance, fuel, and cost of capital over a vehicle's entire lifecycle, the optimal replacement age of vehicles can be determined (such as by using RSI-FC's lifecycle analysis software).

(2) For Fleet Services and Transit, employ a total cost of ownership (TCO) approach to optimize the use of capital. Procurement in Fleet Services and Transit should consider TCO in its competitive bidding proposal structures instead of the lowest-compliant bid approach.

(3) For Fleet Services and Transit, ensure the size of vehicles needed based on their use case; when appropriate, select a smaller vehicle sized appropriately for the task at hand (rightsizing). This would require user group buy-in when outlining what is needed to perform job duties, and has not been quantitatively modelled as fleet managers best understand the usage patterns and demands of their specific vehicles.

(4) For all fleets, decommission under-utilized units to reduce the number of fleet vehicles (downsizing). This can be achieved by monitoring maintenance costs for older, under-utilized vehicles which may be shown to be costing less, when in reality they can be a stranded assets until retirement/replacement. Downsizing has not been quantitatively modelled as fleet managers best understand the usage patterns and demands of their specific vehicles.

(5) For all fleets, allocate auction proceeds into a reserve fund to ensure there is a direct benefit from the sale of used vehicles and that vehicle replacement needs are met. In this way, fleet management is empowered with reducing total lifecycle costs by (a) maximizing sale proceeds from surplus units while (b) ensuring the lowest possible new vehicle acquisition costs, and (c) minimizing operating costs during each vehicle's active lifecycle.

(6) For Fleet Service and Transit, consider a chargeback system for all user groups. By assigning vehicles costs to user groups, it may incentivize and motivate them to encourage their vehicle operators to improve their fuel efficiency and driving habits to reduce their operational expenses. Such chargeback systems are known to deliver tremendous cost-savings.

(7) For all fleets, ensure job suitability of vehicles is appropriate before proceeding with light-weighting enhancements.

(8) For Fire & EMS and Transit, implement fuel-efficient driver training. Auxiliary vehicle operators, including the Chiefs, could benefit from eco-driver training. Eco-driver training does not apply to apparatus; however, it could be applied after leaving the scene.

(9) For all fleets, develop a fuel-efficient driver incentive program, such as through a green card initiative similar to one at the Lake Simcoe Region Conservation Authority, in which drivers are incentivized to improve behaviours or reduce their travel through card stamping and prize draws[64].

(10) Encourage virtual meetings (post Covid-19 pandemic) and staff carpooling, when possible, to reduce fleet vehicle emissions.

Fuel Switching

E85 Ethanol

(1) With significant GHG reduction potential, we recommend that Fleet Services and Transit consider E85 for factory flex-fuel units while the fleets slowly transition to battery electric vehicles (BEVs). As there is limited availability of this fuel (sold outside of Ontario according to our research), finding a reliable supply of E85 may be a barrier; however, interim or "messy middle" solutions all have their challenges that can be overcome with effort and determination.

For Fire & EMS, due to potential supply challenges and given the fleet currently uses retail fuelling stations, the availability and reliability of ethanol poses a risk/concern to the emergency response nature of the operations. As a result, Fire & EMS is not willing to accept the potential risks of E85,

[64] Source: ClimateWise Business Network. ClimateWise Member Spotlight: Lake Simcoe Region Conservation Authority

and we have withdrawn our recommendation to consider a switch to E85 as an interim solution while transitioning to BEVs.

(2) For Fleet Services and Transit, consider a pilot project with several units switched to E85 to determine the fuel-efficiency loss and cost-effectiveness; if successful, consider switching other appropriate units – particularly those with several years of useful life remaining (i.e., ones that will not be replaced with a BEV in the short- to mid-term).

B10 Biodiesel

(1) Fleet Services, currently using B5 year-round for all diesel units, had previously experienced higher downtime and maintenance costs when using biodiesel blends greater than B5. Given these past challenges, management is not interested in switching back to higher blends. As a result of manager feedback, as well as relatively low emissions reduction potential (at the fleet-level) in comparison to other solutions, we have withdrawn our recommendation to consider a switch to higher biodiesel blends.

For Fire & EMS, due to (1) the potential issue of cold-weather gelling if not properly monitored, and (2) potential supply challenges since the fleet currently uses retail fuelling stations, the availability and reliability of biodiesel poses a risk/concern to the emergency response nature of the operations. As a result, management is not willing to accept the potential risks of higher blends of biodiesel, and we have withdrawn our recommendation to consider a switch to B10 (annualized) as an interim solution while transitioning to BEVs.

Compressed Natural Gas

(1) Although compressed natural gas (CNG) conversion is a solution that can potentially deliver significant fuel cost savings and GHG reductions, in the short-term it was shown to be cost effective only for Fleet Services due to the high cost of installing fast-fuelling systems. The larger size of the Fleet Services' fleet compared to the Transit (non-revenue units) and Fire & EMS fleets resulted in the high infrastructure costs being spread over a greater number units (as per our modelling) – demonstrating a viable business case.

Given that medium- and heavy-duty vehicles (MHDVs) are most likely moving away from the internal combustion engine toward battery-electric zero-emission units, a commitment to CNG should be very cautiously assessed. We recommend that Fleet Services consider CNG only as an optional, secondary GHG reduction solution for MHDVs, as a commitment to CNG fuelling infrastructure does not appear to be a prudent choice for the long-term.

Liquified Petroleum Gas

(1) Similar to CNG, a switch to liquified petroleum gas (LPG), or propane, requires significant (albeit much lower) fuelling system investment. Moreover, the GHG reduction potential for LPG is much less than CNG – making this solution not a strong candidate for providing the deep emissions reductions the City of Brampton is aiming to achieve. As mentioned in Part One of the Sustainable Fleet Strategy, Fleet Services had many propane-powered landscape dump trucks and pickups up until the early 2000s; however, there were many complaints regarding high downtime and, consequently, Fleet chose to discontinue their use. With all of these considerations in mind, we have withdrawn our recommendation for Brampton to consider a switch to LPG.

Battery-Electric Vehicle Phase-In

(1) As per our modelling, RSI-FC strongly recommends the City of Brampton have a temporary pause on purchasing new internal combustion engine (ICE) vehicles (when appropriate) for the short term – one year for pickups, three years for medium- and heavy-duty vehicles (MHDVs) – while awaiting battery-electric vehicle (BEV) counterparts to become available. The exception is for light-duty (LD) passenger BEVs which are currently available with sufficient range, such as the Kia Soul and the Chevrolet Bolt.

(2) Through a lens of achieving and exceeding deep GHG-reduction goals, allocate the majority of fleet capital spending on BEVs (for appropriate vehicle categories as BEV models become available).

(3) Strictly through a lens of fiscal planning, prioritize replacement of ICE units with BEVs *only if they would deliver ROI* – typically ones that have relatively high mileage.

(4) Conduct a pilot project for several BEVs when they become available (e.g., pickups) to track range capabilities and cost savings and assess the units' performance for all seasons and varying weather conditions.

(5) Assuming the pilot project is successful, acquire BEVs in bulk to replace units that would provide the greatest ROI.

(6) Closely monitor the acquisition costs for BEVs and re-evaluate the business case (cost-benefit) for individual units as prices come down.

(7) Provide high-voltage training for technicians and closely monitor the launch of new BEV training programs. A pilot for a new EV Maintenance Training Program for automotive technicians was

successfully completed at BCIT and is available to the public[65]. There is also an Electric Vehicle Technology Certificate Program offered by SkillCommons, managed by the California State University and its MERLOT program, which offers free and open learning materials electric vehicle development, maintenance, alternative/renewable energy, and energy storage[66].

Electric Vehicle Supply Equipment

(1) Allocate capital towards charging infrastructure required for the transition to BEVs for all vehicle categories – particularly in the short- to mid-term. Much of the additional capital costs associated with electric vehicle supply equipment (EVSE) may be offset through lower capital spending during the pause recommended for purchasing internal combustion engine (ICE) pickups and medium- and heavy-duty vehicles (MHDVs).

(2) Continue to pursue funding from NRCan's Zero Emission Vehicle Infrastructure Program (ZEVIP).

(3) Assess existing electrical capacity at facilities to determine whether substantial upgrades to power charging stations for multiple vehicles are required.

(4) Explore supplying power to each garage on two separate feeds from the grid to reduce the risk of local failure taking power away from the whole site[67].

Collaboration/Partnership Approaches

With the transition to BEVs in the early stages and expected to gain significant momentum in the short- to mid-term, we recommend that the City of Brampton strengthen current partnerships and establish new partnerships – both internal and external – to leverage knowledge and resources and better prepare for the transition by undertaking the following actions:

(1) Engage in internal partnerships within and across departments or fleets, such as multi-departmental funding applications for charging infrastructure, or sharing of BEV pilot program results to determine vehicles requirements and specifications (e.g., real-world range, real-world charging needs) ahead of large purchasing decisions involving many units.

(2) Engage in external partnerships within the Region of Peel and/or other municipalities/regions in the Greater Toronto and Hamilton Area (GTHA) for potential collaborations, such as joint specification writing and/or joint tenders and sharing of BEV pilot program results through working groups.

[65] Source: https://commons.bcit.ca/news/2019/12/ev-maintenance-training/
[66] Source: http://support.skillscommons.org/showcases/open-courseware/energy/e-vehicle-tech-cert/
[67] Source: https://www.plugincanada.ca/electric-bus-faq/

(3) Leverage the knowledge gained on BEV transition (e.g., procurement of vehicles and charging infrastructure) through organizational memberships such as the Clean Air Partnership or the Municipal Equipment and Operations Association of Ontario (MEOA), both of which Fleet Services is an active member of, and apply any lessons learned to make informed decisions.

Risk/Change Management Approaches

(1) Similar to recommendations on collaboration/partnerships, we recommend that internal and external partnerships be used to share knowledge and educational strategies, as is stated as one of the Collaborations Areas/Tasks of the Clean Air Council[68]. This could entail communicating the business case for BEVs and dispelling myths about BEVs, such as potential negative and/or false perceptions on battery safety, battery life, battery end-of-life, and vehicle performance – facilitating a cultural shift from fossil-fuelled vehicles to clean, zero-tailpipe emission BEVs.

(2) Develop BEV educational and outreach materials for employees and operators summarizing the reasons and benefits of transitioning to BEVs, in terms of the environment (improved air quality and greatly reduced lifecycle GHG emissions), reduced fuel and maintenance expenses (the business case), improved performance (e.g., instant torque, little noise, regenerative breaking), greater reliability due to fewer moving parts than internal combustion engine (ICE) vehicles, and continuously expanding charging infrastructure.

(3) Invite frontline employees to take BEV test drives to familiarize them with fully-electric vehicles and charging, as well as to give them first-hand experience of improved performance (e.g., instant torque, little noise, regenerative breaking).

(4) Provide operators with a BEV orientation before releasing new models into the fleet to enable to become familiar with the different driving experience (e.g., instant torque, little noise, regenerative breaking), as well as to alleviate/eliminate any apprehension or uncertainties such as range anxiety.

(5) As is recommended for the phasing in of BEVs, we recommend a pilot project for several BEVs as they become available (e.g., pickups) to track range capabilities and cost savings and assess the units' performance for all seasons (one year) in varying weather conditions.

Monitoring & Reporting Progress

We recommend that the City of Brampton establish key performance indicators (KPIs) and develop associated data collection, analysis, and reporting protocols to measure and report performance annually or biennially, with a focus on the following actions:

[68] Source: https://cleanairpartnership.org/cac/wp-content/uploads/2020/03/Sustianable-Fleet-Workplan.pdf

(1) Include fuel consumption (L/100 km), or corporate average fuel economy (CAFE), as a KPI, or as part of benchmark and monitoring reports, to set goals and measure progress towards targets for improved fuel efficiency and reduced GHG emissions. To implement this, user groups would need to have more influence in purchase decisions (based on fuel economy and emissions, as well as total cost of ownership).

(2) Include GHG intensity (kg CO_2e/km) as a KPI, or as part of benchmark and monitoring reports. This indicator would allow the City of Brampton to measure its success in reducing GHG emissions while taking into account the potential growth of its fleet due to a growing population.

(3) Include area ratio (no. of units/km^2) and/or population ratio (population/no. of units) as a KPI, or as part of benchmark and monitoring reports, to assess the relative size of the City's fleet proportional to its geographic size and population. Based on results from the Municipal Fleet Comparison in Part One of the Sustainable Fleet Strategy, our recommendation is that the City consider downsizing its fleet by examining underutilized units and stranded assets.

(4) Use RSI-FC's electric vehicle supply equipment (EVSE) costing outlook, which is based on future demand for battery-electric vehicles (BEVs) in the City's fleets, as a benchmark for monitoring and tracking the uptake of BEVs (replacements to ICE vehicles) as well as the progression in the installation of charging infrastructure.

Other Areas of Sustainability Performance

(1) For all fleets, continue to employ the three Rs of waste management (reduce, reuse, recycle).

(2) For Fleet Services, consider the use of wands inside the wash bay (with interceptors) to more effectively remove brine.

(3) Explore solar energy technology options to supply energy for EV charging to reduce GHG emissions that may be produced from the electricity supply used for charging. Our recommendation is to pursue rooftop (vs. canopy) solar energy systems, as this provides renewable energy for the entire building/facility as opposed to charging stations only – which more holistically achieves GHG emissions reductions and allows for additional benefits such as vehicle-to-grid (V2G) technology and battery energy storage (see more details in next section).

(4) Explore a pilot offering one or more BEVs at main corporate locations (e.g., City Hall/West Tower, Williams Parkway Operations Centre) that staff can sign-out to use for site visits and to conduct other City business. As most staff currently use their own vehicles, the majority of which are ICE, and are reimbursed for mileage, providing a small number of BEVs for sign-out would (1) reduce indirect, Scope 3 emissions (i.e., from employee travel in personal vehicles) and (2) would

potentially be cost-effective over the longer term due to the much lower cost of electricity vs. gasoline.

Additional Considerations

B100 Biodiesel

In early 2020, a breakthrough technology allowed high-use dump trucks to run on 100% biodiesel (B100) in Ames, Iowa, a city that experiences extreme winters with blizzards and temperatures below -20°C. The following outlines how the system works[69]:

- The fuel delivery system has a split tank – one for petroleum diesel and the other one for biodiesel installed on the truck.
- In cold weather, diesel is used on start-up. The system warms the biodiesel and automatically switches to B100.
- At shut-off, the truck idles for a couple minutes while the B100 is purged from the lines.

There have been no operational concerns from operators or service technicians, and B100 has proven to be an easy and extremely effective way for the City of Ames to have an immediate impact on its fleet GHG emissions; B100 can reduce net vehicle operation GHG emissions by over 90% compared to ultra-low sulfur diesel (ULSD)[70]. Furthermore, upgrading to a year-round B100 system (split tank) comes at a relatively low cost and only adds one new component – a dedicated biodiesel filter – which requires monitoring; therefore, the maintenance impact is minimal[71]. However, the cost of pure or "neat" biodiesel is significantly higher than regular diesel and B20[72], which may not support the business case for this solution.

Nevertheless, this is an additional and highly effective interim solution that we recommend the City of Brampton consider ahead of (eventually) replacing medium- and heavy-duty vehicles with battery-electric models. We urge the use of ASTM standard quality biodiesel to head off the problems the City reportedly experienced in the past.

Battery-Electric Fire Trucks

In June 2021, Brampton City Council approved the purchase of a 100kWh battery-electric fire truck (with a diesel generator range extender) as well as an accompanying Level-3 direct current (DC) fast charger. The new fully-electric fire truck is expected to arrive at the end of 2022 and be operational

[69] Source: Renewable Energy Group (REG). Getting Aggressive on Sustainability [pdf]. 2020.
[70] Source: Running on 100% Biodiesel? Yeah, That's Happening [PDF]. HDT Truckinginfo.
[71] Source: Running on 100% Biodiesel? Yeah, That's Happening [PDF]. HDT Truckinginfo.
[72] Source: https://www.statista.com/statistics/1200903/us-b20-retail-fuel-price/

by early 2023. The City of Brampton will join a select group of cities to operate fully-electric fire trucks, including Berlin, Amsterdam, Dubai, Los Angeles, and Vancouver.[73]

The higher upfront cost of a battery-electric fire truck compared to a conventional fire truck can be significantly offset over the unit's life – depending on usage – through a reduction in preventive maintenance (PM) and repair costs, as well as lower fuel costs (electricity vs. gasoline). Moreover, there are ancillary costs that would be avoided, such as the idle mitigation system and costs associated with corrosion on the frame rail – further supporting a potential business case for a battery-electric fire truck.

In addition to further GHG emissions avoidance (on top of that already modelled for the rest of the Brampton fleet), a battery-electric fire truck would eliminate harmful smog emissions from the diesel engine of a conventional fire truck, contributing to much improved air quality and healthier air for the Fire & EMS personnel to breathe while performing their duties.

RSI-FC recommends that the City of Brampton continue to explore and assess the business case of battery-electric fire truck options on a case-by-case basis, as well as track and confirm the capabilities of the new squad unit (upon arrival) to demonstrate the benefits of zero-tailpipe emission, battery-electric vehicles for the Fire & EMS fleet as well as Brampton's fleet at large.

Battery Replacement, Energy Storage, and Battery Disposal

Global lithium-ion battery demand has risen dramatically over the last ten years, and this is expected to only be the "tip of the iceberg" as we are only at the beginning of the electric vehicle revolution.

Most, if not all, battery-electric vehicle (BEV) manufacturers have an eight-year or 100,000 mile (160,000 km) warranty on their batteries – whichever one (i.e., vehicle age or distance travelled) comes first[74]. However, the current prediction is that a BEV battery will last from 10-20 years, depending on usage, before it needs to be replaced[75]. Consumer Reports estimates that the average BEV battery pack's lifespan is around 200,000 miles (320,000 km), which is nearly 17 years of use if driven 12,000 miles (19,200 km) per year. As a comparison, the average annual mileage for all in-scope Brampton fleet vehicles is about 10,000 km. Therefore, in most cases, BEVs will likely reach their end-of-life before there is a need for battery replacement.

When battery capacity falls below 80%, drivers may start to see a decline in range[76] – which would most likely occur at or after the typical vehicle replacement age because battery degradation is a very gradual process[77]. Once the BEV battery capacity becomes undesirable for powering a vehicle, it can be used to power a building by contributing to a battery storage system, which stores energy

[73] Source: https://electricautonomy.ca/2021/06/21/brampton-electric-firetruck/
[74] Source: https://www.myev.com/research/ev-101/how-long-should-an-electric-cars-battery-last
[75] Source: https://www.edfenergy.com/electric-cars/batteries
[76] Source: https://www.edfenergy.com/electric-cars/batteries
[77] Source: https://www.myev.com/research/ev-101/how-long-should-an-electric-cars-battery-last

from a battery that can be used at a later time[78]. For example, if a building is powered by renewable energy such as wind or solar, an "old" BEV battery can be used to store energy produced while the wind is blowing or the sun is shining, and then release the stored energy during low-wind periods or at night. This method of generating electricity has multiple benefits, including:

- An effective way of continuing the life of an old BEV battery;
- Reducing energy used from the grid, thereby reducing energy costs; and
- Increasing energy security when using renewables, which have variable energy outputs, by releasing stored energy during off-peak times.

When batteries do reach the end of their working life, they can be recycled, which typically involves separating out valuable materials such as cobalt and lithium salts, stainless steel, copper, aluminium, and plastic. Currently, about half of the materials in a BEV battery pack are recycled, but with BEVs expected to undergo an explosion in popularity over the next decade or so, car manufacturers are looking to improve this.[79] Moreover, battery recycling companies have emerged with the growing need for electric vehicle battery recycling, as well as due to the shortage of domestic critical raw materials including lithium, cobalt, and nickel[80].

End-of-lifecycle lithium-ion batteries are first brought to facilities, known as "spokes," which physically separate materials (e.g., shredded metals, mixed plastics, etc.) – much like municipal material recycling facilities (MRFs). These separated materials are then brought to centralized locations, known as "hubs," where battery-grade end products, i.e., the original raw materials (metals) are produced. In May 2020, the lithium-ion battery recycling company Li-Cycle opened a "spoke" facility in Kingston, Ontario with a capacity to process 5,000 tonnes of lithium-ion batteries per year. [81]

Municipalities, like the City of Brampton, will have the option of packaging and coordinating the shipment of end-of-lifecycle electric vehicle batteries to battery recycling companies, with preliminary cost estimates of 1-2 CAD per kilogram – depending on the size of the battery pack and the cathode materials.

Interior Vehicle Maintenance, Cleanliness, and Infection Control

Fleet Managers have a major responsibility for the at-work safety of their staff and for providing safe vehicles for corporate fleet drivers. This is particularly important during the Covid-19 pandemic.

[78] Source: https://www.edfenergy.com/electric-cars/batteries
[79] Source: https://www.edfenergy.com/electric-cars/batteries
[80] Source: Li-Cycle Corporate Presentation, July 21 [non-confidential]
[81] Source: Li-Cycle Corporate Presentation, July 21 [non-confidential]

Although vaccine rollout programs have shown promising results in the drastic reduction of case numbers in Ontario and, particularly, Peel Region, it is crucial that public health measures continue to be followed – now and in the future – to reduce the spread of diseases such as Covid-19. In addition to mandatory mask-wearing for in-cab driver training and any close contact, RSI-FC recommends the following for the City of Brampton's fleets and their employees:

- Consider the use of an N95 mask, a KN95 mask, or a surgical mask plus a cloth mask (double-masking) when social distancing is difficult or impossible to follow (e.g., in-cab driver training) or when spending time indoors in the same airspace as others for an extended period of time (e.g., open office setting).
- Establish a thorough, City-wide vehicle cleaning procedure for operators and outside contractors – including opening windows and/or doors after an extended period of use as well as a wipe-down of all exposed surfaces with a disinfectant.
- Provide a supply of antiseptic wipes in each vehicle to wipe all areas of contact such as door handles (inside and outside), steering wheels, gearshifts, dash controls, etc.
- Change cabin filters for better air quality (reduced exposure to potential infection).
- Purchase a stock of personal-sized hand sanitizers for placement in each vehicle and also in the workplace.
- Equip fleet vehicles with waste baskets to reduce litter accumulating in vehicles.
- Consider charge-backs to use groups for vehicle cleaning so that user groups are more responsible for keeping vehicles clean.

Section 5.0: Purchasing v. Leasing v. Renting Analysis

A fleet has various vehicle acquisition options – including purchasing, leasing, and renting – and the optimal decision is dependent on multiple factors specific to the needs and usage of the fleet vehicles as well as market conditions. For details on the various vehicle acquisition options, please see *Appendix C*.

From our baseline analysis conducted in Part One of the Sustainable Fleet Strategy, we established that the City of Brampton's Fire & EMS owns all 107 of its fleet units, Fleet Services owns 422 units and rents 35, and Transit (non-revenue fleet) owns only 18 of its units and rents 43.

In this section, we present results of an analysis completed for 40 Transit rentals (Hyundai Class 1 sedans) to evaluate the cost-effectiveness of renting units in comparison to leasing and owning.

Observations – City of Brampton Transit Vehicle Rentals

In April 2021, the City issued a Request for Proposal (RFP) for rental services of subcompact cars and passenger minivan *[sic]* for Brampton Transit for three years. The RFP clearly defined the City's requirements and expectations concerning the prospective rental vendor's:

- Price
- Ability to perform
- Proposed schedule
- Ability to complete within the time required
- Quality
- Level of service
- Proposed personnel and subcontractors
- Experience
- Past performance
- Qualifications
- Other matters of concern to the City

The City of Brampton, Transit section now rents a large number (40+ units) for its requirements. The rental units are on a full-service plan. All scheduled maintenance is included in the cost and performed offsite. The rental agency is responsible for replacing a vehicle if downtime exceeds 24 hours for any reason.

Highlights of the City's Vehicle Rental Contract

Based on the RFP, a contract was subsequently awarded to the successful bidder. Some highlights and features of the bid award and the resultant contract include:

- Vehicles must be no older than three years.
- The City is responsible for paying monthly charges only.
- Maintenance and licensing, normal wear and tear costs are included.
- The only extra is for damages above normal wear and tear.
- Rentals are based on estimated mileage; no over-mileage fees are applicable.

Analysis of Three Vehicle Acquisition Options

To assess the lifecycle total cost of ownership (TCO) impacts, RSI-FC completed discounted cash flow analysis for these three options:

(1) Purchasing (i.e., purchasing vehicles and maintaining them in-house)
(2) Leasing (i.e., leasing vehicles and maintaining them in-house)
(3) Renting (i.e., rental costs including maintenance and licensing)

We completed discounted cash flow analysis to compare the full-lifecycle TCO costs for each of the three vehicle acquisition options: purchasing, leasing and renting. Discounted cash flow (DCF) is described as a valuation method[82] to estimate the value of an investment based on its expected future cash flows. DCF analysis applies to investment decisions of investors in companies or securities, such as acquiring a company, investing in a technology startup, or purchasing a stock, and for business owners and managers looking to make capital budgeting or operating expenditures decisions such as opening a new factory, purchasing or leasing new vehicles or equipment.

Business Assumptions for the Purchase, Lease & Rent DCF Analysis

To complete the DCF analysis for each option, several business assumptions were required. To ensure accuracy of assumptions, we based the analysis and comparisons of the three acquisition options around one vehicle type (Class 1 sedan) currently part of Transit's rental fleet. In this way, accuracy was assured for several key assumptions because monthly rental costs were known for this vehicle type, as were baseline average annual kms-travelled, fuel-used and maintenance expenses for similar Brampton fleet units.

In all types of analysis, business assumptions must be as realistic and accurate as possible. Fortunately, from our baseline Fleet Analytics Review™ (FAR) analysis which we completed in Part One of the Sustainable Fleet Strategy, assumptions relating to baseline costs (repairs and maintenance) and consumptions (fuel used, kms-travelled) had been established for *Option 1 – Purchasing*, and *Option 3 – Renting*. However, for baseline costs relating to *Option 2 – Leasing*, lease service provider costing data was not available, since the City does not have a contracted leasing provider. As a workaround, our team used current market values to fill the lease cost data

[82] Source: https://www.investopedia.com/terms/d/dcf.asp

gap. We suggest that, if Brampton was ever considering the leasing alternative, firm pricing should be acquired via a vehicle leasing provider RFP/Q, as was done for the rental contract. With the vendor's lease cost data confirmed, we recommend completing the leasing DCF analysis[83].

RSI-FC used the following business assumptions for our analysis:

- Vehicle type: Sedan, Class 1 (Hyundai)
- Sedan acquisition cost: $21,115
- HST rate: 1.76%
- Annual kms-travelled: 21,961[84] (low estimate, please see important note below)
- Annual days-of-use: 261[85]
- Optimal economic lifecycle: 12 years[86]
- City of Brampton cost of capital: 2.45%[87]
- Cash flow horizon: 12 years
- Lease term: six (6) years
- Type of leases DCF-modelled: Option 2a: Closed-end (walkaway) and Option 2b: Open-end w/ cash purchase for residual value (in year seven)
- Lease interest rate: 7% (includes estimated fees and surcharges)
- Lease fees and surcharges: estimated, included in lease rate (above)
- Rental sedan cost: $454 per month
- Projected resale value annual decrease: 2%
- Fuel consumption: 8.7 liters/100km[88]
- Fuel cost: $1.13 per liter
- Spare vehicle cost/km[89]: $0.10 ($0.00 for the rental option)
- Oil changes and minor PM inspection intervals: 5,000 km
- Maintenance, repair costs: owner/lessee expense (for purchase & lease options only)
- License costs: owner/lessee expense (for purchase option)

[83] At no additional cost, RSI-FC will provide our DCF analysis data-modeling software tool template to the City for its own use, should leasing ever be under consideration in the future

[84] Many of the rental units were new during the study period. Based on historical usage of the previous rental fleet, they are expected to have significantly higher mileage than what has been used in this analysis – an average of 4,000 km per month per unit. For high-mileage applications like this, rentals would deliver cost savings over buying.

[85] Analysis based on five days per week, nine Statutory holidays per year

[86] Based on upper threshold per RSI-FC lifecycle analysis modeling for Brampton's Class 1 sedan/saloon units

[87] Canada's prime rate at the time of the DCF analysis

[88] Based on Transit's Class 1 FAR™ analysis

[89] Average acquisition cost of Brampton's Class 1 vehicles – used for the purchase option DCF analysis

Important note. Many of the rental units were new during the study period. Based on historical usage of the previous rental fleet, they are expected to have significantly higher mileage than what has been used in this analysis – an average of 4,000 km per month per unit. It is likely that due to the impact of higher maintenance costs for the purchase and lease options (maintenance done in-house), the rental option (currently in place in Brampton's Transit section) would become much more favourable after DCF analysis. Therefore, RSI-FC recommends that, with certainty around this key data input, rent versus buy DCF analysis should be recalculated using the same principles presented in this analysis.

DCF Analysis – Option 1: Purchase

With the assumptions described above, we calculated the lifecycle total cost of ownership (TCO) for Option 1: Purchasing. In this scenario, the analysis was data-modelled for a sedan; it depicts the impacts of purchasing a sedan and maintaining the unit in-house through its entire lifecycle. We calculated the TCO over a 12-year horizon for a single vehicle, then extrapolated the single-vehicle results to 40 units to model the estimated potential fleet-wide implications.

Please see *Figure 2: DCF Analysis – Purchase – Sedan* (below). RSI-FC calculated the average annual TCO for a sedan to be $7,149. The TCO over a 12-year lifecycle was estimated to be $85,785, and the impact for 40 units was estimated to be ~$3.4m.

Figure 2: DCF Analysis – Purchase – Sedan

Annual Cost Summary Table for Purchase - Sedan

	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr	11-Yr	12-Yr	Average Annual Cost	Total Lifecycle Cost	Impact - 40 Units
Fixed Costs	$ 5,068	$ 4,459	$ 3,949	$ 3,518	$ 3,152	$ 2,841	$ 2,575	$ 2,346	$ 2,148	$ 1,976	$ 1,826	$ 1,694	$ 2,963	$ 35,550	$ 1,422,014
Fuel	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 25,908	$ 1,036,313
Repairs	$ 1,700	$ 1,700	$ 1,967	$ 1,900	$ 2,000	$ 2,100	$ 2,043	$ 2,025	$ 2,056	$ 2,090	$ 2,136	$ 2,142	$ 1,988	$ 23,859	$ 954,360
Downtime	$ 34	$ 34	$ 39	$ 38	$ 39	$ 41	$ 40	$ 40	$ 40	$ 41	$ 41	$ 41	$ 39	$ 468	$ 18,711
Total	**$ 8,960**	**$ 8,352**	**$ 8,114**	**$ 7,615**	**$ 7,350**	**$ 7,141**	**$ 6,817**	**$ 6,570**	**$ 6,403**	**$ 6,266**	**$ 6,162**	**$ 6,036**	**$ 7,149**	**$ 85,785**	**$ 3,431,399**

DCF Analysis – Option 2: Lease

RSI-FC completed analysis for two leasing scenarios:

(1) 2a: Closed-end lease (walkaway)
(2) 2b: Open-end lease (with buyback)

Leasing was estimated to be the highest cost option for vehicle acquisition, whether the leases are open-ended or closed-ended. However, we must be very clear that **several key assumptions used in the analysis were unknown** to our analysts. Specifically, these were:

- **Purchase price.** Since vehicle(s) would be purchased by the lessor and that leasing companies may be able to buy vehicle(s) for a substantially lower price, this one assumption could be a game-changer.
- **Interest rate.** The interest rate that would be charged to the City of Brampton by a potential lessor is unknown. Typically, this rate is the product of the lessor's cost of capital and reflective of the lessee's creditworthiness, both of which are unknown to our analysts for the aforementioned reason. RSI-FC used an estimated market-based rate as a workaround.
- **Profit.** It is safe to assume all leasing companies wish to make a profit, and that a profit adder would be charged to the City of Brampton on top of interest charges. Exactly how much the lessor's profit would be is unknown. As a workaround, RSI-FC used a "safe" (low) rate as a business assumption, given Brampton's presumed creditworthiness.
- **Service charges and fees.** It is safe to assume that all leasing companies include administrative and other service fees in their lease charges. Exactly which fees and what the costs might be are unknown. As a workaround, RSI-FC used a safe (low) rate as a business assumption.
- **Reconditioning.** For option 2a, closed-end leasing, lessors typically charge the lessee to restore the vehicle to a predetermined state at the end of the term. The degree or standard of reconditioning should be negotiated with potential lease vendors at the outset – for our analysis this was unknown.
- **Lease term.** For our analysis, we used a six-year term; shorter periods are available, impacting the monthly lease charges.
- **Residual value.** The residual value at the end of an open-end lease can be negotiated with lessors. For our analysis, we reduced the vehicle value by 2% annually.

Important note. The many unknown business assumptions (listed above) could significantly alter the outcomes of the leasing cost analysis. It is entirely possible that due to the impact of preferable interest rates combined with a reduced cost of vehicle acquisition (and other factors), the lease option could become more favourable. Therefore, RSI-FC recommends that, should Brampton ever be considering leasing as an alternative to purchasing or renting, the City first issue an RFP or RFQ to determine these costs with absolute clarity. Then, with certainty around these key assumptions, lease versus buy DCF analysis should then be recalculated.

Option 2a: Closed-end Lease (Walkaway)

RSI-FC completed DCF analysis to data-model the closed-end lease option. As we described earlier, this type of leasing is sometimes referred to as a "walkaway" lease. At the end of the lease term, the vehicle is simply handed back to the lessor. At the end of a closed-end lease, it is typical that lessors charge the lessee the costs of reconditioning the vehicle. We estimated reconditioning charges to be $1,000 at the end of each 6-year lease term for this analysis.

As shown in *Figure 3: DCF Analysis – Closed-end Lease – Sedan* (below), the average annual cost is estimated to be $8,021 per unit, while the total lifecycle cost is $96,250/unit. The impact for 40 units is estimated to be ~$3.9m.

Figure 3: DCF Analysis - Closed-end Lease - Sedan

Annual Cost Summary Table for Closed-end Lease - Sedan

	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr	11-Yr	12-Yr	Average Annual Cost	Total Lifecycle Cost	Impact - 40 Units
Fixed Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fuel	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 25,908	$ 1,036,313
Lease payments & fees, mtce., re-conditioning costs	$ 5,468	$ 5,468	$ 5,734	$ 5,668	$ 5,768	$ 6,018	$ 5,939	$ 5,905	$ 5,923	$ 5,948	$ 5,977	$ 6,059	$ 5,823	$ 69,875	$ 2,794,982
Downtime	$ 34	$ 34	$ 39	$ 38	$ 39	$ 41	$ 40	$ 40	$ 40	$ 41	$ 41	$ 41	$ 39	$ 468	$ 18,711
Total	**$ 7,660**	**$ 7,661**	**$ 7,932**	**$ 7,865**	**$ 7,966**	**$ 8,218**	**$ 8,138**	**$ 8,104**	**$ 8,122**	**$ 8,148**	**$ 8,177**	**$ 8,259**	**$ 8,021**	**$ 96,250**	**$ 3,850,007**

Option 2b: Open-end Lease with Buyback

We completed DCF analysis for the open-end lease with buyback option. We modelled a six-year lease term with buyback in year seven. The unit would remain in service until year 12.

As shown in *Figure 4: DCF Analysis – Open-end Lease with Buyback – Sedan* (below), the estimated average annual TCO for one unit is $7,686, while the lifecycle TCO is estimated to be $92,235. The estimated lifecycle TCO impact for 40 units is estimated to be ~$3.7 million.

Figure 4: DCF Analysis - Closed-end Lease with Buyback - Sedan

Annual Cost Summary Table for Open-end Lease - Sedan

	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr	11-Yr	12-Yr	Average Annual Cost	Total Lifecycle Cost	Impact - 40 Units
Fixed Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ 9,221	$ 3,325	$ 2,405	$ 1,911	$ 1,594	$ 1,369	$ 1,652	$ 19,824	$ 792,957
Fuel	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 25,908	$ 1,036,313
Lease payments & fees, mtce., buy-back costs	$ 5,468	$ 5,468	$ 5,734	$ 5,668	$ 5,768	$ 5,851	$ 2,300	$ 2,112	$ 2,011	$ 1,940	$ 1,891	$ 1,825	$ 3,836	$ 46,036	$ 1,841,422
Downtime	$ 34	$ 34	$ 39	$ 38	$ 39	$ 41	$ 40	$ 40	$ 40	$ 41	$ 41	$ 41	$ 39	$ 468	$ 18,711
Total	$ 7,660	$ 7,661	$ 7,932	$ 7,865	$ 7,966	$ 8,051	$ 13,719	$ 7,636	$ 6,615	$ 6,051	$ 5,685	$ 5,394	$ 7,686	$ 92,235	$ 3,689,404

DCF Analysis – Option 3: Rent

We completed analysis to evaluate the current vehicle rental arrangements at the City of Brampton. We based the business assumptions on the contractual agreements from the rental RFP and contract which was awarded in 2020.

As we see in *Figure 5: DCF Analysis – Rent – Sedan* (below), the estimated annual TCO for one unit is $7,607, while the total lifecycle cost is estimated to be $91,284. The lifecycle cost for 40 units is estimated to be ~$3.7m.

Figure 5: DCF Analysis - Rent - Sedan

Annual Cost Summary Table for Rent - Sedan

	1-Yr	2-Yr	3-Yr	4-Yr	5-Yr	6-Yr	7-Yr	8-Yr	9-Yr	10-Yr	11-Yr	12-Yr	Average Annual Cost	Total Lifecycle Cost	Impact - 40 Units
Fixed Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fuel	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 2,159	$ 25,908	$ 1,036,313
Rental Costs	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 5,448	$ 65,376	$ 2,615,040
Downtime	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Total	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 7,607	$ 91,284	$ 3,651,353

Summary of DCF Analysis

After completing DCF analysis for the three options of purchasing, leasing and renting, based on data inputs from the time of the analysis, modelling results showed that *Option 1: Purchase* would provide the lowest total cost of ownership (TCO) over a 12-year lifecycle. However, with that stated, we are unable to make that pronouncement with confidence since (1) annual mileage has been underestimated (based on the City's management team feedback), and (2) several key business assumptions for the leasing options are unknown, as we explained earlier.

As noted earlier, many of the rental units were new during the study period. Based on historical usage of the previous rental fleet, they are expected to have significantly higher mileage than what has been used in this analysis – an average of 4,000 km per month per unit. Therefore, it is likely that due to the impact of higher maintenance costs for the purchase and lease options (maintenance done in-house), the rental option (currently in place in Brampton's Transit section) would become much more favourable after DCF analysis.

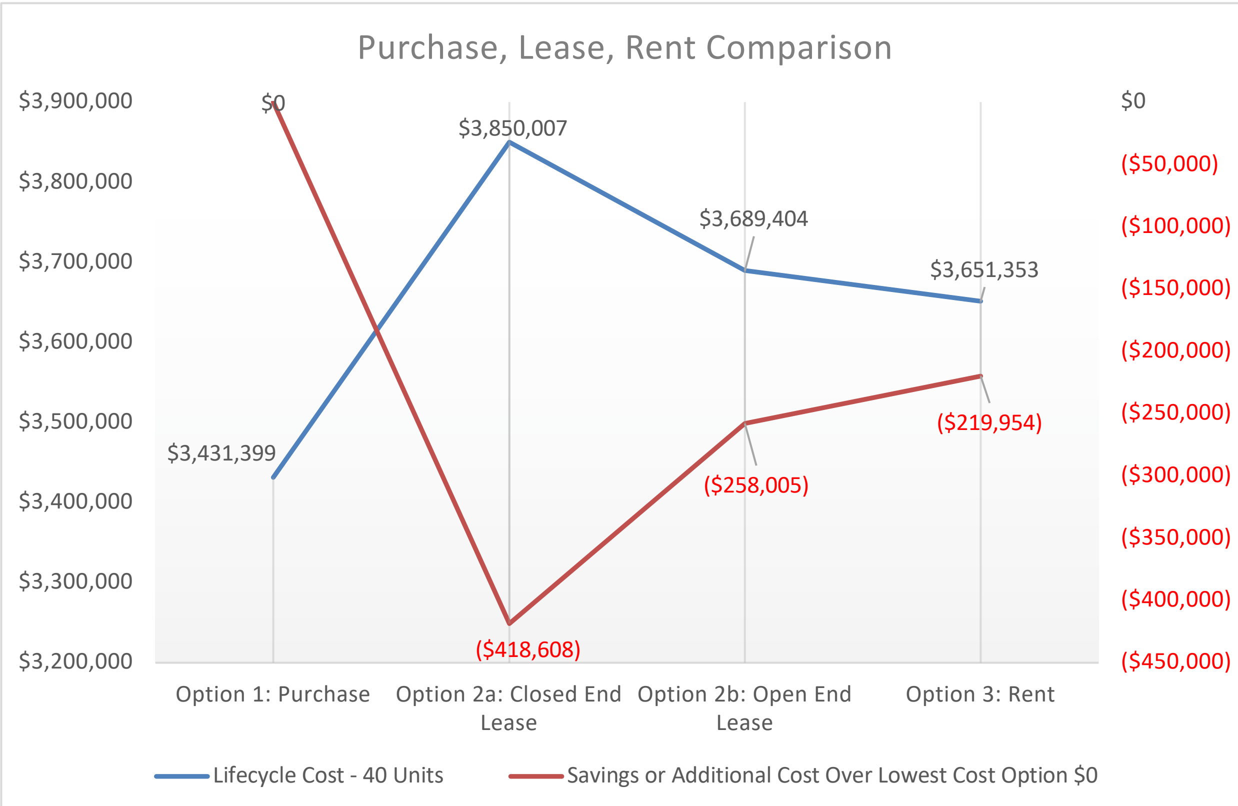
Additionally, given the much higher mileage of the rental units than what has been modelled, the lifecycle of operator shuttle vehicles would likely we less than 12 years due to the high mileage accumulated and high availability required.

A summary of the purchase, lease and rent analysis is displayed in *Table 11* and *Figure 6* (below). The lowest cost option, based on our modelling, is to purchase vehicles, followed by the rental option and then the open-end leasing with buyback. As shown, the most expensive option is the closed-end lease with a lifecycle impact, over a 12-year horizon and 40 vehicles, is estimated to result in a cost increase of more than $418,000 (over the purchase option).

Table 11: Summary of Purchase, Lease & Rent Analysis

Vehicle Acquisition Option	Lifecycle Total Cost of Ownership - 40 Units	Savings or (Additional Cost) Over Lowest Cost Option
Option 1: Purchase	$3,431,399	$0
Option 2a: Closed End Lease	$3,850,007	($418,608)
Option 2b: Open End Lease	$3,689,404	($258,005)
Option 3: Rent	$3,651,353	($219,954)

Figure 6: Summary of Purchase, Lease & Rent Analysis



Cost Savings from Reduced Administrative Effort

As per our calculations and estimates, the rental option has the least *negative* financial impact over purchasing, followed by open-ended leasing with buyback. Over a 12-year horizon and 40 vehicles, the lifecycle impact is estimated to result in a relatively small cost increase of ~$219k and $258k, respectively, over the purchase option. On the surface, it could be said that purchasing 40 vehicles instead of renting would be like receiving ten free vehicles over 12 years. But viewing the situation more holistically, renting can mean a reduction in administrative effort for the City – many responsibilities managed internally by the City may be transferred to the rental (or leasing) agency.

The cost of administrative effort may be significant. For example, tasks such as preparing vehicle specifications and preparing, issuing and awarding RFQs for vehicle purchases every year, managing, scheduling and supervising vehicle maintenance, and maintaining vehicle service histories are routines that incur administrative effort and, hence, cost. Exactly how much this cost is unknown – but is likely significant.

Although out of scope for this project, the cost impact of reduced administrative effort could be determined by undertaking an activity-based costing[90] (ABC) exercise. From our experience with ABC for municipal fleets, we suspect that the administrative costs avoided by renting vehicles could have the potential to negate the cost increase for 40 rental units over their 12-year lifecycles. In other words, it is entirely possible that the current rental agreement could very well have cost parity with the vehicle purchasing option, and provide cost savings in high annual mileage applications.

Purchase, Lease or Rent – Recommendations

(1) If the City considers leasing as an alternative to purchasing or renting, first issue an RFP or RFQ to determine these costs with absolute clarity. Then, with certainty around these key assumptions, lease versus buy DCF analysis should be recalculated.

(2) Carefully prepare bid specifications for a vehicle leasing RFP/Q so that *all* cradle-to-grave leasing costs, including all service charges and fees, can be identified and evaluated.

(3) In RFP/Qs, consider adding a requirement that potential lease vendors must state their beginning-to-end, total-cost-of-leasing projections, including all fees and surcharges over the entire lease term in their proposals.

(4) To ensure consistent bid responses, include in the RFP/Qs a standard response format, such as a fillable .pdf template, for bidders to list their charges, rates, additional fees, and surcharges in a common way that competing bidders’ responses can be compared like-for-like.

(5) Require vendor proposals to include their proposed fixed or floating interest rate; if the latter, the percentage of the profit "adder" (markup) for the lessor that will be applied must be stated.

(6) Require vendor proposals to guarantee that all conceivable service charges and other fees that may be applied over the leased vehicle's entire cradle-to-grave lifecycle have been stated.

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[90] Source: https://www.investopedia.com/terms/a/abc.asp

Section 6.0: Overview and Discussion

In Part Two of the City of Brampton's Sustainable Fleet Strategy: Framework and Action Plan Report, we presented:

a) The results of various data models which evaluated the cost and GHG impacts of go-forward fuel-reduction solutions relative to the 2019 baseline (proxy for 2020) over a 15-year budget cycle, and resulted in a long-term capital planning (LTCP) outlook;

b) Estimations of electric vehicle supply equipment (EVSE) requirements to model the cost of charging infrastructure over a 15-year budget cycle, in consideration of the specific needs of Brampton's fleets;

c) Recommendations for low-carbon fleet options and a structured, phased-in transition to battery-electric vehicles (BEVs) with consideration of LTCP; and

d) An overview of purchasing v. leasing v. renting fleet assets and discounted cashflow analysis (DCA) for the rental units in the Transit (non-revenue) fleet.

We developed 15-year low-carbon fleet plans for the City of Brampton's fleets involving various immediate and/or interim fuel-reduction solutions and a battery-electric vehicle (BEV) phase-in to 2035, as this is the most effective long-term GHG-reduction strategy as battery-electric technology continues to advance. Using balanced capital expenses (Capex) using optimized lifecycles, as was determined in Part One, our approach was to model "house-in-order" solutions first, then add potential fuel-switching options which we term the "messy middle," and, finally, phase-in BEVs as they become available in the near future for all vehicle classes. The recommended BEV transition plan (in addition to all best management practices (BMPs)) provided in Part Two of the Sustainable Fleet Strategy, if fully implemented, has the potential to reduce the City of Brampton's fleet (Fleet Services, Fire & EMS, and Transit (non-revenue) combined) GHG emissions by **86% by 2035**. Our recommendations are pragmatic and fiscally-prudent, based on research, data-driven analysis, and sound economic principles and practices.

It is important to note that the scenarios we have presented are meant to provide guidance and stimulate thought regarding each individual solution, and not serve as an accounting-accurate evaluation. In reality, the City of Brampton may consider multiple fuel-switching options in conjunction with one another, depending on unit age, vehicle condition, and kilometres-travelled.

RSI-FC's BEV transition plan for the City of Brampton follows closely the steps provided by the Pembina Institute for transitioning urban delivery fleets in the Greater Toronto and Hamilton Area (GTHA) to BEVs, which include[91]:

- Identifying suitable electric vehicle models;
- Creating a phasing plan that incorporates a trial or pilot period;
- Assessing facility and site infrastructure requirements;
- Identifying the ideal ratio of chargers to vehicles;
- Selecting the preferred financing or leasing model; and
- Training maintenance staff.

BEV Transition

BEVs have a very high potential for achieving significant fuel cost savings and GHG emissions reductions for the City of Brampton. With zero tailpipe emissions and significant lifecycle emissions reductions compared to internal combustion engine (ICE) vehicles, transitioning the fleet to electric is the ultimate fuel-reduction solution. In our proposed scenario-modelling, we are essentially suggesting a temporary hold on purchasing new vehicles for the short term – one to two years for pickups, three to four years for medium- and heavy-duty vehicles (MHDVs), while waiting for battery-electric versions to become available. The exception, of course, is for light-duty (LD) passenger BEVs which are currently available with sufficient range, such as the Kia Soul or the Chevrolet Bolt. Moreover, BEV refuse/recycling trucks and transit buses (the latter are outside the scope of this report) are also available for purchase now.

A phased-in approach is recommended for the City of Brampton to transition to a BEV fleet for fiscal responsibility reasons, in addition to this being the only option for fleets over the next few years. Municipal replacement cycles are long-term – up to 10 or 12 years – or more for some vehicles. Therefore, a BEV phase-in plan over the long term is needed for a balanced approach to capital spending. Our position is that fleets should avoid buying fossil-fuelled units because ICE vehicles are quickly becoming an outdated and archaic technology. The purchase of a new ICE vehicles now, whether gasoline or diesel, means that a fleet will commit to using new fossil-fuelled vehicles for approximately the next decade when zero-emissions BEVs, which are often more economical than their fossil-fuel counterparts, are just around the corner.

The "workhorse" of municipal fleets is the pickup truck. Of all the fleet vehicles in RSI-FC's 50,000 vehicle Canadian municipal fleet database, 46% are pickup trucks. For Brampton's in-scope vehicles, pickups comprise about 39% of the fleet based on the data provided (244 pickups out of a total of 625 units). Therefore, BEV options in the pickup category have the potential to make a significant impact on helping the City reach its GHG-reduction goals. At this time, there are no BEV

[91] Source: https://www.pembina.org/pub/guide-electrifying-urban-delivery-fleets-canadian-cities

pickups available for purchase, but at several manufacturers, including General Motors and Ford, are preparing BEV pickups to hit the market starting in the year 2022.

We expect that battery-electric models for Class 5-8 trucks will come to market in the near future – almost all truck manufacturers have announced plans to launch battery-electric trucks in these classes soon, likely by 2024. Several are taking orders now, including Lion Electric, Tesla, and others.

Compressed natural gas (CNG) conversion is a solution that can potentially deliver significant fuel cost savings and GHG reductions; however, the cost of installing a fast fuelling system in far greater than installing a direct current (DC) fast charger for BEVs. Moreover, if BEVs come down in price over time, the business case will continue to improve. Given that MHDVs are likely moving away from the internal combustion engine toward battery-electric zero-emission units, a fleet-wide commitment to CNG may not be a prudent choice for the future.

If Brampton decides to proceed with a plan that is similar to the one RSI-FC is suggesting and have a pause on purchasing new (otherwise fossil-fuelled) pickups (for one year) and MHDVs (for three years) when appropriate, we recommend, in the interim, to fully implement best management practices (BMPs) and also consider switching flex-fuel units to ethanol 85 (E85). Driver eco-training and anti-idling policy/technologies, if fully implemented fleet-wide, have the greatest GHG-reduction of all BMPs, based on our modelling. Switching all flex-fuel units to ethanol 85 (E85) has the greatest GHG-reduction potential of all fuel-switching options, based on our modelling. As there is limited availability of this fuel (sold outside of Ontario according to our research), finding a reliable supply of E85 may be a barrier; however, interim or “messy middle” solutions all have their challenges that can be overcome with effort and determination.

Moreover, in the interim we recommend that the City of Brampton allocate capital towards charging infrastructure required for the transition to BEVs for all vehicle categories. The additional capital costs associated with electric vehicle supply equipment (EVSE) can be recovered through lower capital spending during this pause we are recommending for purchasing ICE vehicles. Importantly, existing electrical capacity at facilities may require significant upgrades to power charging stations for multiple vehicles – a potential challenge that should be addressed as early as possible.

Implementation

Part Two of the Sustainable Fleet Strategy describes the analysis we have completed to evaluate and determine viable fuel-reduction solutions that are available to the City of Brampton, now and in the near future. We have presented the strengths, weaknesses, and cost-benefit analysis to help inform fleet management in decision-making around which solutions are effective interim solutions and which help to achieve longer-term goals. Such decisions should be made with consideration for budgets and cash flow planning, current and expected future business climate, and the level of ambition in achieving deep reductions in GHG emissions (and at the same time, potentially significant cost savings).

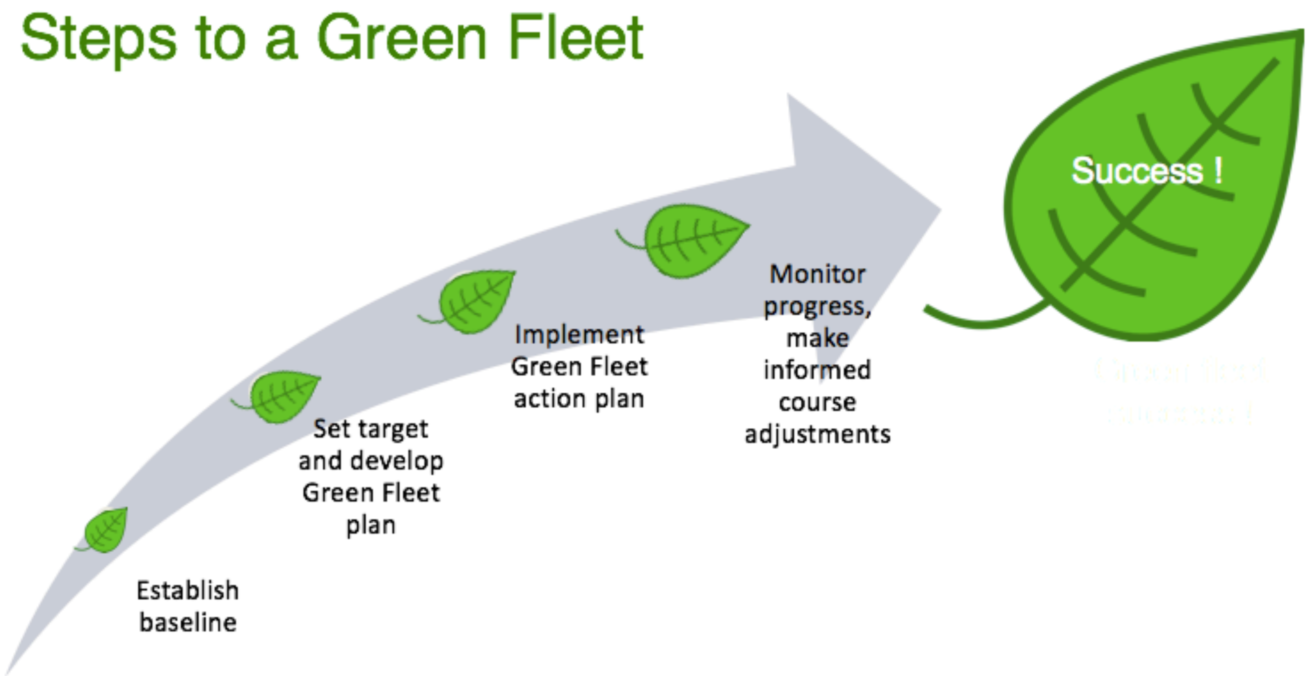
From our work in developing fuel-reduction strategies for more than 15 years, we have observed that certain elements lead to the highest rates of successful implementation. These include:

- A corporate culture that encourages environmental leadership;
- An internal "champion";
- Commitment to greening the fleet – from the ground floor operational level up to the most senior level of the organization;
- Carefully managed risk and a willingness to experiment;
- A strong green fleet commitment stated in policy, clearly defined timelines, and responsibilities;
- Procurement policies that take into consideration lifecycle costs of vehicles;
- Carefully prepared green fleet plans that are based in reality and practicality;
- Reliable and consistent fleet operating data;
- Monitoring and reporting to facilitate accountability;
- Measurable, measured, and achievable goals – with a degree of stretch; and
- A strong communications team to share successes.

Illustration 1 (below) is a simple but effective visualization of the steps for achieving a successful green fleet. The first step (establishing baseline) has been achieved in Part One of the Strategy, and step two (setting target and developing green fleet plan) is well underway through RSI-FC's Fleet Analytics Review™ (FAR) scenario analysis and recommendations presented in Part Two.

Our software tool, FAR, will be provided to the City of Brampton for its own internal use post-project. The tool can be useful for both steps 3 and 4 (implementation and monitoring) to precisely evaluate any number and combination of fuel-saving solutions for specific units (implementation) as well as to re-evaluate solutions as progress is made (monitoring).

Illustration 1: Steps to a Green Fleet



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Appendix A: Fleet Analytics Review™

Fleet Analytics Review™ (FAR) is a user-friendly, interactive decision support tool designed to aid our team and fleet managers in developing short- to long-term green fleet plans by calculating the impacts of vehicle replacement and fuel-reduction solutions on operating costs, cost of capital, and GHG emissions. Moreover, it is used for long-term capital planning (LTCP) through an approach that works to balance, or smoothen, annual capital budgets and avoid cost spikes if possible.

FAR is a complex, sophisticated MS Excel software developed by the RSI-FC team in 2016. Since its inception, FAR has been used by our team as the foundational analysis platform for our work in helping fleets with green fleet planning and the transition to low-carbon fuels/technologies.

Clients to date for which reports were completed using FAR include:

- City of Hamilton (2021)
- City of Kawartha Lakes (2020)
- Durham Region (2020)
- Town of Gander (2020)
- Town of Whitby (2020)
- Town of Aurora (2019)
- NW Natural Gas Distribution, Portland, OR, USA (2018)
- The County of Middlesex Centre (2017)
- The Region of Peel (2017)
- The Town of Enfield, CT, USA (2017)
- Toronto-Hydro Electric (2017)
- Winnipeg Airport Authority (2017)
- Greater Toronto Airport Authority (2016)
- Oxford County (2016)
- The City of Vaughan (2016 - 2018)

Purpose

The core functionality of the FAR software is to calculate the financial and GHG reduction impacts of vehicle replacements, operational improvements, and low-carbon fuels/technologies for a fleet.

In the context of assessing fleet modernization, FAR is especially useful in calculating the operating expense (Opex) impacts of vehicles being retained in the fleet beyond their viable age and with diminishing salvage values. Aged, older-technology vehicles consume more fuel, produce more GHGs, usually cost more to operate, are less reliable, and may also present a safety risk. FAR automatically calculates and quantifies these impacts in a defensible business case format.

For fuel-reduction solutions under consideration by fleet management as a means of saving fuel costs and avoiding GHGs, including best management practices (BMPs), alternate or renewable fuels (natural gas, propane, biodiesel, etc.), and EVs (battery-electric, plug-in hybrid, or hybrid), FAR calculates the cost-benefit of the investment in vehicle upgrades, vehicle conversion costs, fuelling infrastructure, or EV charging infrastructure, i.e., whether these solutions would yield a net operating cost reduction, unit-by-unit and fleet-wide.

Approach

The FAR software tool employs a holistic approach – all relevant factors and controllable expenses are considered in its analysis. The data points in our approach include energy equivalency factors of each alternative fuel type (compared to a fossil diesel fuel baseline), vehicle upgrade costs, alternately-fuelled vehicle acquisition (or vehicle retrofit) capital costs, vehicle maintenance considerations (higher or lower maintenance demand), fuel system/charging infrastructure capital costs, and any additional expenses for storage, handling & dispensing the fuel(s). All of these factors are modelled within the context of planned vehicle lifecycles – a total cost of ownership (TCO) approach.

The FAR process uses historical cost metrics and vehicle operating data (i.e., miles/km-driven, fuel usage, repair and maintenance costs, unit age, cost of capital, downtime, residual value, etc.) to establish not only the fleet's fuel usage and GHG emissions baseline, but also financial and service levels (i.e., utilization, availability/uptime) performance.

FAR highlights "exception" units, vehicles that are performing in a sub-standard way in terms of cost and performance, thus potentially enabling management to identify the reason(s) and take appropriate action(s).

Go-Forward Fuel-Reduction Solutions

With the FAR baseline established, the software is used to analyze go-forward fuel-reduction solutions. FAR takes into consideration the Opex implications and determines whether Opex reductions will offset any capital expenses (Capex) including vehicle upgrades, vehicle conversions, "up-charges" for premium vehicles (e.g., EVs), and investment in infrastructure.

The FAR analysis includes, but is not limited to:

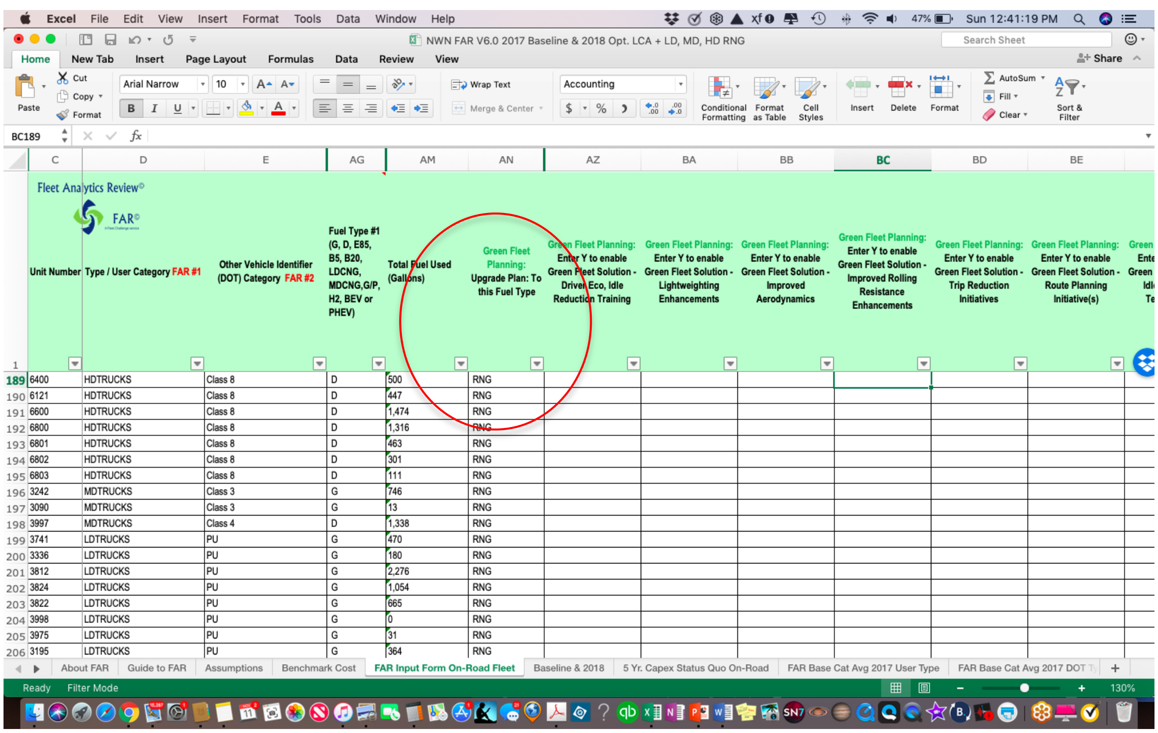
- The fuel usage and cost differential (+ or -) for the fuel type selected vs the current type (if applicable)
- The energy-efficiency difference

- The unit cost of upgrade for the fuel-saving technology
- The unit cost of conversion to the selected fuel type
- The cost of fueling infrastructure for the selected fuel type apportioned evenly to the chosen vehicles for the fuel-switch
- The cost of charging infrastructure for EVs apportioned evenly to the chosen vehicles to be replaced
- The cost of capital for vehicle replacement for the selected fuel type

FAR then calculates whether a cost-savings or return-on-investment (ROI) would result within the remaining lifecycle for each of the vehicles selected for the vehicle upgrade or fuel switch.

Figure 7 shows a sample screen capture from FAR demonstrating the FAR fuel-switching capabilities. In this example, the user is switching several light-, medium-, and heavy-duty trucks from their current fuel source to renewable natural gas (RNG), and this is accomplished simply by selecting the vehicle(s) to be evaluated and then choosing (in this example) RNG from a drop-down list.

Figure 7: Sample Screen Capture of FAR Showing Fuel-Switching Options



	Unit Number	Type / User Category FAR #1	Other Vehicle Identifier (DOT) Category FAR #2	Fuel Type #1 (G, D, E85, B5, B20, LDCNG, MDCNG,G/P, H2, BEV or PHEV)	Total Fuel Used (Gallons)	Green Fleet Planning: Upgrade Plan: To this Fuel Type
189	6400	HDTRUCKS	Class 8	D	500	RNG
190	6121	HDTRUCKS	Class 8	D	447	RNG
191	6600	HDTRUCKS	Class 8	D	1,474	RNG
192	6800	HDTRUCKS	Class 8	D	1,316	RNG
193	6801	HDTRUCKS	Class 8	D	463	RNG
194	6802	HDTRUCKS	Class 8	D	301	RNG
195	6803	HDTRUCKS	Class 8	D	111	RNG
196	3242	MDTRUCKS	Class 3	G	746	RNG
197	3090	MDTRUCKS	Class 3	G	13	RNG
198	3997	MDTRUCKS	Class 4	D	1,338	RNG
199	3741	LDTRUCKS	PU	G	470	RNG
200	3336	LDTRUCKS	PU	G	180	RNG
201	3812	LDTRUCKS	PU	G	2,276	RNG
202	3824	LDTRUCKS	PU	G	1,054	RNG
203	3822	LDTRUCKS	PU	G	665	RNG
204	3998	LDTRUCKS	PU	G	0	RNG
205	3975	LDTRUCKS	PU	G	31	RNG
206	3195	LDTRUCKS	PU	G	364	RNG

FAR is user-friendly and intuitive; it is based on standard off-the-shelf MS Excel. It is dynamic, and users can run future scenarios (such as assessing different vehicle types, fuels, or engine/drivetrain combinations) to see how such decisions impact Opex ahead of their implementation, thereby mitigating risk and heading off potentially costly errors.

Recent Enhancements and Upgrades to FAR™

FAR V30.5 (beta) features upgrades and enhancements to the functionalities of the FAR tool. These include:

Fuel-Efficient Green Fleet Planning Tools – Fuel Switching. FAR now includes several powerful "Green Fleet Planning" tools. One of these tools is used to estimate the financial and GHG impacts of switching vehicle fuels from fossil-based (gas or diesel) to alternate or renewable fuels or BEVs.

In the Input Form, FAR analysts may make choices as to fuel-switching (for example, changing all gas or diesel-powered vehicles in specific categories to E85, B5-B100 biodiesel, hybrid, plug-in hybrid, battery-electric, CNG, or even hydrogen fuel cells). FAR calculates the net cost and GHG reduction of the fuel-switch being considered, taking into consideration not just the fuel/electricity costs, but the change in fuel efficiency, as well infrastructure costs such as installing a CNG fueling station, electric vehicle chargers, etc.

Enhanced Vehicle Replacement Cost-Benefit Analysis. Comparisons and analysis regarding either (a) aging a vehicle (or vehicles) that are now due for replacement for another year or (b) going ahead and replacing the vehicle(s) is now based on the actual average historical peer fleet cost data from our proprietary municipal fleet database.

In FAR, when a vehicle is due for replacement, it calculates the annual cost for a new replacement vehicle (including the capital, fuel, repairs, PM, and downtime) and then compares that amount to the actual average cost for a similar vehicle —that is one-year older (from our peer fleet database). FAR now displays the cost-benefit of replacing each unit that is due for replacement in the 5+ year Capex plan tab – in blue font each vehicle that will save Opex if it is replaced, and red font if it will incur more Opex. This marks a significant change in FAR and eliminates all guesswork or sketchy assumptions and supplants it with real peer fleet operating cost data by model year and vehicle categories we have collected since 2006.

Fuel-Usage and GHG Reduction for New Vehicles. For each vehicle that is due for replacement, FAR now shows the potential fuel-usage and GHG reduction.

Appendix B: Details on Fuel-Reduction Solutions

Here, we provide further details on many of the 20+ fuel-reduction solutions modelled in FAR, which have been researched by RSI-FC – some of which have already been implemented by the City of Brampton, and many of which have been modelled as potential go-forward strategies.

Best Management Practices

Best management practices – Group One - include: (1) enhanced vehicle specifications – vehicle choice and/or vehicle upgrades – which lower fuel consumption, lower GHG emissions, and improve overall performance; (2) proper maintenance procedures including tire inflation systems; and (3) fleet operational improvements including:

- Idling reduction initiatives
- Driver training to educate drivers on efficient driving practices
- Ongoing feedback and motivation to maintain good driving habits
- Route planning and optimization, including trip reduction, minimization, or elimination

Enhanced Vehicle Specifications at a Glance

There are a number of vehicle specifications that can aid in fuel-use and emissions reductions. *Table 12* lists sample vehicle specifications and their respective impacts.

Table 12: Strengths and Weaknesses of Enhanced Vehicle Specifications

Specification	Strengths	Weaknesses
Smaller Vehicles	Consume less fuel and thus have reduced emissions	Might not always be suitable for the job
Lighter Vehicles	Consume less fuel, produce less emissions, and can carry larger payload (e.g., if a truck is lighter by “x” pounds/kg, it can carry a commensurately increased payload), which increases efficiency	Light weighting may overstress some vehicles, increasing maintenance demand and lifecycle cost
Aerodynamically Designed Vehicles	Reduces fuel consumption and emissions	Minimal effectiveness in urban setting, high cost, increased maintenance demand for some solutions

Specification	Strengths	Weaknesses
Low Rolling Resistance (LRR) Tires and Wide-base Tires	Reduces fuel consumption and emissions, reduce frequency of tire replacement	Potential for on-road service issues, axle loading restrictions in some jurisdictions with wide-base tires
Electronically Controlled, Programmable Diesel Engines	Allow tailoring/minimizing power and torque needs, road speed, and idle time limits therefore reducing fuel consumption and emissions	Seldom give problems, however when they do, often require specialized and costly diagnostic skills (might need to be outsourced) with potentially protracted downtime
Idling-Reduction Devices	Reduces idle time and therefore lowers fuel use and emissions	Actual idling reduction benefits are dependent on the use of technologies by drivers, some who resent intervention by such devices; some may feel devices could cause a safety concern

Fleet Downsizing

Getting a fleet's "house in order" should include shedding any under-utilized vehicles, so that stranded capital tied up in low-usage units can be re-applied to fleet modernization and new electric vehicles (EVs). When exception data demonstrates that a vehicle's usage has been less than the organization's acceptable minimum threshold, the vehicle is incurring cost without serving a purpose. Hence, the vehicle is a liability, unless it has some redeeming value, i.e., a special-purpose or backup vehicle for emergencies, or a unit reserved for peak periods.

Low-usage units should be routinely and regularly reviewed to determine if there are more cost-effective ways of accomplishing the corporate end-goal. If a specific vehicle is used infrequently, management should be empowered to consider creative solutions for a less costly travel mode, e.g., an inter-departmental vehicle sharing arrangement, a 3rd party service-provider, video conferencing, use of employee's vehicles, etc.

A fleet's first step in cost reduction is to reduce the total number of low-utilization vehicles. Management should undertake a review to determine if some vehicles can be eliminated through early decommissioning.

Right-Sizing

In days past, some fleet managers subscribed to the adage "identify the size of truck you really need for the job — and then buy one bigger." Today, we know this is anachronistic thinking that led to fleets with oversized vehicles, poorer fuel economy, and higher operating costs and GHG emissions.

Instead, savvy fleet managers are leaving the old approach behind and employing the correct and most efficient approach, which is to right-size fleet vehicles – that is, correctly specify the size of vehicle for the job at hand, which leads to lower overall operating costs.

Job Suitability

The types of vehicles and the equipment staff members are fitted should be aligned with the vocational and load requirements. For example, a passenger sedan would be completely unsuitable for plowing snow or carrying loads of anything other than people. Rather, fleet vehicles types are matched specifically to the tasks at hand; in this case, a light-duty truck would be required for snow removal in, for example, parking lots.

Choose the Size Down When Appropriate

Downsizing is a recommended best management practice which results in a lower total cost of ownership (TCO). An example is acquiring light-duty (Class 2a) vans and pick-ups as opposed to heavier-duty units (Class 2b), which have higher acquisition and maintenance costs.

Another example is with heavy-duty units; selecting a single-axle plow-dump unit, which has inherently lower operating costs than a tandem-axle unit, is recommended when appropriate (i.e., when the specific task at hand, or job suitability, is fulfilled by either unit).

Accounting for Limited Space

Limited space for roads, as a result of urban development and densification, may lead to an increased number of traffic roundabouts. Roundabouts pose unique problems for snowplows as well as refuse and recycling trucks because of tight turning movements and lack of adequate space to maneuver. Single axle units are shorter in overall length and, therefore, turn in a smaller radius than tandem or tridem axle units. They also cost less to acquire and maintain. The disadvantages are that single axle trucks may have less traction/control in slippery conditions and have less load-carrying capacities, such as salt/sand or waste (less productivity). However, in urban, low-speed, traffic-congested environments with limited space, such as roundabouts, single axle plows or refuse/recycling trucks will have an advantage over multi-axle units. In this example, it is important to weigh the pros and cons for different sized vehicles; when space is tight, it is often recommended to go smaller when it is safe (i.e., at low speeds) and productivity is acceptable.

Right-Sizing Summary

In summary, it is important for a fleet to consider the following in regard to right-sizing:

- Ensure that fleet vehicles are matched specifically to the tasks at hand (i.e., are job suitable) in terms of both vocation and load requirements.
- When multiple sized units fulfil a task equally well, choose the size down.
- When space is limited, it is often best to choose smaller units, given that it is safe to do so and that the productivity level is acceptable.

Low-Rolling Resistance Tires

Rolling resistance is the energy lost from drag and friction of a tire rolling over a surface[92]. The phenomenon is complex, and nearly all operating conditions can affect the final outcome. With the exception of all-electric vehicles, it is estimated that 4%–11% of light-duty vehicle fuel consumption is used to overcome rolling resistance. All-electric passenger vehicles can use approximately 23% of their energy for this purpose. For heavy trucks, this can be as high as 15%–30%.

A 5% reduction in rolling resistance would improve fuel economy by approximately 1.5% for light and heavy-duty vehicles. Installing low-rolling resistance (LRR) tires can help fleets reduce fuel costs. It is also important to ensure proper tire inflation (see sections below).

Tires and fuel economy represent a significant cost in a fleet's portfolio. In Class 8 trucks, approximately one-third of fuel efficiency comes from the rolling resistance of the tire. The opportunity for fuel savings from LRR tires in these and other vehicle applications is substantial.

According to a North American Council for Freight Efficiency (NACFE) report, the use of LRR tires, in either a dual or a wide-base configuration, is a good investment for managing fuel economy. Generally, the fuel savings pay for the additional cost of the LRR tires. In addition, advancements in tire tread life and traction will reduce the frequency of LRR tire replacement.

[92] Source: https://afdc.energy.gov/conserve/fuel_economy_tires_light.html

Automatic Tire Inflation Systems

Proper tire inflation pressure is critical to the optimal operation of a commercial vehicle. Underinflated tires result in decreased fuel efficiency and increased tire wear[93]. A 0.5-1.0% increase in fuel consumption is seen in vehicles running with tires underinflated by 10 psi. Appropriate pressure reduces tire wear, increases fuel efficiency, and leads to fewer roadside breakdowns due to tire failures. An example of an automatic tire inflation system (ATIS) is shown in *Figure 8*.

Figure 8: Automatic Tire Inflation System (courtesy NACFE)

In the U.S., a large truckload carrier with 5,000 tractors and 15,000 trailers averaging 124,000 miles a year on tractors and 41,000 miles on trailers, conducted a fuel economy test with 60 trucks pulling trailers without tire inflation systems and 75 trucks matched with trailers with the systems installed. The results of the test showed a 1.5% improvement in fuel consumption for trucks with ATIS.

Tire Inflation with Nitrogen

Nitrogen is said to permeate tire walls up to four times slower than air. Tires will lose one to two psi over one month versus the six months it takes a nitrogen-filled tire to lose that same amount of pressure. As a result, the time spent adjusting the tire pressure is reduced.

Supporters of nitrogen for tire inflation claim better tire pressure retention. This is believed to result in:

- A smoother ride
- Improved steering and braking
- Reduced risk of blowouts by as much as 50 percent[94]
- Increased tires tread life by up to 30 percent, improving the tire's life and its grip to the road[95]
- Reduced fuel consumption by up to 6%[96]

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93 Source: https://nacfe.org
94 Source: http://www.gonitrotire.com
95 Source: http://www.gonitrotire.com
96 The fuel consumption reduction estimates vary considerably. Enviro-fleets, A guide to helpful resources, June 2010, report an improvement of up to 10%, but the industry standard is between 3% and 6%.

It must be noted that it is not the nitrogen itself that improves the fuel efficiency, but rather the enhanced retention of inflation pressure over time[97]. Reduced tire pressure leads to increased fuel consumption. Therefore, if vehicle tire pressure is well monitored, there might not be a fuel consumption benefit of using nitrogen.

Idling Reduction

Idling reduction is an important concern for all leading fleets that are looking to optimize costs and reduce the environmental impact. Municipal fleet vehicles left idling for no apparent reason are seen by the public as being wasteful and polluting. These negative messages are potentially damaging to the reputation of any municipality.

Fuel consumption from idling of heavy-duty vehicles is significant. While we acknowledge there are times when idling is simply unavoidable, the U.S. Department of Energy estimates that unnecessarily idling heavy-duty vehicles wastes from half to one U.S. gallon (1.89 to 3.79 liters) or more per hour. Some fleets idle 30 to 50% or more of their operating time[98]. These are several main approaches to idling reduction, including:

- Idling-reduction policy
- Driver training and motivation
- Idling-reduction awareness and fact-based training
- Incentive programs
- Ongoing driver education
- The use of idling reduction devices, including:
    - Auxiliary power units (APU)
    - Stop/start devices
    - Auxiliary cab heaters
    - Battery backup systems
    - Block heaters / engine preheaters

Idling-Reduction Policy

An idling-reduction policy is a way to motivate fleet drivers to limit unnecessary idling. However, for an idling-reduction policy to be successful continuous enforcement such as spot-checks and fuel use tracking must be present. An idling-reduction policy could be used as an overarching commitment to idling reduction that is carried out though driver training and motivation sessions, rather than an initiative on its own.

[97] Source: NHTSA Report, 2009: https://one.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/.../2009/811094.pdf
[98] Source: FC Best Practices Manual 2008

When Engine Idling is Unavoidable

There are times when idling is unavoidable. These include:

- Cab heating/ventilation and air conditioning (HVAC)
- Power for critical equipment (such as the use of a PTO for ancillary equipment)
- Maintaining brake air pressure (MD and HD trucks)

It is important to differentiate between *unnecessary* idling and idling that is *unavoidable* due to operational requirements. The focus of all idling-reduction initiatives should be to reduce and, ideally, eliminate *unnecessary* idling and to explore alternatives of how to limit idling for operational purposes with solutions that do not impede with operations, but offer environmental and economic benefits.

Idling Reduction Devices

There are several idling-reduction technologies available that can aid in idle reduction. Their functionality, potential, and costs vary considerably and are described in *Table 13.* To reap the most benefits any idling-reduction technology, installation should always be accompanied by behavioural solutions of driver training and motivation.

Table 13: Idling Reduction Devices and Their Associated Costs

Technology	Description	Cost Estimates
Auxiliary Power Units (APU)	An APU consists of a small engine that provides power to heat and cool the cab, as well as to power accessories, heat the engine, and charge the start battery. DC-powered APU systems are also available.	APUs can cost anywhere from ~$8,500 to ~$10,000. Annual maintenance cost is estimated as high as $500.
Stop/Start Devices (Idle-Stop systems)	A stop/start system automatically shuts down and restarts the internal combustion engine to reduce the amount of time the engine spends idling. This technology is particularly useful for vehicles that spend significant amounts of time waiting at traffic lights or frequently come to a stop in traffic jams.	Stop/start devices typically are part of OEM hybrid vehicle systems, but more recently has also been introduced in regular combustion engine vehicles to reduce fuel consumption. Such devices can also be purchased separately (offered by companies like Bosch that also manufacturers OEM devices) and their costs average at about $300-$350.

Technology	Description	Cost Estimates
Auxiliary Cab Heaters	There are two types: 2) Gas- or diesel-fired auxiliary air heater: In most cases, it is fitted in the cab, drawing in cab air through a blower and heating it. 2) Gas- or diesel-fired auxiliary coolant heater: It is installed in a vehicle's engine compartment and enables the vehicle's own coolant circuit to work without the use of the entire engine. Such water-based auxiliary heaters use small amounts of fuel to heat up the liquid in the air-exchange system and provide warm air in the cabin. Compared to air-based auxiliary heaters, the advantage of water-based auxiliary heaters is that they also warm the engine in the process (similarly to block heaters), thus enhancing starting performance. Auxiliary coolant heaters are manufactured by companies like Webasto and Espar.	~$1,250 +
Battery Backup Systems	A battery backup system powers electric devices (emergency lights, etc.) without drawing power from the primary battery. The system consists of adding an isolator and an additional battery to a vehicle's electric system. When the vehicle is off, the isolator prevents power being drawn from the primary battery and instead uses the alternate battery to power any electronic systems. When the vehicle is running, both batteries are recharged; charging to the start battery is prioritized and it is charged first.	The system costs between $400-$600 plus the price of a battery which varies based on the required capacity.
Block Heater / Engine Preheater	Engine block heaters use power from electrical outlets in corporate facilities, where vehicles are parked overnight to heat the engine block. The block heater on timer can be set to switch-on a few hours	Block heaters cost between $70 and $150 and have a negligible annual maintenance cost.

Technology	Description	Cost Estimates
	before the vehicle is used to warm up the engine block. This decreases required warm-up idling time. This is a very low-cost option, and a necessity in Canadian winters; however, it is limited to reducing warm-up idling only.	

Emissions Reduction Potential

Despite the wide selection of idling reduction solutions, when it comes to internal combustion engines, there is no technology that completely eliminates CO_2 and other emissions. Only battery-electric and hydrogen fuel cell vehicle technologies can eliminate tailpipe emissions. Idling-reduction initiatives can be helpful in reducing unnecessary idling in the short and medium term, and as a segue to gradual transition to electric trucks and, potentially, hydrogen fuel cells in the long-run.

Driver Training and Motivation

Idling-Reduction Training and Incentives

Driver training to modify driver behaviours and ongoing motivation to continue good behaviours are crucial components of successful idling-reduction programs. While most drivers understand the vehicle idling issue, many continue their inefficient practice of excessive idling due to lack of knowledge and/or motivation.

Driver training can be used to optimize the use of idle reduction technologies. The technologies can reduce idling but the drivers have the ability to override the technologies. Proper training can aid in utilizing the technologies to their full potential.

In addition to establishing corporate idling reduction policies, behaviour-based approaches for idling reduction include:

- Idling-reduction training for drivers; and
- Incentive programs to encourage drivers to limit idling.

For best results, these approaches should be used in conjunction. Regardless of the approach, the greatest impact pledges of idling-reduction should be made in a public forum. Moreover, idling-reduction targets should be customized as various fleet vehicles may have different operating requirements and will benefit from targets that accurately reflect their work environment. Beginning from a measured starting point, progress should be evaluated at regular intervals to modify and adapt the approach if progress is not occurring.

Driver Eco-Training

Driver eco-training should be fact-based and aimed at increased awareness and promotion of good practices. Typically, eco-training courses address the following areas:

- Progressive shifting (or use of automated transmissions)
- Starting out in a gear that doesn't require using the throttle when releasing the clutch
- Shifting up at very low RPM
- Block shifting where possible (e.g., shifting from third to fifth gear)
- Maintaining a steady speed while driving
- Using cruise control where appropriate
- Anticipating traffic flow
- Coasting where possible
- Braking and accelerating smoothly and gradually
- Avoiding unnecessary idling

Driver eco-training programs vary considerably. They can be organized as short (typically an hour long) information sessions/workshops or can be considerably longer and involve more hands-on activities. Extended training can vary in length from a half to a full day, or can also be scheduled into shorter sessions over a period of time.

Online Training

Online training courses are gaining popularity thanks to their flexibility. This trend has accelerated due to the Covid-19 pandemic and the need for social distancing measures. It is strongly recommended that discussion sessions among the drivers be organized to review training topics to deepen their understanding and provide a forum for questions and concerns. The individual responsible for the idling reduction incentives program could facilitate such sessions.

In-Person Training

In-person driver eco-training courses vary greatly in length, depth, and format. These courses offer a more personalized approach, facilitate immediate discussion, and typically allow for practical application. For best results, eco-training could be combined with professional driver improvement training.

NRCan SmartDriver Training Series

SmartDriver provides free, practical training to help Canada's commercial and institutional fleets lower their fuel consumption, operating costs, and harmful vehicle emissions. Fleet energy-management training that helps truckers, transit operators, school bus driver, and other professional drivers is claimed by NRCan to improve fuel efficiency by up to 35 percent. RSI-FC highly recommends NRCan's SmartDriver training: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/greening-freight-programs/smartdriver-training-series/21048

Continuous Motivation

Studies have demonstrated that driver training benefits, although significant, are likely to diminish over time. Ongoing feedback and motivation is recommended as a preventive measure. This can include:

(1) Tracking Idling to Provide Feedback to Drivers

- Monitoring the progress of any initiative is crucial not only to determine the impact, but to also provide feedback to the drivers to provide them the opportunity to modify their behaviour.
- Practices that track and report fuel consumption establish a valuable monitoring basis. Knowledge and comprehensive factual information can help build a stronger business case and "buy-in" for idling reduction.
- Telematics technologies help managers and drivers track idling and provide measurable data to manage goals. Such technologies, however, can be expensive as they typically use GPS systems and OBD monitoring devices.

(2) Implementing a Corporate Idling Reduction Policy

- It is our opinion that in most cases drivers want to "do the right things." By ramping up communications about excessive idling and instituting a clear idling policy, a reduction of unnecessary idling will likely result.

(3) Ongoing Information Campaigns and Reminders

- In general, information campaigns are low-cost, easy to manage, and lead to a more knowledgeable and receptive public. To raise awareness of the issues these can be initiated even before driver training commences. Numerous resources that address idling awareness issues are available free of charge and ready to implement.

(4) Non-Monetary Incentives Programs

- There are a few approaches that can aid in motivating drivers to continue to apply the skills gained during eco-training. Competition among departments/teams to reduce idling can be an effective approach. Periodic recognition of high-performers can be either public or private. An example of a non-monetary reward might be the donation to a charity in the amount of the lowest idling department's fuel cost savings.

Summary and Potential Impact

Driver training is an initiative that attempts to change an individual's behaviour and thus the results are hard to predict and the variance is large. A multitude of aspects, such as the current level of driver education and driving practices, the level of idling, corporate culture and policy, and individual receptiveness and willingness to change will influence results. It is estimated that driver training has a potential to reduce vehicle fuel consumption by anywhere from 3% to 35%, with the typical results between 5% and 10%.

Route Planning and Optimization

In addition to vehicle upgrades, proper maintenance, driver training, and continuous motivation to maintain good driving habits, a fleet can further minimize fuel consumption and exhaust emissions through route planning and optimization. Route planning software can be used optimize multi-stop trips. There are different software available for categories in both public and private fleets (e.g., service dispatch software, courier software, trucking software, etc.) [99].

Route planning software used for delivery services ensures the minimum driving time for multi-stop trips by using advanced algorithms to arrive at the optimal route that provides the highest collective reduction in total driving time and, consequently, fuel consumption. This can also mean fewer vehicles and less traffic on the road at one time.[100]

Route planning software can also be used for idling reduction initiatives by integrating GPS tracking software to monitor driver activity in real-time. Moreover, reporting and analytics features within route planning software can help with identifying when a fleet vehicle requires maintenance to ensure optimal fuel efficiency and thus minimize cost and emissions.[101]

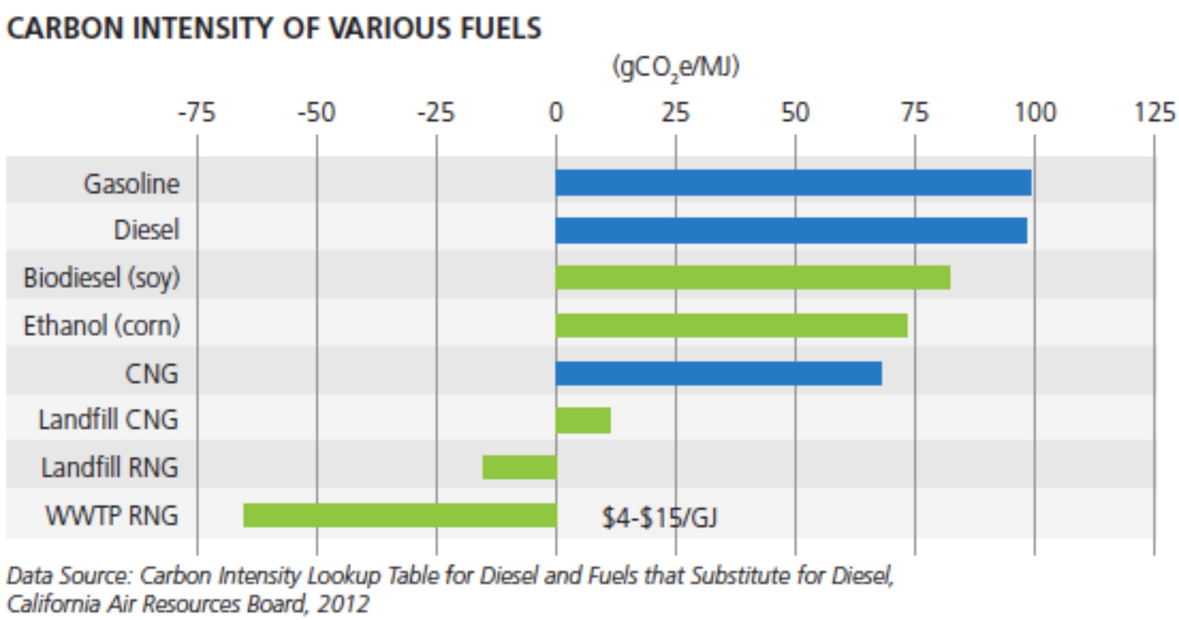
[99] Source: https://www.capterra.com/route-planning-software/
[100] Source: https://blog.route4me.com/2020/05/carbon-emissions-reduction-route-optimization-helps-cut-tons-carbon-emissions/
[101] Source: https://blog.route4me.com/2020/05/carbon-emissions-reduction-route-optimization-helps-cut-tons-carbon-emissions/

Low-Carbon Fuel Switching

Of all current-day fuel-reduction solutions, fuel switching is often the most expedient way to reduce emissions in the short term. As awareness of climate change issues amplify, the use of low-carbon fuels is gaining increased domestic and global interest. Fuel switching is a process of diverting a fleet's fuel consumption away from traditional fossil-based sources to either alternate or renewable energy sources.

Figure 9 shows the carbon intensity of various fuels relative to baselines for traditional fossil gasoline and diesel.

Figure 9: Carbon Intensity of Various Fuels

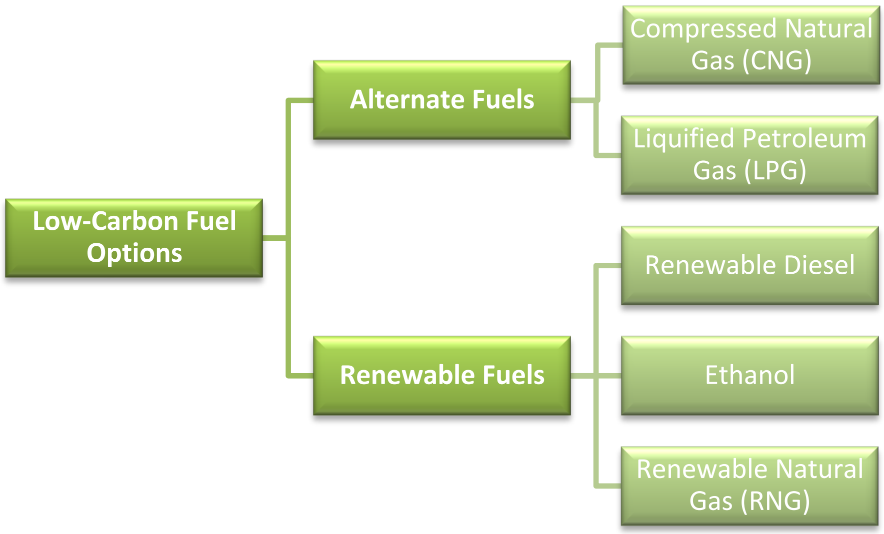


No Pain, No Gain!

Unfortunately, regardless of which fuel-switching options are selected, the reality is that each will require some degree of effort to implement. For example, although transit buses are capable of using biodiesel and/or renewable diesel, obtaining the fuels would likely bring new operational challenges such as switching bulk suppliers and/or requiring extra efforts from vehicle drivers to attend different retail fuel stations instead of those they are accustomed to frequenting. Adding B10 biodiesel to the in-house fuelling supply system will require minor modifications, extra work routines, and procedures for staff to follow.

Figure 10 provides an overview of the low-carbon fuel alternatives now available to reduce a fleet's fuel consumption and GHG emissions.

Figure 10: Low-Carbon Fuel Options



An alternate route to changing the fuel used to power an internal combustion engine is to introduce a complete change such as battery-electric or hydrogen fuel cell vehicles. Some jurisdictions have already legislated elimination of the internal combustion engine in coming years. How successful that will be remains to be seen, but in response to the need to and regulation supporting the transition away from fossil fuels, zero-emission electric and fuel cell trucks are already planned for production. These technologies will be explained in later sections of this Appendix. First, we will explore low-carbon fuel options, also known as the "messy middle."

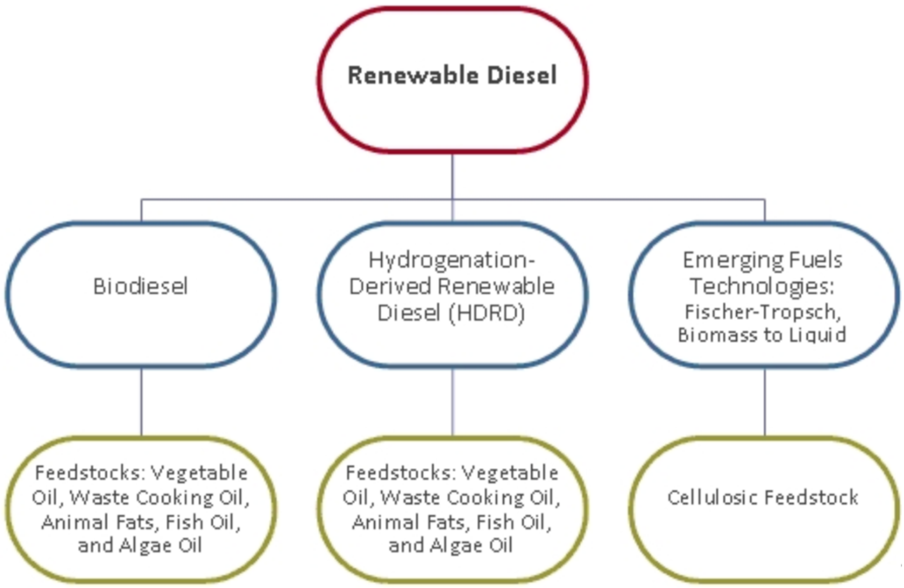
Renewable Diesel

Renewable diesel is a fossil diesel fuel substitute currently made from plant and animal oils and fats as well as from cellulosic feedstock consisting of agriculture and forest biomass[102]."

There are two main renewable diesels – biodiesel and hydrogenation-derived renewable diesel (HDRD), explained below – and other technologies to convert biomass into renewable diesel are being developed (outlined in *Figure 11)*[103]. All diesel fuel sold in Canada contains a percentage of renewable diesel owing to a renewable fuels standard.

[102] Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669
[103] Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669

Figure 11: Renewable Diesel Types and Feedstocks



Biodiesel Overview

Biodiesel is a renewable fuel made from vegetable oil and waste cooking oil, animal fats such as beef tallow and fish oil, and even algae oil[104]. In technical terms, biodiesel is a vegetable oil- or animal fat-based diesel fuel consisting of long-chain alkyl (methyl, ethyl, or propyl) esters made by chemically reacting lipids (e.g., vegetable oil, soybean oil, animal fat) with alcohol-producing fatty acid esters. Biodiesel is often referred to as fatty acid methyl ester or FAME[105].

Biodiesel can be blended in a variety of ratios with conventional fossil diesel. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix (e.g., B2 indicates 2% biodiesel and 98% fossil diesel). Biodiesel blends include: B2, B5, B10, B20, blends greater than B20, and B100 (100% biodiesel, also known as "neat" biodiesel).[106]

Canadian regulations require fuel producers and importers to have an average renewable fuel content of at least 2% based on the volume of diesel fuel and heating distillate oil that they produce or import into Canada. The regulations include provisions that govern the creation of compliance

[104] Source: https://www.nrcan.gc.ca/energy/alternative-fuels/resources/nrddi/3669
[105] Source: https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any
[106] Source: https://www3.epa.gov/region9/waste/biodiesel/questions.html

units, allow trading of these units among participants and also require record-keeping and reporting to ensure compliance[107].

Blends of 20% biodiesel and lower can be used in diesel equipment with no or only minor modifications, although certain manufacturers do not extend warranty coverage if equipment is damaged by poor quality fuel in these blends.

Biodiesel used in its pure form (B100) may require certain engine modifications to avoid maintenance and performance problems. A new system recently emerged involving the use of a heated fuel storage tank in which the engine starts on standard diesel, and then after warm-up of the fuel tank, switches over to B100. The system is said to allow the use of B100 year-round in cold, winter conditions.

Hydrogenation-Derived Renewable Diesel vs Traditional Biodiesel

Hydrogenation-derived renewable diesel (HDRD) is made from animal fats or vegetable oils – alone or blended with petroleum – refined by a process called hydro treating. HDRD and traditional biodiesel (also known as fatty acid methyl ester or FAME, as stated earlier) are often confused; however, they are distinctly different products, even though both are made from organic biomasses. The differences can be found in their production process, cleanliness, and quality.

Unlike biodiesel, HDRD is made primarily from waste and residues and impurities are removed during the hydro treating process at a high temperature[108]. The outcome is a colorless and odorless fuel of an even quality that has an identical chemical composition to fossil diesel. It is also often called an "advanced biofuel" or "second-generation biofuel."

Traditional, first-generation FAME-type biodiesel, on the other hand, is produced by esterifying vegetable oils or fats. The esterification process restricts the use of poor quality or impure raw materials, such as waste and residues. The quality of traditional biodiesel also varies in other respects based on the raw materials used.

HDRD is cleaner and has a lower carbon footprint than petroleum-based diesel, and it can also operate at colder temperatures than fossil diesel and biodiesel. Therefore, HDRD can be used in higher concentrations than biodiesel and even as a standalone product in diesel engines. However, it generally cost significantly more than traditional biodiesel; biodiesel has been on average 60% cheaper than HDRD from 2010-2017[109].

[107] Source: https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/renewable.html
[108] Source: https://www.neste.com/what-difference-between-renewable-diesel-and-traditional-biodiesel-if-any
[109] Source: https://www.naviusresearch.com/wp-content/uploads/2019/05/Biofuels-in-Canada-2019-2019-04-25-final.pdf

Biodiesel At a Glance

Table 14: Strengths and Weaknesses of Biodiesel

Strengths	Weaknesses
1. Safe and non-toxic 2. Proven, mature technology in North America and Europe 3. No conversion costs to vehicles 4. Minor costs to convert fuelling infrastructure (tanks and pumps) 5. Warranty approved by most engine manufacturers[110,111,112] 6. Increases lubricity and therefore is known to extend engine life (Note: Today's ultra-low sulfur diesel suffers from reduced lubricity and biodiesel is commonly used to counteract this issue.) 7. Can reduce GHG emissions, depending on blend used and source of biodiesel	1. Although production is abundant, there are a limited number of vendors and distributors; locating vendors/suppliers may be challenging 2. Viscosity issues related to the higher-blends (B5 or higher) in cold weather conditions that require special attention 3. Possible perception that "food" production is sacrificed for fuel production 4. Potential of higher fuel cost, depending on blend and market conditions (Note: Prior to the recent market situation for oil, B20-B50 was approximately the same price or less than fossil diesel.) 5. Marginal level of reduced energy efficiency, which varies from 1% in the case of B20 reaching 7.5% in the case of B100

Biodiesel Emissions Reduction Potential

Tailpipe GHG emissions reductions are dependent on the biodiesel blend used; for a given unit mass or volume, the higher the blend, the lower the GHG emissions. B20, in particular, reduces CO_2 by 15% in comparison to conventional diesel per unit mass/volume[113]. However, actual tailpipe emissions reduction potential for the same distance travelled is dependent on both GHG emissions per unit mass/volume and fuel economy. The energy content of pure biodiesel (B100) is close to 8% lower than pure diesel[114]. Taking into account this energy loss, using blends ranging from B5 to B20,

[110] Source: www.neste.com. Neste is a producer of renewable diesel. The company describes itself as the global leader in the renewable diesel market and wants to develop significant business from non-traffic renewable product markets by the end of the decade.
[111] Source: http://biodiesel.org/using-biodiesel/oem-information
[112] Source: https://www.afdc.energy.gov/fuels/biodiesel_blends.html
[113] Source: https://www.fueleconomy.gov/feg/biodiesel.shtml
[114] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.

the latter of which may be restricted to summer due to gelling in cold weather, requires slightly more fuel than pure diesel and lowers tailpipe GHG emissions by an estimated 10 percent as a whole. Using biodiesel can also reduce several other tailpipe emissions including particulates and unburned hydrocarbons[115]. Moreover, the lifecycle CO_2 emissions can be significantly lower for biodiesel than for conventional diesel[116].

Biodiesel – Ease of Implementation

There are no vehicle conversion or infrastructure costs associated with biodiesel use. Therefore, either biodiesel or HDRD could be immediately introduced without delay to begin reducing emissions for a fleet following research into the optimal blends for operational needs and cold-weather considerations.

Biodiesel Production in Canada

In 2016, Canadian biodiesel production increased due to new production capacity coming on-line. Canada's biodiesel production was estimated to reach 400 million liters in 2016 and forecast to reach 550 million liters in 2017, but is still below the level needed to meet the federal mandate. The balance will continue to be met by imports.

Primary feedstocks remain canola, animal fat, and recycled oils. Canola feedstock was expected to account for nearly 29 percent of Canadian biodiesel production by the end of 2016 and in 2017. Cooking oil was forecast to account for 49 percent of the feedstock in 2016 and 46 percent in 2017. Soybean oil was expected to increase to 20 percent by 2017.

Biodiesel Gelling

Biodiesel is essentially oil; therefore, it solidifies in cold temperatures (commonly referred to as gelling). If the fuel begins to gel, it can clog engine filters and eventually thicken enough to prevent flow from the fuel tank to the engine. The temperature at which crystals begin to form is called the cloud point. The cloud point varies considerably from one biodiesel source to another. Due to Canadian climate conditions, the flow properties of biodiesel are an important consideration. It must be noted that even petroleum diesel can gel, thus additives are often used during wintertime as a preventative. In the case of biodiesel blends, such additives can aid in reducing the cloud point during winter months.

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[115] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/biodiesel/3509
[116] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/biodiesel/3509

According to the U.S. Department of Energy, the temperature at which B100 starts to gel will vary with the feedstock and can range from 0°C to 15°C. Soy is the most common source of biodiesel, and has a cloud point of 0°C.

Biodiesel blending aids in reducing the cloud point temperature, as conventional diesel has a considerably lower cloud point temperature. The goal for users is to ensure that the fuel's cloud point temperature is appropriate for weather conditions. The U.S. Department of Energy sought to obtain a biodiesel blend with cloud point safe for use in cold weather. They used a specially formulated cold weather conventional diesel fuel that has a cloud point of -38°C. This diesel was mixed with soy biodiesel to make a B20 blend. As a result, the cloud point of that B20 blend was -20°C. [117]

Generally speaking, keeping the biodiesel and diesel fuel to a lower blend (e.g., B10) will have better cold weather operability properties than a higher blend (e.g., B20 +).

Operational Considerations when Choosing Higher Biodiesel Blends

To minimize risk, a higher blend (B20 or higher, depending on the cloud point of a particular biodiesel) could be used in the warmest months of the year and B5 could be used during the rest of the year. Many Canadian and U.S. fleets using biodiesel follow this practice.

To maximize the overall impact of the biodiesel's usefulness in reducing GHGs it is recommended that the highest possible biodiesel blend be used during the summer months. For example, if diesel consumption remains relatively constant month-to-month, then using B20 during cold months (winter) and shoulder seasons (some of spring and fall) and B5 the rest of the year may be approximately equal to using an average annual blend of B10. However, for deeper emissions reduction, if B60 were used from June to August, and B5 during colder months, the yearly average equivalent would increase to B18.75.

Future Technologies to Support B100 Use

Emerging technologies are looking to address the cloud point issues via fuel heating systems. One such provider is *Optimus Technologies*[118] that offers heated fuel system solutions. This could prove to be a cost-effective way to use pure B100 biodiesel to maximize emissions reduction potential.

Given that these technologies are relatively new and results of further testing in real-world applications are limited, as well as the associated risks involved, RSI-FC does not recommend considering this solution for widespread implementation at this time. Nevertheless, a fleet should

[117] Source: https://www.afdc.energy.gov/uploads/publication/biodiesel_handling_use_guide.pdf
[118] Source: https://www.optimustec.com

periodically evaluate this and other technological advancements for potential application, with an openness to pilot-testing any technologies under review.

ASTM Standards

The American Society for Testing and Materials (ASTM) sets out standards for biodiesel, diesel, and heating oil. Four ASTM standards have relevance to consumer use of biodiesel and biodiesel blends, which are[119]:

ASTM D6751 - Biodiesel Blend Stock Specification B100
ASTM D975 - Diesel Fuel Specification
ASTM D7467 - 17 Standard Specification for Diesel Fuel Oil, Biodiesel Blend (B6 to B20)
ASTM D6468 - Standard Test Method for High Temperature Stability of Middle Distillate

Most commonly, manufacturers that support B20 usage will require the biodiesel to conform to ASTM specifications. B100 must conform to ASTM D6751 prior to blending, and the finished B20 blend must conform to ASTM D7467. Any product marketed as biodiesel must meet the standard set by the ASTM D6751.

BQ9000

Customers should purchase the biodiesel blend from a BQ9000 Certified Marketer. The B100 fuel used in the blend should be sourced from a BQ9000 Accredited Producer. BQ9000 Certified Marketers and Accredited Producers can be found at www.bq-9000.org.

Biodiesel fuel should meet ASTM D6751 or ASTM D7467 standards and fuel should be used within 6 months of production.

Storage and Handling

Biodiesel fuels have shown poor oxidation stability, which can result in long-term storage problems. When biodiesel fuels are used at low ambient temperatures, filters may plug and the fuel in the tank may thicken to the point where it will not flow sufficiently for proper engine operation. Therefore, it may be prudent to store biodiesel fuel in a heated building or storage tank, as well as heat the fuel system's fuel lines, filters, and tanks.

Additives also may be needed to improve storage conditions and allow for the use of biodiesel fuel in a wider range of ambient temperatures. To demonstrate their stability under normal storage and use conditions, biodiesel fuels tested using ASTM D6468 should have a minimum of 80% reflectance after

[119] Source: Fleet Challenge publication – Fleet Managers Comprehensive Guide to Use and Storage of Biodiesel

aging for 180 minutes at a temperature of 150°C. The test is intended to predict the resistance of fuel to degradation at normal engine operating temperatures and provides an indication of overall fuel stability.

Biodiesel fuel is an excellent medium for microbial growth. Since water accelerates microbial growth and is naturally more prevalent in biodiesel fuels than in petroleum-based diesel fuels, care must be taken to remove water from fuel tanks. The effectiveness of using conventional anti-microbial additives in biodiesel is unknown. The presence of microbes may cause operational problems, fuel system corrosion, premature filter plugging, and sediment build-up in fuel systems.

Health and Safety

Pure biodiesel fuels have been tested and found to be nontoxic in animal studies. Emissions from engines using biodiesel fuel have undergone health effects testing in accordance with EPA Tier II requirements for fuel and fuel additive registration.

Tier II test results indicate no biologically significant short-term effects on the animals studied other than minor effects on lung tissue at high exposure levels. Biodiesel fuels are biodegradable, which may promote their use in applications where biodegradability is desired (e.g., marine or farm applications). Biodiesel is as safe in handling and storage as petroleum-based diesel fuel.

Vehicle Warranties

Back in 2003, the Engine Manufacturers Association issued a technical statement indicating biodiesel use up to B5 should not cause engine or fuel systems problems[120]. Most North American engine manufacturers now offer full support using biodiesel blends up to a B20 with no vehicle modifications required[121].

Heavy-Duty Vehicle Warranties

Detroit Diesel, Caterpillar, Volvo and Cummins are the big four manufacturers of HD truck diesels. They all support the use of B20 in most of their modern engines. Older engines were produced with rubber which is eroded by biodiesel, instead of Viton injections system seals. In general, most modern engines are suited for biodiesel of up to 20% and ASTM standard biodiesel is required (almost all commercially produced biodiesel is ASTM standard).

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[120] http://www.truckandenginemanufacturers.org/file.asp?A=Y&F=7036%2Epdf&N=7036%2Epdf&C=documents

[121] http://biodiesel.org/news/news-display/2017/01/17/automakers-fuel-the-u.s.-market-with-more-biodiesel-capable-diesel-vehicle-models

Renewable Diesel Summary

Should supply be readily available, and the price point competitive with fossil diesel, renewable diesel may have good potential for a fleet due to the following:

- Implementation is straightforward and can be done without significant change management.
- No vehicle modifications are required.
- Minimal to no price increase for biodiesel, and possibly a decrease in price depending on prevailing market conditions as compared to conventional diesel fuel.
- Biodiesel blends higher than B2 and lower than B20 may provide substantially better fuel economy than conventional biodiesel, B2, and B100, thereby reducing fuel cost and CO_2 emissions.

Ethanol

Ethanol is a renewable fuel made from various plant materials known as biomass or feedstocks. Corn and wheat are most commonly used to produce ethanol. In most North American jurisdictions, renewable fuel standards require all gasoline sold to be a 5-10% ethanol blend (E5-10). Ethanol burns cleaner and more completely than gasoline or diesel fuel; blending ethanol with gasoline increases oxygen content in the fuel, thereby reducing air pollution[122].

A higher blend of ethanol, known as E85 (85% ethanol, 15% gas), is available in some areas and can lead to significant GHG reductions. The 15% gasoline is needed to assist in engine starting because pure ethanol is difficult to ignite in cold weather[123]. This fuel must be used in dedicated “flex-fuel” vehicles (FFVs), which can run on any combination of gasoline and ethanol blends (up to 85%). However, in some jurisdictions, it may be challenging to find a local supplier of E85 as it is only available through specialized providers.

Production of Ethanol

In chemical terms, ethanol production involves the fermentation of sugars or starches contained in grains or other feedstocks. Ethanol fuel is then distilled and dehydrated to create a high-octane, water-free alcohol[124].

[122] Source: https://afdc.energy.gov/fuels/ethanol_fuel_basics.html
[123] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[124] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493

Several steps are involved in making ethanol available as a vehicle fuel. First, biomass feedstocks are grown, collected, and transported to an ethanol production facility. Then, ethanol is made from these feedstocks at the production facility along with by-products such as animal feed and corn oil. Next, the fuel is transported to a blender/fuel supplier. Finally, ethanol is mixed with gasoline by the blender/fuel supplier at the desired blend (up to 85%) and distributed by truck to fueling stations.[125]

Feedstock Sources and Environmental Considerations

Corn and wheat are the most common feedstocks used to produce ethanol, requiring arable land to be grown. As a result, there are environmental considerations, including:

- Using food crops to produce fuel (i.e., the perception of food used as fuel)
- Using arable land to produce fuel reduces the available land to produce food, which potentially leads to increased food prices
- Use of fertilizers and pesticides to grow food-grade crops
- Upstream lifecycle emissions associated with land use, fertilizer production, crop growth, crop harvesting, crop transportation, and ethanol production

As biofuel technologies develop, the focus is turning towards feedstocks that take up less space and land, require less fertilizer and pesticide, and are more energy efficient. These include "cellulosic" feedstock or energy crops, namely tall grasses like switchgrass and miscanthus as well as fast-growing trees like hybrid poplar and willow. Energy crops are attractive because they produce energy efficiently, require only modest amounts of fertilizer and pesticides, and require less fertile soil than is needed for other crops. Technologies are also currently being developed to produce ethanol from wood and algae. It is expected that non-edible plant materials will become sources of ethanol in the future. Cellulosic materials cannot be used as food, so concerns for food production and pricing issues, as is the case with corn and wheat, would be avoided.

Emissions Reduction Potential

Emissions reductions from using ethanol as fuel instead of pure gasoline varies according to biomass used and percentage blend. Although the production and burning of ethanol produce emissions, the absorption of carbon dioxide from the growing of feedstocks can result in the net effect being a large

[125] Source: https://afdc.energy.gov/fuels/ethanol_fuel_basics.html

reduction of GHG emissions compared to fossil fuels such as gasoline. The higher the ethanol blend, the greater the GHG reductions. [126]

In terms of lifecycle GHG emissions, E10 made from corn produces 3-4% less GHG emissions compared to gasoline, and E10 made from wood or agricultural cellulosic materials produces 6-8% less emissions compared to gasoline[127]. Corn-based E85 is estimated to reduce lifecycle GHG emissions by 25-50% compared to gasoline[128]. If cellulosic feedstocks are used, ethanol can have lifecycle GHG emissions reductions ranging from 88 – 108% compared to refined petroleum, meaning that potentially more carbon dioxide is captured when the feedstock crops are grown than released by a vehicle when ethanol is burned[129].

In terms of tailpipe emissions, E85 has a GHG emissions reduction potential of about 30% when compared to the same volume of gasoline[130]. However, E85 contains about 29% less energy than gasoline per unit volume[131]. Given this energy loss, about 42% more E85 is required to achieve the same amount of work as gasoline. After accounting for the increase in volume to achieve the same work, using "net vehicle operation" emissions factors from GHGenius Version 5.01a still results in an overall operative GHG emissions reduction of over 80% (i.e., the carbon that is sequestered through the biomass growth nearly completely offsets carbon output from combustion).

Ethanol Cost

Given the significant energy losses per unit volume as compared to gasoline, the cheaper cost of E85 per unit volume compared to gasoline does not always offset the higher volume required to achieve the same distance travelled, potentially making E85 more expensive than gasoline. Based on October 2020 fuel prices, and accounting for energy equivalence (i.e., same distance travelled), E85 is slightly less expensive than gasoline[132].

Flex-Fuel Vehicles

E85 cannot be used in a conventional, gasoline-only engine. Vehicles must be specially designed to run on E85. These flex-fuel vehicles can run on E85, gasoline, or any blend of the two. These vehicles feature specially designed fuel systems and other components that allow a vehicle to operate on a

[126] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[127] Source: https://www.nrcan.gc.ca/energy-efficiency/energy-efficiency-transportation/alternative-fuels/biofuels/ethanol/3493
[128] Source: https://www.tandfonline.com/doi/pdf/10.3155/1047-3289.59.8.912
[129] Source: https://afdc.energy.gov/fuels/ethanol_benefits.html
[130] Source: http://www.patagoniaalliance.org/wp-content/uploads/2014/08/How-much-carbon-dioxide-is-produced-by-burning-gasoline-and-diesel-fuel-FAQ-U.S.-Energy-Information-Administration-EIA.pdf
[131] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.
[132] https://afdc.energy.gov/fuels/prices.html

mixture of gasoline and ethanol, with mixtures varying from 0 percent to 85% ethanol. Also, given that ethanol is not as energy-efficient as gasoline and thus more fuel is required, the fuel tank in a flex-fuel vehicle must be larger than a conventional vehicle. These cars and trucks have the same power, acceleration, payload, and cruise speed as conventionally fueled vehicles and are priced similarly to gasoline-only vehicles.

Ethanol Supply and Storage

E85 is available at some retail fuel stations and can also potentially be delivered direct-to-vehicle. Alternatively, it could be stored and dispensed in bulk from an onsite fuel station. Ethanol tanks require a water monitoring system. In addition, a 10-micron filter, signage, and other upgrades are required to ensure the system is compliant.

Ethanol Summary

E85 has an excellent emissions reduction potential for a fleet, particularly when the fleet is already E85 capable (i.e., has flex-fuel vehicles). If electric vehicles are not a viable option, new light-duty vehicles purchases should be flex-fuel capable to further enhance the GHG reduction potential for a fleet.

The implementation of E85 vehicles can be expedient if there are only minimal costs and effort required to prepare the infrastructure for E85 storage. In addition, the availability of E85 supply in a particular jurisdiction must be confirmed to proceed with this alternative fuel option. The downfall is that there are significant energy losses per unit volume as compared to gasoline, which may make E85 more expensive because more is required to achieve the same distance travelled.

Natural Gas

Natural gas (NG), a fossil fuel composed of mostly methane, is one of the cleanest burning alternative fuels. It is also thought to be safer than traditional fuels since, in the event of a spill, NG is lighter than air and thus disperses quickly when released. NG can be used in the form of compressed natural gas (CNG) or liquefied natural gas (LNG) to fuel cars and trucks. Vehicles that use NG in either form are called natural gas vehicles (or NGVs).

NG is found in abundance in porous rock formations and above oil deposits. After NG is extracted from the ground, it is processed to remove impurities and compressed to be stored and transported by pipeline. CNG is used in traditional gasoline internal combustion engine vehicles that have been modified, or in vehicles which were manufactured for CNG use, either alone (dedicated), with a segregated gasoline system to extend range (dual-fuel), or in conjunction with another fuel such as diesel (bi-fuel). CNG is most commonly used in fleet vehicles like buses and heavy-duty trucks because it requires a larger fuel tank than gasoline and diesel fuel[133].

In Canada, business case modelling[134] demonstrated that the use of natural gas (NG) by medium and heavy-duty truck applications provides substantial economic and environmental benefits. The cost and placement of fuel storage tanks is the major barrier to wider and quicker adoption of CNG as a fuel. However, CNG offers many advantages for fleets, and although there are major upfront capital costs ($1m or far more), savings may ensue.

According to the Canadian Urban Transit Association (CUTA) more Canadian cities are transitioning their public transportation fleets away from diesel-powered buses and opting for transit vehicles fueled by NG[135], a trend that is gaining momentum across North America and worldwide. This is due in part to government regulations that mandate a reduction in nitrogen oxide and greenhouse gas emissions that harm air quality, as well as a heightened sense of awareness about the health threats caused by local and toxic diesel particulate emissions.

CNG at a Glance

Table 15: Strengths and Weaknesses of CNG

Strengths	Weaknesses
1. Lower fuel cost than gasoline or diesel on an energy-equivalent basis 2. Can be used in heavy-duty truck applications 3. A CNG-powered vehicle gets approximately the same fuel economy as a conventional gasoline vehicle on a diesel-gallon-equivalent basis 4. Potentially reduces GHG emissions by more than 20% compared to a diesel vehicle[136,137] 5. Lower CACs compared to other fuels 6. Low safety risk	1. Vehicle conversion costs are significant but payback is typically in 3-10 years depending on the application and usage 2. An in-house CNG fuelling system carries *significant* capital costs 3. Additional electricity costs for CNG refuellers 4. Potentially increased fueling time: if slow refuellers are employed, fuelling will take overnight; with fast refuellers, fuelling will take approximately the same time as traditional gas/diesel vehicles

[133] Source: https://consumerenergyalliance.org/2019/04/energy-explorer-cng-vs-lng/#:~:text=The%20reason%20you%20see%20CNG,requires%20a%20larger%20fuel%20tank.&text=Like%20CNG%2C%20LNG%20is%20compressed,state%20into%20a%20liquid%20state.
[134] Source: Natural Gas Use in the Medium and Heavy-Duty Vehicle Transportation Sectorin Roadmap 2.0 June 2019
[135] Source: https://cutaactu.ca/en/news-media/natural-gas-buses-cost-operational-and-environmental-alternative
[136] Source: https://brc.it/en/categorie_faq/cng/
[137] Source: https://envoyenergy.ca/cng-benefits/#:~:text=Commercial%20fleets%20all%20over%20the,solution%20for%20fuelling%20their%20fleets.

Strengths	Weaknesses
7. Piping directly to fuelling sites reduces upstream emissions resulting from delivery	5. Scarcity of refuelling centres in Canada

Safety

According to the U.S. Department of Energy's Alternative Fuels Data Center, NGVs are safer than vehicles powered by gasoline or diesel and the industry is highly regulated to address any additional safety concerns. There are an estimated 11 million NGVs[138] in use in over 30 countries globally. Codes, standards and regulations ensure that CNG vehicles are safe and that CNG refueling stations have been installed according to industry standards.

Compressed natural gas (CNG) has several inherent properties that make it safer than diesel or gasoline, including the following:

- It has a higher ignition temperature than gasoline (about 1022°F, compared to about 482°F for gasoline).
- Natural gas burns only if the concentration in air is within specific limits, which is between 5 and 15 percent; this property along with a high ignition temperature make combustion of CNG very unlikely.
- It is lighter than air, thus in the unlikely event of a leak it dissipates quickly into the atmosphere.

In addition, the CNG industry is highly regulated and there are a series of safety measures in place, including the following:

- Natural gas is odourless; however, for safety reasons it is odorized to enable easy leak detection. According to a safety article in the *Natural Gas Vehicle Knowledge Base*, the average person can detect odorized natural gas at concentrations as low as 0.3 percent.
- Fuel cylinders are significantly stronger than diesel tanks and fuel tanks are up to a half-inch thick and are made of steel, or a composite designed to be stronger than steel.
- Cylinders and tanks are fitted with valves to handle high pressure, prevent leakage and eliminate risks of explosion.

In the U.S., the Federal Transit Administration followed 8,331 natural gas utility, school, municipal, and business fleet NGVs that traveled 178.3 million miles on CNG. They found that the NGV fleet

[138] Source: Closing the Loop. Canadian Biogas Association. 2015.

vehicle injury rate was 37% lower than the gasoline fleet vehicle rate. Furthermore, the examined fleet was involved in seven fire incidents, only one of which was directly attributable to failure of the natural gas fuel system. Finally, there were no fatalities compared with 1.28 deaths per 100 million miles for gasoline fleet vehicles.

Emissions Reduction Potential

Based on the same work performed, a CNG vehicle has tailpipe GHG emissions about 20-30% less than a comparable diesel vehicle[139,140]. NGVs also emit up to 95% less nitrogen oxides (NO_x) compared to diesel and gasoline vehicles[141]. Furthermore, CNG vehicles do not emit particulate matter (PM10), a main cause of air pollution[142].

Feasibility Considerations

The business case for natural gas is, in most cases, made on the differential in price between diesel fuel and natural gas – the higher initial investment costs for NGVs are typically offset by the fuel savings by using CNG over diesel. New NGVs for fleets may cost up to $50,000 more than conventional diesel fleet vehicles (based on truck Classes 7, 8 and 9)[143,144]. New CNG buses can cost $120,000 more than conventional diesel buses[145,146], likely making the payback period longer than for trucks, depending on kilometres-driven.

For Class 5 to 7 medium-duty trucks in the fleet that are currently powered by gasoline, CNG conversions are available. Conversion costs range from $6k to $10k CAD. CNG powered trucks could be re-fueled with overnight slow-fill systems which cost much less than fast-fill systems. Trucks being considered for conversion to CNG must have ample available frame space for CNG tanks and often this is not possible due to the types of add-on equipment and bodies mounted on the trucks. CNG conversions may present operational challenges if their range was less than fossil-fuelled units. In the event of a power interruption, such as during a severe weather event or some other cause, overnight slow re-fuellers would cease to function and CNG powered vehicles would be sidelined, which could negatively affect the City's emergency preparedness plans.

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139 Source: https://brc.it/en/categorie_faq/cng/
140 Source: https://envoyenergy.ca/cng-benefits/#:~:text=Commercial%20fleets%20all%20over%20the,solution%20for%20fuelling%20their%20fleets.
141 Source: Northwest Gas Association – Natural Gas Facts
142 Source: https://brc.it/en/categorie_faq/cng/
143 Source: Closing the Loop. Canadian Biogas Association. 2015.
144 Source: Consultations with Change Energy
145 This value represents the additional cost, in CAD, of a CNG transit bus over a traditional diesel bus.
146 Source: Electric Buses in Cities: Driving Towards Cleaner Air and Lower CO_2. Bloomberg Finance L.P. 2018.

An operational concern is that in certain situations, such as an electrical power interruption, CNG compressor or other fuel system failure, etc., dedicated CNG vehicles (i.e., vehicles powered solely by CNG) would be sidelined, and this is a significant risk that must be managed.

Infrastructure Costs

CNG filling station infrastructure costs could run to $1m or much more, depending on capacities and complexities, and this is a conservative estimate. A CNG station would consist of the following elements:

- Compressor
- Storage
- Dispenser
- Slow and fast fill positions
- Engineering and permitting
- Site prep and gas service

Types of Filling Infrastructure

There are three main types of CNG fuelling stations:

(1) Slow-fill refuellers: use a compressor only; fuelling typically takes place overnight
(2) Fast-fill refuellers: storage capacity is required; fuelling time is 8 minutes per vehicle
(3) Hybrid refuellers: have both slow and fast-fill-up

Thinking Ahead

Despite the increased capital costs for NGVs and their fuelling systems, many fleets have embraced the technology and apparently achieved success from their investments. We emphasize that NG is a fossil fuel – albeit a clean burning one – and it is important to keep in mind the global shift away from internal combustion engines and non-renewable fossil fuels. Some jurisdictions have already legislated the end of the internal combustion engine.

Zero-emission battery-electric vehicle options are available "here and now" in the case of transit buses and fully electric Class 5 to 8 trucks are not far off in the future. Experts agrees that the world is transitioning to battery-electric vehicles (BEVs) and, potentially, hydrogen fuel-cell electric vehicles (FCEVs). With that reality, the use of NG as a vehicle fuel may be considered as an interim solution for organizations wishing to achieve immediate carbon reductions in the short-term while awaiting the availability of EVs. Unless subsidies were available to offset the cost, a major investment in an NG fuelling system would need to be a long-term capital investment for it to be cost-effective. Few would disagree that a large capital investment with a protracted payback period would not be a prudent decision for what may be an interim, short-term solution with a marginal business case.

Natural Gas Summary

Should the goal be for a NG fuelling system to be a long-term capital investment, NG may have good potential for a fleet due to the following:

- A CNG vehicle saves fuel costs and has significantly reduced tailpipe CO_2 emissions compared to a diesel vehicle.
- NGVs nearly eliminate the emissions of nitrogen oxides (NO_x), and do not emit particulate matter (PM10).
- NG is considered safer than traditional fuels since, in the event of a spill, NG is lighter than air and thus disperses quickly when released.

Renewable Natural Gas

An alternative to fossil sources is renewable natural gas (RNG), which is a methane biogas – a gaseous product of the decomposition of organic matter obtained through biochemical process such as anaerobic digestion. It is recovered from landfills, wastewater treatment plants, anaerobic digesters at dairies, food processing plants, or waste processing facilities that are cleaned to meet natural gas pipeline standards.[147]

RNG, or biomethane, is a fully renewable energy source that is fully interchangeable with conventional natural gas. Like conventional natural gas, RNG can be used as a transportation fuel in the form of compressed natural gas (CNG) or liquefied natural gas (LNG).

RNG production has become an important priority thanks to its environmental benefits. RNG production is usually based on capturing and purifying the gas from collected organic waste — anything from crop residues and animal manures to municipal organic wastes and food processing by-products.

[147] Source: https://www.mjbradley.com/sites/default/files/MJB%26A_RNG_Final.pdf

RNG at a Glance

Table 16: Strengths and Weaknesses of RNG

Strengths	Weaknesses
1. Interchangeable with fossil natural gas 2. Can be used to power natural gas vehicles without conversion 3. Very low GHG emissions 4. RNG can be produced year-round without intermittency	1. Costs for an anaerobic digester are considerable and depend on the required size and capacity

Production

In general, the feedstocks for RNG systems can be grouped into five broad categories, based on the primary source of the organic material:

- Agricultural organics
- Residential source separated organics (SSO)
- Commercial SSOs
- Landfill gas
- Wastewater treatment residuals

Anaerobic digestion is a process during which the waste (from landfills or waste water treatment plants) is converted into methane and carbon dioxide in a digester or holding tank. The gas produced is then cleaned or purified to meet utility pipeline specifications. The digesters can be located at waste water treatment plants, landfills, or at green bin waste facilities.

Emissions Reduction Potential

When RNG is used to fuel fleet vehicles, GHG emissions reductions are significant; different sources estimate the lifecycle reduction to be between 75% and 90% compared to diesel. The carbon dioxide that is generated during the production and combustion of RNG is used in the regeneration of new biomass, representing a closed-loop cycle for carbon dioxide that is released[148].

Feasibility Considerations

Without the commercial availability of RNG in a fleet's jurisdiction, a fleet would need to invest in an anaerobic digester to make their own RNG. This would add to the already large cost of $1m or much

[148] Source: Closing the Loop. Canadian Biogas Association. 2015.

more to build a CNG fuelling station. Also, unlike CNG which would likely offer fuel cost savings, compressed RNG is approximately equal in price to diesel and gasoline in terms of diesel litre equivalent (DLE)[149]. Therefore, in many situations the use of RNG is not a financially viable option. However, with GHG reduction potential of up to 90% compared to diesel, a fleet manager may still want to consider RNG as an option.

RNG Summary

The use of RNG is a natural progression from the use of fossil-based CNG. While use of natural gas as fuel requires large infrastructure investments, RNG has a very high emissions reduction potential.

RNG is thus an important fuel to consider for use in medium and heavy-duty vehicles. Nevertheless, the technology of producing RNG is still under development and it is expected to become more widespread in the near future.

Liquified Petroleum Gas

Propane, otherwise known as liquefied petroleum gas (LPG), is produced as part of natural gas processing and crude oil refining. In natural gas processing, the heavier hydrocarbons that naturally accompany natural gas, such as LPG, butane, ethane, and pentane, are removed before the natural gas enters the pipeline distribution system. In crude oil refining, LPG is the first product that results in the refining process.

Propane is a gas that can be turned into a liquid at a moderate pressure (160 pounds per square inch). It is stored in pressure tanks at about 200 psi and 100 degrees Fahrenheit. When propane is drawn from a tank, it changes to a gas before it is burned in an engine.

Application

Propane has been used as a transportation fuel since 1912 and is the third most commonly used fuel in the United States, behind gasoline and diesel. More than four million vehicles fuelled by propane are in use around the world in light-, medium- and heavy-duty applications. Propane holds approximately 73%[150] of the energy of gasoline and so requires more storage volume to drive a range equivalent to gasoline, but it is usually price-competitive on a cents-per-km-driven basis.

Propane vehicle conversions and fueling systems generally cost much less than natural gas systems.

[149] Source: Closing the Loop. Canadian Biogas Association. 2015.
[150] Source: Department of Energy GREET (Greenhouse gases, Regulated Emissions, and Energy use in Transportation) Model, Jan 20, 2011.

Emissions Reduction Potential

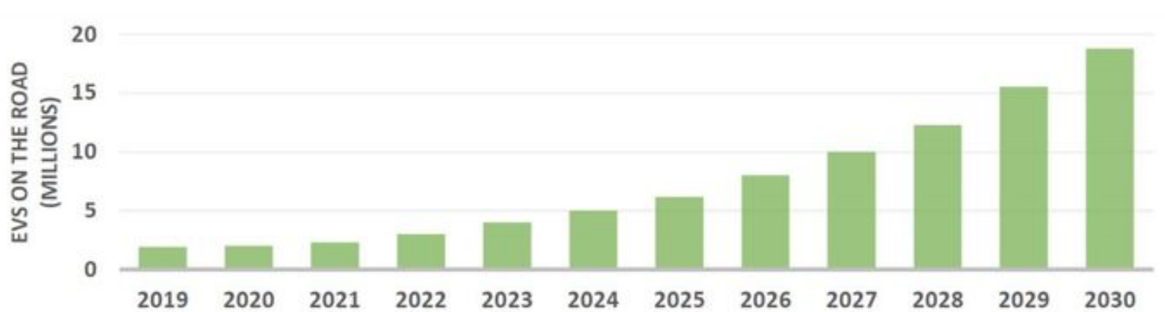
In terms of tailpipe emissions, propane has a GHG emissions reduction potential of about 33% when compared to the same volume of gasoline based on GHGenius version 5.01a. However, as mentioned, propane contains about 27% less energy than gasoline per unit volume. Given this energy loss, about 37% more fuel is required to achieve the same amount of work as gasoline. Therefore, the emissions reduction for the same work performed is actually around 9.5% when compared to the energy equivalent of gasoline (i.e., for the same distance travelled the emissions for a vehicle running on propane are about 90.5% of those of a gasoline vehicle, which is 67% multiplied by 1.37 accounting for the additional volume required to achieve the same work).

Electric Vehicle Technologies

Over the past decade, electric transportation technologies including hybrid-electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and battery-electric vehicles (BEVs), have been rapidly developing and quickly gaining popularity in the market. Electric vehicle (EV) technologies offer significantly reduced or no tailpipe emissions and vastly improved energy efficiency.

Today, EVs have reached their tipping point and sales are booming while the public vehicle charging infrastructure rapidly grows. Demand for EVs accelerated during the 2010s and is expected to continue accelerating during the 2020s, as shown in *Figure 12* for the United States.

Figure 12: Forecasted EV Growth in US (Source: Edison Electric Institute)



For fleet managers looking to reduce their annual fuel budget and corporate emissions, battery-electric, hybrids, and plug-in hybrids are a good option. Savvy fleet managers will seek applications where the type of vehicle used will deliver sufficient fuel cost savings to offset their additional cost of capital and, after the vehicles are fully depreciated (usually ~5 years), deliver net cost savings until the end of their economic lifecycle (often ~10 years).

There are a number of light-duty electric vehicle technologies currently available in the market. They include:

- **Mild Hybrid Electric Vehicles (MHEVs)**, which are equipped with internal combustion engines (ICEs) and a motor-generator in a parallel combination allowing the engine to be turned off whenever the vehicle is coasting, braking, or stopped and which restart quickly. MHEVs use a smaller battery than full hybrid electric vehicles (HEVs, see below) and do not have an exclusively electric mode of propulsion; rather, the motor-generator has the ability to both create electricity and boost the gas engine's output, resulting in better performance and reduced fuel use. Examples of MHEVs are the Honda Insight and the 2019 Ram 1500. [151]

- **Hybrid Electric Vehicles (HEVs)**, which use two or more distinct types of power, such as an ICE and a battery-powered electric motor as the modes of propulsion, albeit with very limited range when in electric mode. When an HEV accelerates using the ICE, a built-in generator creates power which is stored in the battery and used to run the electric motor at other times. This reduces the overall workload of the ICE, significantly reducing fuel consumption and extending range. Examples of HEVs include the Toyota Prius and Ford Fusion Hybrid. [152]

- **Plug-In Hybrid Electric Vehicles (PHEVs)**, which use rechargeable batteries, or another energy storage device, that can be recharged by plugging into an external source of electric power. PHEVs can travel considerable distances in electric-only mode, typically more than 25 km and up to 80 km for some models, due to their much higher battery capacity than hybrids. When the battery power is low (usually ~80% depleted), the gasoline ICE turns on and the vehicle functions as a conventional hybrid. Such vehicles typically have the same range as their gasoline counterparts. Examples of PHEVs include the Chevrolet Volt and Toyota Prius Prime.[153]

- **Battery-Electric Vehicles (BEVs)**, or all-electric vehicles, which are propelled by one or more electric motors using electrical energy stored in rechargeable batteries. BEVs are quieter than ICE vehicles and have no tailpipe emissions. In recent years, BEV range has been considerably extended, thereby providing much wider BEV applications and reducing range anxiety. Today, many BEV models have EPA-estimated ranges exceeding 400 km, which provide much greater reliability when travelling longer distances. Recharging a BEV can take significantly longer than refuelling a conventional vehicle, with the difference depending on the level of charging speed; a full battery charge using a level 2 charger takes several hours, but charging from a nearly depleted battery to 70% at a fast (level 3) charge station can take 30 minutes[154]. Examples of BEVs include the Nissan Leaf, Chevrolet Bolt, Kia Soul, and Tesla Model 3.

[151] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[152] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[153] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/
[154] Source: https://www.autotrader.ca/newsfeatures/20180410/types-of-electric-vehicles-explained/

While commercial hybrid (HEV and PHEV) and full battery-electric (BEV) pickups, trucks and vans are still limited, options are quickly becoming available. Medium and heavy-duty battery-electric trucks are quickly being developed by many manufacturers. Demand for those offered by Tesla, Volvo, Freightliner, and others exceeds current supply and will soon be available for fleet purchase. Battery-electric buses are currently available for purchase.

Almost daily, manufacturers are announcing new electric cars, pickups, vans, buses and trucks of all gross vehicle weight ratings. There is no question that BEVs are taking over for traditional internal combustion engine (ICE) vehicles in a big way. Some jurisdictions have already legislated the end of ICEs. If they haven't done so already, fleet managers should start making plans for BEVs now.

While their upfront costs will be higher, BEVs have increasingly proven to be a viable solution to rising fuel costs and emissions. Since BEVs have few moving parts, tune-ups or oil changes are never required, and they seldom, if ever, require brake relining due to regenerative braking. And best of all, they burn zero fuel.

Plug-in hybrid electric vehicles would be an excellent solution for a low-mileage, return to base fleet. PHEVs have a much larger all-electric range as compared to conventional first-generation hybrid vehicles, and they eliminate any range anxiety that may be associated with all-electric vehicles, because the combustion engine works as a backup when the batteries have become depleted.

Zero Emission Battery-Electric Vehicles

Since the release of the first mass-produced BEV, the Nissan Leaf, which debuted in 2010 with an EPA range estimated at only 73 mi or 117 km[155], there has been a surge in lithium-ion battery production leading to a drastic decline in prices. Today, several more affordable BEV models have ranges exceeding 400 km, which provide much greater reliability when travelling longer distances. For example, the 2020 Tesla Model 3 Standard Plus has an EPA-estimated range of 402 km[156], while the 2020 Chevrolet Bolt has an EPA-estimated range of 417 km[157].

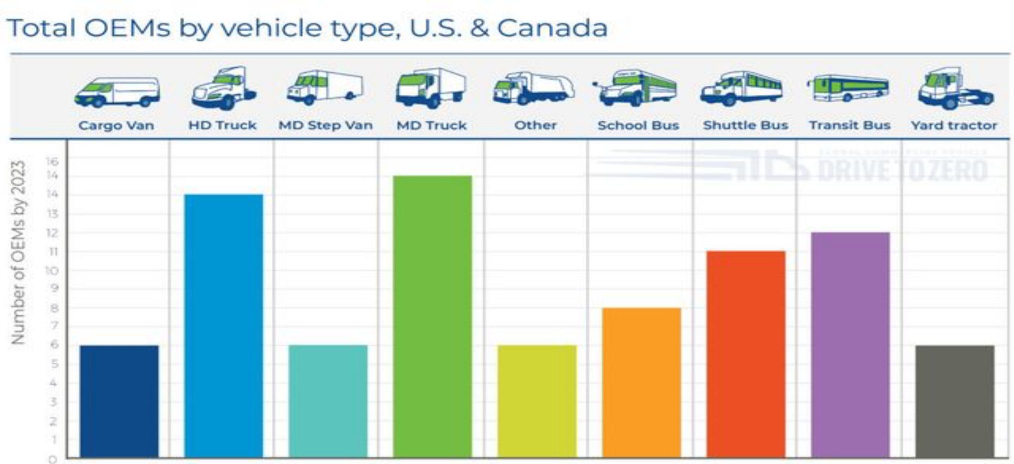
There has also been significant expansion in charging infrastructure through publicly available charging stations. As of early 2020, there were nearly 5,000 charging outlets across Canada, and Natural Resources Canada is investing $130 million from 2019-2024 to further expand the country's charging network, making range anxiety even less of a barrier to BEV ownership.

In addition to battery-electric pickups that are soon to emerge, emerging battery-electric buses and medium and heavy-duty trucks such as those planned by Tesla, Volvo, Freightliner, and other manufacturers are attracting considerable interest because of their the elimination of tailpipe GHG

[155] Source: https://www.mrmoneymustache.com/the-nissan-leaf-experiment/
[156] Source: https://www.tesla.com/en_ca/model3
[157] Source: https://www.chevrolet.com/electric/bolt-ev

and CAC emissions, in addition to the potential for significant maintenance and fuel cost savings. In *Figure 13*, we see that the OEMs are quickly ramping up with other types of commercial EV trucks (medium- and heavy-duty truck categories) that are suited for municipal work environments.

Figure 13: Total EV OEMs by 2023 (Source: Calstart)



Fleet managers who operate battery-electric trucks and buses can see massive savings in maintenance and fuel costs. BEVs have considerably fewer parts than internal combustion engine (ICE) vehicles. A drivetrain in an ICE vehicle contains more than 2,000 moving parts, compared to about 20 parts in an BEV drivetrain. This 99% reduction in moving parts creates far fewer points of failure, which limits and, in some cases, eliminates traditional vehicle repairs and maintenance requirements, creating immense savings for fleet managers. BEVs do not require oil changes or tune-ups, have no diesel exhaust fluid (DEF), and their brake lining life is greatly extended over standard vehicles due to regenerative braking. Though each fleet's electrification journey will be different, the transition to electricity offers significant cost reductions over the long term.

A new study[158] quantified what commercial EV-makers have been saying for years: electric trucks and buses are a triple win. They save money for fleet operators, and reduce both local air pollution and GHG emissions. The study, which was commissioned by the National Resources Defense Council (NRDC) and the California Electric Transportation Coalition, and conducted by the international research firm ICF, looked at the value proposition for fleet operators of battery-electric trucks and buses (and apparently invented a new acronym: BETs).

Today, BETs have an upfront price premium compared to legacy diesel trucks and buses. However, the costs of battery packs and other components are rapidly falling, and the study found that, by

[158] Source: Posted January 2, 2020 by Charles Morris (https://chargedevs.com/author/charles-morris/) & filed under Newswire (https://chargedevs.com/category/newswire/), The Vehicles (https://chargedevs.com/category/newswire/the-vehicles/)

2030 or earlier, electric vehicles will offer a lower total cost of ownership (TCO) for nearly all truck and bus classes, even without incentives.

Battery-Electric Vehicles at a Glance

Table 17: Strengths and Weaknesses of BEVs

Strengths	Weaknesses
- Well-designed, no noise, few moving parts, long warranties - Little/no maintenance - Government grants and incentives may be available - Effectively eliminates need for idling-reduction initiatives - Very positive driver feedback - Very positive public opinions - Potential for significant lifecycle GHG emissions, depending on electricity source	- High capital cost for battery-electric trucks/buses and chargers - Limited availability of new battery-electric trucks - For faster charging, 240V (Level 2) or 480V (DCFC) charging equipment required at extra cost - Existing electrical capacity at facilities may require significant upgrades to power charging stations for multiple vehicles - Potential driver range anxiety - Potential for costly battery replacements in aged BEVs

Air Quality and Upstream Emissions

Air quality is a growing concern in many urban environments and has direct health impacts for residents. Tailpipe emissions from internal combustion engines are one of the major sources of harmful pollutants, such as nitrogen oxides and particulates. Diesel engines in particular have very high nitrogen oxide emissions and yet these make up the majority of the global bus fleet. As the world's urban population continues to grow, identifying sustainable, cost-effective transport options is becoming more critical.

Battery-electric vehicles (BEVs) require electricity to recharge the batteries; therefore, electricity is effectively a "fuel" in these types of vehicles. Battery-electric vehicles (BEVs) may be defined as zero emissions vehicles (ZEVs) since the California Air Resources Board (CARB) defines a ZEV as a vehicle that emits no exhaust gas from the onboard source of power[159]. However, CARB's definition accounts for pollutants emitted at the point of the vehicle operation and the clean air benefits are usually local. Depending on the source of the electricity used to recharge the batteries, air pollutant emissions are shifted to the location of the electricity generation plants. For example, if electricity used for charging vehicles comes primarily from "dirty" sources such as coal, lifecycle vehicle emissions will result.

[159] Source: California Air Resources Board (2009-03-09). "Glossary of Air Pollution Terms: ZEV"

From a broader perspective, to have almost none or zero well-to-wheel emissions, the electricity used to recharge the batteries must be generated from renewable or clean sources such as wind, solar, hydroelectric, or nuclear power. In other words, if BEVs are recharged from electricity generated by fossil fuel plants, they cannot truly be considered as ZEVs. Upstream emissions should be considered when evaluating the effectiveness of ZEVs in reducing emissions. Generally, when considering upstream emissions from electricity supply, BEVs still emit more than 50% less GHG emissions than their gasoline or diesel counterparts[160], and in some cases emit over 80% less in a grid composed of mostly renewable electricity[161]. This level of emissions reduction is what cities need in order to collectively achieve the "deep decarbonization" necessary to mitigate the most serious impacts of climate change.

Charging Technologies

The time it takes to fully charge a BEV is dependent on the type (level) of charger used, the vehicle's technology (i.e., the maximum amount of current allowed by the vehicle, in amps), and range (i.e., battery capacity). Charging speed is expressed in kilometers/miles of range per hour of charging. BEVs can be charged by varying levels of chargers ranging from level 1-3 with the following general characteristics shown in *Table 18*[162]:

Table 18: Characteristics of BEV Charging Levels

BEV Charging Levels	Outlet Voltage	Amperage	Added Range Per Hour
Level I	120V	12-16 amps	5-10 km
Level II	240V	16-40 amps	22-56 km
Level III	480+V	100+ amps	>250 km

Level 1 chargers can be plugged right into a standard outlet. They are the most economical option for private owners; however, at such a low charging rate it is usually not practical to use level 1 chargers exclusively. For example, it would take about 40 hours to fully charge a light-duty BEV with a range of 400 km starting at 20% battery (80 km range remaining).

Level 2 chargers are common in private households as well as public spaces such as mall parking lots. They incur an installation cost but are similar to common 240V installations such as the outlets that power clothes dryers. For a light-duty BEV with a range of 400 km and at 20% battery (80 km range remaining), it would take about eight hours to fully charge. Level 2, 240-volt chargers typically range in cost from around $1.5-5k, depending on electrical system requirements. Each Level 2

[160] Source: https://www.eei.org/issuesandpolicy/electrictransportation/Pages/default.aspx
[161] Source: https://blog.ucsusa.org/rachael-nealer/gasoline-vs-electric-global-warming-emissions-953
[162] Source: https://calevip.org/electric-vehicle-charging-101

charger can serve two vehicles at any time of day; usually, charging is done overnight during the off-peak period. The vast majority of the time, BEV owners only need a level II charger; the exception is when travelling longer distances. During these times, much faster charging rates are required through level 3 charging.

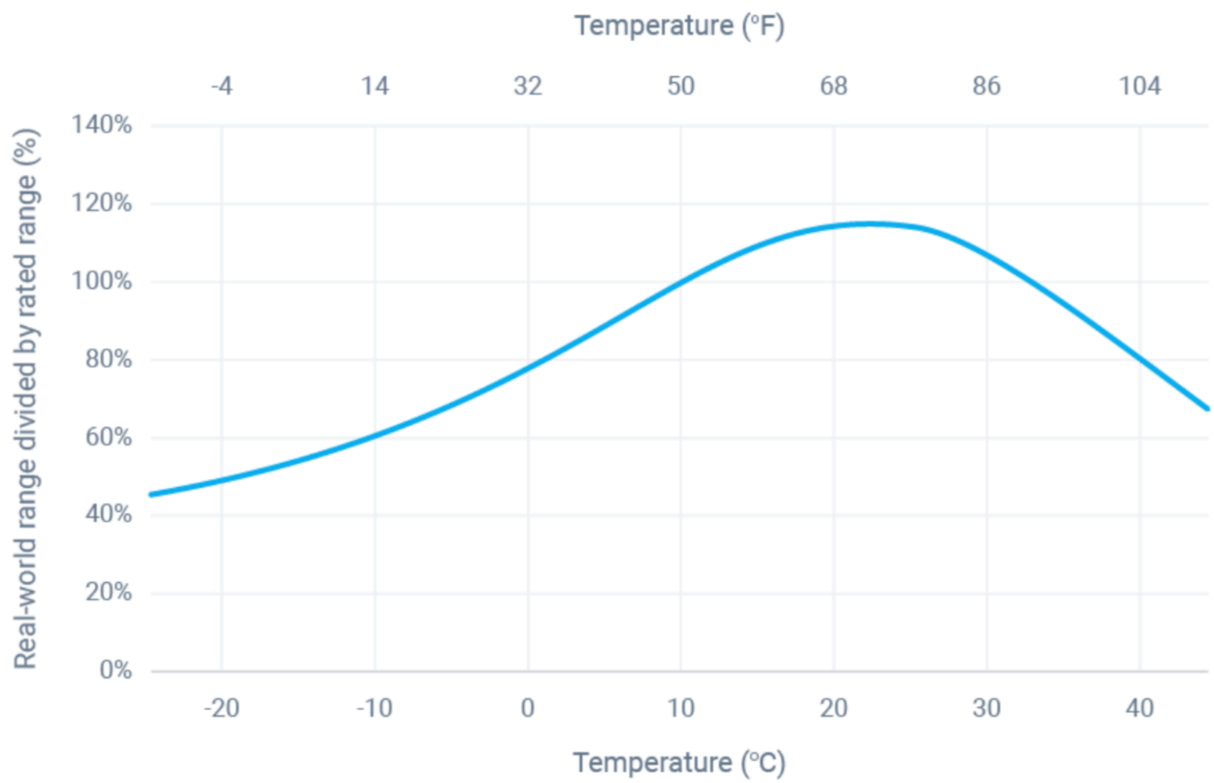
Level 3, or direct current fast chargers (DCFCs), requiring inputs of 480+ volts and 100+ amps (50-60 kW)[163], are specialized systems designed to quickly charge vehicles and provide flexibility to owners travelling longer distances or in need to partial quick charge. For a light-duty BEV with a range of 400 km and at 20% battery (80 km range remaining), it would typically take less than one hour to fully charge. Installations of DCFCs require a commercial electrician due to the electrical load and wiring requirements[164]. The costs for installing a level 3 DCFC vary greatly. Costs for a fast-charging station are dependent on the electrical supply available at the chosen charging site, site preparation costs including trenching, cable runs and many other installation considerations. Equipment and installation costs for DC fast charging stations can range from $50,000 to $200,000[165].

Impact of Temperature on Battery Performance

Canadians enjoy the ebbs and flows of seasonality and extreme temperatures. BEV range is adversely affected by cold and hot temperatures because of auxiliary heating and cooling – that is, heating/cooling the vehicle cabin, and heating/cooling the battery itself to maintain optimal performance. Batteries are susceptible to temperature fluctuations which hinder, but in some cases helps, range. For example, on a typical winter day in central Canada with a temperature at -15°C, range can drop by over 50% of the EPA estimated range, meaning that a BEV with a range of 400 km will only get 200 km (*Figure 14*, below). Conversely, at temperatures in the low-twenties, range can significantly exceed the EPA-estimated range given that other conditions are optimal (e.g., starting temperature, terrain, and driver habits). With some preparation and knowledge, owners and operators of BEVs can mitigate the effects of temperature on performance by pre-conditioning their vehicle (i.e., warming up or cooling down before use) as well as keeping their vehicle plugged in when temperatures are extreme; this allows the system to maintain battery temperature controls and also prolongs battery life.[166]

[163] Source: https://calevip.org/electric-vehicle-charging-101
[164] Source: https://calevip.org/electric-vehicle-charging-101
[165] Source: https://www.toronto.ca/wp-content/uploads/2020/02/8c46-City-of-Toronto-Electric-Vehicle-Strategy.pdf
[166] Source: https://www.geotab.com/blog/ev-range/

Figure 14: The Effects of Temperature on BEV Range



Training Options and Recommendations

While there is a paucity of BEV technician training in Canada, due to the rapid onset of electric mobility we suspect that reality will soon change. A pilot for a new EV Maintenance Training Program for automotive technicians was successfully completed at BCIT and is available to the public[167].

There is an Electric Vehicle Technology Certificate Program offered by SkillCommons, managed by the California State University and its MERLOT program, which offers free and open learning materials electric vehicle development, maintenance, alternative/renewable energy, and energy storage[168]. There is also a Hybrid and Electric Vehicles course offered at Centennial College in Toronto, which appears to focus more on hybrid systems than fully electric vehicles[169].

Before BEVs are deployed in a fleet to any great extent, we recommend high-voltage training for technicians. Published high-voltage guidelines specific to vehicle technicians servicing BEVs are not readily available through traditional sources. However, we suggest that anyone working with high voltage in any format, including BEVs, should be provided guidance on applying Occupational Health

[167] Source: https://commons.bcit.ca/news/2019/12/ev-maintenance-training/
[168] Source: http://support.skillscommons.org/showcases/open-courseware/energy/e-vehicle-tech-cert/
[169] Source: https://db2.centennialcollege.ca/ce/coursedetail.php?CourseCode=CESD-945

& Safety Management System fundamentals. This includes a “plan, do, check, and act” philosophy while working with energized electrical equipment[170]. Such training is available for non-electrical workers from Lineman’s Testing Laboratories (LTL) of Weston, Ontario. LTL offers an awareness-level course for non-electrical workers which is claimed by the company to provide a basic-level understanding of workplace electrical safety.

Aside from awareness training, fleet technicians should also have access to, and be trained on the use of, electrical-specific personal protective equipment (PPE). Such PPE would include tested and certified non-conductive gloves as well as non-conductive tools and equipment as a last line of defence, ensuring all such gear is appropriately used and maintained. Protective gloves and other PPE, as well as non-conductive tools, must be re-tested periodically to ensure safety.

BEV Summary

For light-duty vehicles and buses, and soon for medium- to heavy-duty trucks, BEVs have excellent potential for a fleet due to the following:

- Significant lifecycle GHG emissions reductions
- Significant reduction in operational costs due to elimination of fuel consumption, low costs for electricity, and minimal maintenance costs
- Relatively low charging infrastructure costs in comparison to infrastructure costs for other fuel-reduction / emission-reducing technologies such as CNG

If BEVs were to be considered by a fleet, it would be prudent to consider installing a direct current fast charger (DCFC). Such a fast charger would enable fleet management staff to quickly charge their light-duty vehicles in situations where plugging in for overnight charging may not been possible or for emergency situations. For heavy-duty BEVs such as transit buses, it is important to consider that, depending on available amperage, a full charge may take several hours even with DCFCs.

Evaluation of the fleet to identify vehicles that have a potential for a replacement with a BEV should be completed. Furthermore, change management is recommended to be part of the transition process to help drivers accept and adapt to BEVs and overcome any lingering range anxiety.

[170] Source: https://training-ltl.ca/

Hydrogen Fuel Cells

Hydrogen fuel cells are able to produce electricity for motive power with zero tailpipe emissions and, therefore, can offer enormous environmental and sustainable energy benefits. Fuel cells are flexible in size, power density, and application. Industry experts are in general agreement that in the next phase zero-emission vehicle (ZEV) batteries will be recharged with onboard hydrogen fuel cells.

Although fuel-cell technology has been around since 1960 (GM introduced the first fuel-cell vehicle, the Electrovan, in 1966), adaptation of the technology has been slow. Only in recent years, supported by the focus on zero-emissions technologies, has the hydrogen fuel cell regained momentum. Leading (light-duty) vehicle manufacturers including Honda, Toyota and Hyundai have launched their first mass-production hydrogen-powered vehicles.

Sources of Hydrogen and Emissions

Hydrogen is the most abundant element in the universe. It can be produced from several sources including:

- Fossil sources include natural gas, coal, and oil; and
- Renewable energy sources such as wind, solar, geothermal, and hydroelectric power.

Hydrogen also has a potential to be made locally at large central plants or in small distributed units at or near the point of use.

Although hydrogen vehicles have no tailpipe emissions, currently most hydrogen is produced from fossil sources. As a result, presently there are no emissions benefits to switching to a hydrogen-powered vehicle – the lifetime emissions may be the same, or even higher, than those of conventional fuels.

At the same time, this technology has a high potential to be very clean through use of renewable sources, which would effectively eliminate all fuel-related emissions. Alas, due to low demand this technology is still too expensive to be commercially viable.

Currently, much work is taking place around the world toward “green” hydrogen from renewable sources. The hydrogen fuel-cell trucks shown in *Figure 15* (below) will be refueled with green hydrogen made from hydropower in Switzerland, as opposed to “grey” hydrogen made from methane with very high CO_2 emissions, which is the case in most countries.

Figure 15: Hydrogen Fuel-Cell Trucks Bound for Switzerland

Fuel-Cell Technology for Transportation

Hydrogen fuel-cell vehicles (FCVs) are like electric vehicles in that they use an electric motor to power the drive wheels and have no smog-related or greenhouse gas tailpipe emissions. Rather than being plugged in to charge a battery, these vehicles use onboard fuel cells to generate electricity.

In a fuel cell, hydrogen from the fuel tank (filled similarly to gasoline/diesel) is combined with oxygen from the air to electrochemically generate electricity. Water is also produced in this process[171]. The electricity generated is used to power the vehicle. A fuel cell is two to three times more energy efficient than traditional gasoline or diesel engines.

In the zero-emissions transportation area, fuel cells have particular benefits over electric vehicle technology, namely they can easily meet the extended range requirements and offer rapid refuelling to satisfy driver and consumer interests.

Technological Advancement

One of the main issues with the development of hydrogen transportation has been the shortage of hydrogen fuelling stations. Manufacturers are not willing to produce vehicles that customers cannot fuel, while developers are reluctant to build hydrogen stations (costing $2,000,000 and more) due to lack of demand.

A critical mass must be reached for most transportation technologies to develop and expand, typically done through governmental leadership and financial support, as with the evolution of electric vehicles.

California has made significant investments to develop the fuelling station network to support hydrogen-fuelled vehicles. As of Spring 2017, there were thirty-six hydrogen fuelling stations in the

[171] Source: https://www.epa.gov/greenvehicles/hydrogen-fuel-cell-vehicles

U.S.; all but three were in California. There are currently about 2,000 hydrogen vehicles on California roads.

There are several medium and heavy-duty hydrogen vehicles being developed[172]:

California-based US Hybrid Inc., a company that has been building fuel cell engines for transit buses, step vans, and military vehicles for several years, recently unveiled its first Class 8 fuel cell port drayage truck featuring its proton-exchange membrane (PEM) fuel cell engine that will run at the Ports of Los Angeles and Long Beach. The fuel cell truck is estimated to have a driving range of 200 miles under normal drayage operation and can be fully refueled in less than nine minutes.

Toyota Motor Corp. has unveiled their "Project Portal" venture, a Class 8 truck powered by a hydrogen fuel cell. Toyota will begin testing the concept vehicle in real-world use shuttling shipping containers between the ports of Los Angeles and Long Beach and various freight depots up to 70 miles away.

Kenworth Truck Co. was the first major heavy-duty truck maker to join the fuel cell race and recently announced they are developing a hydrogen fuel cell tractor to haul freight from the Southern California ports to nearby warehouses. The tractor uses lithium-ion batteries to power an electric motor.

UPS unveiled an extended range Class 6 fuel cell vehicle that it will deploy in its "Rolling Laboratory" fleet of alternative fuel and advanced technology vehicles.

Fuel-Cell Powered Public Transit

In British Columbia, 20 fuel-cell buses were operated in its transit fleet between 2010 and 2014. At the time, it was the largest fleet of its kind in the world, providing regular revenue transit service to residents in the community of Whistler, British Columbia[173]. In late 2014, the program was discontinued. It was estimated that the cost of Whistler's hydrogen buses were $1.34 per kilometre to maintain, versus 65 cents per kilometre for diesel-powered buses.
In the short-term, hydrogen vehicle technology is infeasible. Nevertheless, based on current trends future changes are expected as the market develops. Although progress on FCVs development has picked up speed, the technology has not yet been fully commercialized. Thus, it is extremely difficult to make projections of vehicle classes available in the future and their related costs.

[172] Source: http://www.gladstein.org/hydrogen-fuel-cell-trucks/?elqTrackId=6a5315625a44431c811600250fbe96e3&elq=f9398669248a444fa236415f8ae2dde6&elqaid=1302&elqat=1&elqCampaignId=700
[173] Source: http://www.chFC.ca/say-h2i/cars-and-buses/cars-and-buses

Hydrogen Fuel Cell Summary

Fuel cell technology has a very high potential for future applications for vehicles in all classes. Nevertheless, the technology currently is still very expensive, lifecycle emissions are high and FCVs as well as fuelling stations are not yet available. As a result, any projections of fuel cell application in the future must be approached with caution and understanding of the inherent limitations. Therefore, it is recommended that a fleet monitor the development and availability of fuel-cell technology for future applications in fleet operations.

Appendix C: Details on Purchasing v. Leasing v. Renting

A fleet has various vehicle acquisition options – including purchasing, leasing, and renting – and the optimal decision is dependent on multiple factors specific to the needs and usage of the fleet vehicles as well as market conditions. Here, we provide details on the various vehicle acquisition options.

Vehicle Acquisition Methods and Definitions

There are many available options for fleets to acquire new vehicles. In the list below, we identify the most common methods of vehicle acquisition.

1) **Rent** – Vehicles are rented from a vendor, typically to fill short-term, seasonal or temporary requirements.

2) **Purchase (Cash)** – Vehicles are purchased with cash.

3) **Purchase (Loan)** – Vehicles are purchased with debt financing.

4) **FMV (Closed-End) Lease** – Vehicles are leased with Fair Market Value lease structure and are not purchased at the end of lease term.

5) **FMV (Closed-End) Lease w/ Cash Purchase** – Vehicles are leased with Fair Market Value lease structure and are purchased at the end of the lease term with cash.

6) **FMV (Closed-End) Lease w/ Loan Purchase** – Vehicles are leased with Fair Market Value lease structure and are purchased at the end of the lease term with debt financing.

7) **TRAC (Open-End) Lease** – Vehicles are leased with Terminal Rental Adjustment Clause lease structure and are not purchased at the end of lease term.

8) **TRAC (Open-End) Lease w/ Cash Purchase** – Vehicles are leased with Terminal Rental Adjustment Clause lease structure and are purchased at the end of the lease term with cash.

9) **TRAC (Open-End) Lease w/ Loan Purchase** – Vehicles are leased with Terminal Rental Adjustment Clause lease structure and are purchased at the end of the lease term with debt financing.

Of the methods outlined (above), purchasing, leasing, or renting are the three primary methods for private and public sector commercial fleets to acquire vehicles.

On the surface, the purchase *v.* lease *v.* rent decision may seem obvious; one may assume that if a fleet uses another party's capital (such as a lender or a lessor) to purchase its vehicles, as opposed to using its own funds, the lender/lessor will most certainly wish to make a profit for the use of their funds, and therefore it will cost more. However, there are several complexities that may influence the "big-picture" view and the **total cost of ownership** (TCO) for each option for vehicle acquisition.

Next, we explore the three primary options for vehicle acquisition and discuss the features and benefits of each.

Option 1: Purchasing Fleet Vehicles

Years ago, purchasing vehicles was the only option for vehicle acquisition. Purchasing vehicles required either cash or credit. But over the past several decades, fleet management has seen a steady evolution from a relatively straightforward task of managing owned vehicle assets to a complex discipline requiring fleet managers and their organization's leadership to adapt to a changing financial landscape[174].

A vehicle fleet of any size can require a massive capital outlay. In the private sector, such an outlay may constrain a company's ability to manage its primary business. In the private sector, such as a municipality, the outlay for rolling stock and the ongoing capital for annual fleet modernization may impede the community's ability to fund other capital expenses and programs such as new facilities or infrastructure improvements.

Advantages of Purchasing Fleet Vehicles

Purchasing vehicles may be more expensive – at least initially – and require keeping assets longer than leasing, but there are many advantages. For example:

- **No Mileage Restrictions.** Vehicle owners are not subject to mileage or wear and tear limitations as with leases. The distance the fleet travels annually is solely up to the owner.

- **More Flexibility.** Unlike leases, owners are not restricted to keep vehicles for a specific period. Fleet managers can remove a vehicle(s) from the fleet at any time and without penalties.

- **Pricing Leverage**. Fleets can usually attract price concessions (discounts) from vehicle original equipment manufacturers' (OEMs) seeking their business. If a fleet continues to purchase vehicles from a particular dealer or company, it may negotiate lower vehicle prices for future business. Fleets purchasing vehicles from large national fleet dealers may be eligible to receive enterprise fleet pricing.

- **Tax Benefits.** While not applicable to tax-exempt entities, including municipalities, the depreciation benefits of purchased vehicles reside with the owner. The value of fleet vehicles

[174] Source: Mapping the Changing Funding Environment of Fleet Management

depreciates over time, and the deductions can be used to help offset profits. In leasing, the depreciation benefit remains with the owner – the lessor.

- **Depreciation.** Depreciation of vehicles' value is one of the highest fleet costs. Vehicle owners have more control over this number. Leasing companies resell their vehicles in large volumes, sometimes for discounted prices, but owners can sell or trade in their vehicles individually, potentially resulting in lower net depreciation and reduced lifecycle total cost of ownership (TCO).

- **Equity.** Vehicles will gain equity over time. If funds for purchasing are borrowed, ideally, the owner will gain positive equity meaning the amount the fleet owes for its vehicles is less than it is worth. The owner can then reinvest that positive equity back into the company. With leasing, earned equity remains with the lessor.

Cost of Capital and Interest Rates

Timing is crucial for any organization looking to fund its fleet, whether the choice is to borrow capital to purchase its vehicles or to lease them. Market conditions change, sometimes drastically, and interest rates follow these changes. For example, before 1977, rates remained relatively stable, with 3% or 4% fluctuations over several years considered exceptional. In 1977, rates skyrocketed, almost tripling through 1981. A steady decline followed through the 1990s, with a recovery in the 2000s. The global financial meltdown of 2008 caused rates to plummet to historic lows. In 30 years, rates (in the U.S.) were more than 16% in 1981 and as low as 0.1% by 2011. In Canada, interest rates averaged 5.82 % from 1990 until 2021, reaching an all-time high of 16% in February of 1991 and a record low of 0.25% in April of 2009[175]. Fast-forwarding to 2021, while interest rates have been stable and low for a considerable time, we know from history that this reality can change. Fleets that borrow or lease vehicles based on floating interest rates can be vulnerable to swings in their cost of capital, which ultimately affects their costs of conducting business.

Option 2: Leasing Fleet Vehicles

Leasing fleet vehicles may offer advantages over purchasing. For example, fleet leasing companies, often referred to as "Fleet Management Companies" (FMCs), through their tremendous volume purchasing, may offer lower vehicle costs to a fleet client that does not have the same buying power.

Leasing may enable cash-strapped organizations to have a more modern and reliable fleet without significant capital investment. However, leasing vehicles can be a complex process, requiring fleet managers to make increasingly difficult decisions about the type of lease, method of financing and the fleet lessor or FMC they should choose.

[175] Source: https://tradingeconomics.com/canada/interest-rate

Today, leasing is the most common way private sector fleets finance their vehicles. From a tax standpoint, private sector businesses can deduct the business percentage of their lease payments. For leased vehicles, the limit on the monthly lease payment that can be deducted is $800 per month/vehicle plus HST, which works out to a maximum of $9,600 in expenses that are tax-deductible annually.

While tax deductions may be advantageous to the private sector, the same does not apply to tax-exempt municipalities—one of the primary reasons that, in the public sector, most municipalities purchase their fleet vehicles.

Advantages of Leasing Fleet Vehicles

Leasing is similar to renting a vehicle[176], but instead of using the vehicle for a few days, it's for at least one year. Basically, leasing and renting are like *paying for the use of a vehicle* instead of paying for the asset itself.

Some advantages are:

- **Preserving Capital**. Leasing (or renting) preserves capital compared to owning vehicles. By leasing, an entity can get newer fleet vehicles without a capital budget line item for rolling stock and potentially apply that capital to other business requirements and priorities.

- **Less Maintenance and Fuel Costs**. Since leased vehicles are typically newer models, they require fewer reactive repairs and, hence, overall maintenance costs (aside from preventative maintenance) and better fuel economy. As a result, the fleet can benefit from more uptime, lower maintenance expenses and lower fuel costs than older fleet vehicles. Some lease agreements may include maintenance options.

- **Off-Balance Sheet Treatment**. Purchasing vehicles is a significant capital expense that impacts the debt-to-equity ratio, potentially making an organization appear less attractive to lenders or investors. Leasing is not as substantial an expense and can potentially be treated off the balance sheet.

- **Flexibility.** Lease terms are generally shorter than ownership lifecycles, which may translate to a more modern fleet.

- **Less Administration**. With a vehicle lease may come fewer administrative tasks. Since the lessor owns the vehicle(s), the lessee's name is not on the registration. Tasks like license

[176] Source: https://www.fleetio.com/blog/lease-or-purchase-your-fleet-vehicles

renewal are up to the leasing company. Preparing specifications, obtaining competitive bids, and other administrative tasks are the lessor's responsibility.

Open-Ended Leasing

The open-ended lease is the most flexible and popular fleet leasing option. In an open-ended lease, an amortization rate is agreed on at the time the lease begins. When vehicles are sold after being removed from service, the lessee receives or pays additional funds based on whether the sale price is greater or less than the unamortized balance.

Leases are billed monthly, and the lease rate factor (including the funding cost component) is applied to the average annual outstanding (unamortized) vehicle asset balance. Because the annual average balance is used for the first six months of any year, the lessee underpays the actual funding cost and overpays for the last six.

According to research completed by Deloitte[177], North American customers favour open-end lease contracts over closed-end (90 percent/10 percent). In an open-end lease, the lessee bears the residual risk but is more flexible in terms of contract length and does not have restrictions on usage or kms-travelled. If the market value exceeds the agreed residual value at the end of the lease, the lessee is rewarded by the lessor and can purchase the vehicle for the agreed residual value. If the actual market value is below the agreed residual value, the customer must pay the difference to the lessor.

Closed-Ended Leasing

Another leasing option is the closed-end lease, which has a fixed rate and term. In a closed-end lease, the lessor is the party responsible for resale gains and losses, the depreciation factor, and price-setting for the lessee.

In a closed-end lease, the lessor bears the risk of overestimated residual values. Closed-end leases come with more restrictions in terms of vehicle usage. Usually, the mileage is limited to ~19,000 to 25,000 kilometres per year. Additional mileage and excessive wear and tear will be charged at the end of the lease. However, the lessee can hand in the vehicle without being concerned about the actual market value. The closed-end contract is therefore often called a "walkaway" lease.

Tax Treatment of Leases in Canada

For tax purposes, there is no distinction between a capital lease and an operating lease[178]. A capitalized lease is both an asset and a liability at the same time. If the lease allows the lessee to

[177] Source: Fleet leasing and management in North America | A key enabler of future mobility. Deloitte
[178] Source: https://www.bookkeeping-essentials.com/capital-lease.html

own the asset at the end of the lease, perhaps for a nominal amount (bargain purchase option), it must be capitalized; the lessee must turn the lease into an asset with an associated liability. However, if a lease has a 10% buyout at the end of the lease, this does not constitute a bargain purchase option. The lease can then be treated as an operating lease and capitalize the asset if purchased at the end of the lease. It is not classified as a capital lease as it does not meet all the criteria of a capital lease[179].

Service Charges and Other Fees

Both open- and closed-ended lease types will contain an administrative fee and a funding cost component. The funding cost component is applied to the declining balance of the asset — since the monthly amortization is deducted from the capital cost. When any particular lease is terminated, the lessor sometimes bills the fleet for the cumulative difference between the average and the actual balance, which is also known as the "deficit interest" adjustment.

From RSI-FC's professional experience, we have observed numerous additional costs that lessors may apply to a lessee's lease charges. Examples of such surcharges may range from lease initiation fees to environmental charges, licensing, disposal, termination or various other expenses. Service fees and surcharges can substantially increase the lessee's monthly costs per leased vehicle, and in some cases, potentially place any anticipated cost-benefit advantage of the lease at risk.

Often, surcharges and fees are levied by lessors in ways that are very difficult to evaluate when comparing one lessor to another, such as during the competitive bidding process (i.e., RFPs or RFQs). For example, some lessors may apply a specific service fee monthly/annually or apply other surcharge(s) at the end of the contract. At the same time, another lessor may apply costs based on kilometres-travelled thresholds or in some other creative way. The methods of applying these surcharges may vary widely from lessor-to-lessor, and for this reason it becomes incredibly challenging to compare these extra costs from one vendor to another.

End-of-Lease Considerations

In closed-end leases, vehicle reconditioning charges at the end of the lease can be substantial. In a recent example, RSI-FC's fleet client returned a leased sedan after a three-year lease. Knowing the lease requirements regarding end-of-lease vehicle condition, pro-actively, the lessee had the front tires replaced just one day before the vehicle was returned. Despite the vehicle being returned with new tires and tires with an acceptable level of wear on the rear tires, the lessor charged the costs of two new tires to the lessee, stating that the new front tires installed by the lessee were not suitable because they were "not the same make/model as the factory-installed original tires" – *even though*

[179] Source: Theme: Loans vs. Leases by John W. Day www.reallifeaccounting.com

the lessee could not possibly purchase the factory-installed tires since they were not available for purchase by the public.

In another example, an RSI-FC client operating a large fleet of highway tractors and trailers returned several (17) end-of-lease tandem-axle trucks to its lessor. Unbeknownst to RSI-FC's client, the fine print in the truck's leases entitled the lessor to be compensated for these mechanical conditions:

- The tread depth for all ten tires on each tandem-axle truck had to meet the lessors' requirements; if not, the cost of new tires for each truck would be charged to the lessee. Even though the tires on the 17 trucks met provincial safety standards, the tread depth was less than the lessor's requirements and considerable costs were incurred.

- Each truck was equipped with three (or four) wet cell starting batteries. According to the lease agreement, every battery was to have a specific gravity reading acceptable to the lessor; if not, significant charges would be, and were, levied to the lessee.

- Each brake lining and all brake drums were to be measured at the end of the lease; if any were out of the lessor's threshold for wear, additional costs would be charged to the lessee.

In the examples above, in addition to the fees levied, the garage labour costs for making all of the above assessments were to be paid by the lessee – an amount that was substantial by itself.

Such examples of end-of-lease costs will add significantly to the total cost of each vehicle's lifecycle total cost of ownership (TCO). Therefore, fleets considering a new lease vendor should take extreme care to ensure that all language in proposed vehicle lease contracts is carefully reviewed and fully understood before committing.

Interest Rates

Lease interest rates can be fixed or floating. Historically with a fixed rate lease, the rate is set at the lease's inception and fixed at the prime lending rate plus one. Fixed rates were the only funding option available until recently when some lessors began to offer the same rate basis, but with the lease rate floating as the prime rate changed. For example, if the fleet manager or the company's financial leadership believed that the prime rate would fall, they'd likely choose a floating rate to fund their leases.

Choosing the Right Lease Option

The evolution of leases and funding options, in addition to purchasing vehicles outright, has given fleet managers and their companies' financial leadership more control but requires considering several factors to determine the correct option(s). There is no one-size-fits-all solution. Every organization must consider their own needs, comfort level with risk, and anticipated return-on-investment (ROI).

The factors that come into play when considering funding options include:

- **Rate**: This is the most fundamental funding factor to consider. Lessees seek the lowest rate available at the inception of the lease transaction. Historically, borrowing rates on many of the available options have been volatile, and if the timing is wrong, it can be costly.

- **Consistency**: Some funding rates are more volatile than others. Consistent, predictable rates are preferable.

- **Availability**: Not all funding types are available at all times.

- **Matching**: Funding should match the life of the asset as closely as possible.

- **Fees and Surcharges**: What are the total costs of leasing, including hidden charges?

Option 3: Renting Fleet Vehicles

In both the private and public sectors, fleets may choose to rent additional vehicles for short-term, seasonal or temporary requirements. Some fleets will opt to rent for longer-term needs, as does the City of Brampton's Transit section.

Advantages of Renting Vehicles

In many ways, similar to leasing (see Option 2), renting vehicles may offer several advantages. Rental agreements will vary from vendor to vendor, but given the right set of circumstances, the benefits may include:

- A way to expand the fleet to meet a defined business need or to modernize the fleet by replacing aging fleet units without capital investment;

- No upfront costs;

- Covered maintenance and repair costs;

- Replacement vehicles at no additional cost when primary rental units are out of service for repairs or maintenance; and

- Little, and possibly no, downtime and associated costs.

Renting fleet vehicles for long-term needs has become more prevalent in recent years. There are several players in the fleet rental market space, including Somerville www.somervilleauto.com and Enterprise https://www.efleets.com/en/locations/toronto.html.

The leading fleet rental service providers are huge-volume purchasers of vehicles, often purchasing tens of thousands of units each year. They have access to vehicle concessions (discounts) that are not available to smaller fleets that buy a much smaller number of units. Some creditworthy rental vehicle service providers may also benefit from long-term, preferential low-interest rates for vehicle acquisition, which can mean a lower cost of capital for vehicle purchases than some private and public sector entities.

Rental companies are expert at knowing precisely how long units should be kept in service. They take a very studied approach to their end of lifecycle disposal practices to ensure the maximum end of lifecycle resale values.

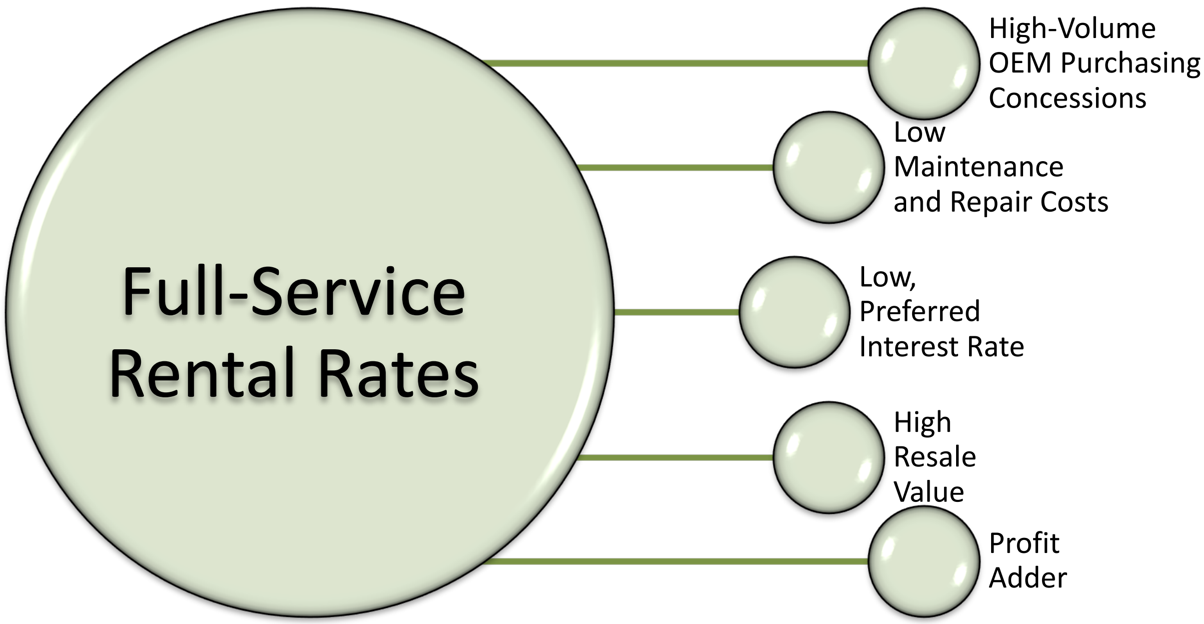
Rental firms may operate their own maintenance facilities, and they will likely purchase replacement and service parts at wholesale prices. In-house labour costs for their fleet maintenance technicians may be less, all of which means low maintenance costs.

The effects of low initial purchase price, low-interest rates, maximum resale prices for end of lifecycle units, combined with low maintenance costs, all result in a very low lifecycle total cost of vehicle ownership (TCO).

To be profitable, rental providers must add a profit margin to their retail fleet rental rates. Their skill is adding just sufficient profit margin for their needs while ensuring their rental rates are competitive. Despite the profit adder, by having a low TCO, rental service providers can offer competitive rental rates to fleet customers, potentially making fleet vehicle rentals an attractive alternative to traditional ownership or leasing.

Please see *Illustration 2: Full-Service Rental Rates* (below). The combined effects of large purchasing volumes, preferential interest rates, high resale value, low maintenance costs and a profit margin are depicted.

Illustration 2: Full-Service Rental Rates



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